Chapter One

Concepts of Chemistry

Once you get this book in your hand, a number of questions will be raised in your minds. - What is chemistry? Why should we learn chemistry? How will we be benefited from chemistry? Does it have any relation to other branches of science? - We shall learn the answers to these questions in this chapter.

By the end of the lesson, we will be able to:

- explain the concepts of chemistry
- identify the scopes of chemistry
- explain the relation of chemistry to the other sciences
- explain the importance of learning chemistry
- describe the methods of investigation and research in chemistry
- plan types of investigative tasks, choose hypothesis and conduct experiments
- take necessary safety measures while experimenting practically
- explain the phenomenon of natural and physical world in terms of chemistry

1.1 Introduction to Chemistry

In prehistoric times, people did not know how to wear clothes, or how to build houses. Even they did not know how to cook and eat. How much people are advancing today in the age of digitalization! They are controlling heat and using it for various purposes, and eventually learning to generate electricity. So many things people are doing by using electricity! By using the internet, people can see what is happening around the world just staying at home. All these are contributions of science. As a result, naturally the question arises- what is science? Science is the systematic, orderly and continuous effort of mankind to manipulate nature for their own betterment. There are many branches of science and chemistry is one of the major branches. [Question: Write the names of various branches of science.]

Here the question is- what is chemistry? The branch of science which deals with the composition of compounds composed of elements, structure and nature, properties, uses, etc. is called chemistry. It also deals with the mutual conversion or transformation of objects, and absorption and emission of energy (mainly thermal energy) during the conversion.

We know that burning coal produces heat as well as carbon dioxide compounds. Some of the examples of chemistry are the rusting of iron or iron-made objects when left in a moist environment, the extraction of medicines and perfumes from the extracts of various plants, the extraction of various metals from ores, etc. Thus, it can be said that from prehistoric times, people have been using chemistry in different ways knowingly or unknowingly. According to the information available so far, the first metal used is copper. Apart from that, people have been using metals like gold, silver, tin, iron etc. since ancient times.

Humans learned to melt copper and tin, mix them and cool the mixture into another hard alloy named bronze at around 3500 BC. Bronze was used to make quality weapons. These were used by the people to hunt animals, cultivate crops, cut fire wood etc. This alloy became an essential product of the then human race. Bronze contributed a lot to the progress of human civilization.

Like bronze, people have made many alloys, including steel, and are using them for various purposes. [Question: Gold used in the manufacture of jewelry is an alloy. - Explain.]

The ancient philosophers used to think a lot about structure of matters. The Greek philosopher Democritus declared in 380 BC that, a small particle will be available at a stage when we synthesize any metal. This particle is indivisible and he called it atom. Some Indian philosophers of the age also had similar views. But none of these ideas had a practical base. Aristotle opposed this idea. He along with another school of philosophers believed all matters are made of soil, fire, water and wind. That is why humans did not accept the idea of atom for quite a long time.

Fig 1.01: Antony Lavorsiere, Robert Boyle, Sir Francis Bacon and John Dalton.

In the mediaeval age, some Arab Muslim philosophers tried to make gold out of cheaper materials like copper, tin and lead. They also tried to get an elixir which would lengthen the life of humans. Though they failed in their original attempts yet they wrote down their experiments. Basically, these were the earliest attempts of systematic study of chemistry or experimentation. These mediaeval Arab experimentation with chemistry was called Alchemy and the philosophers were known as Alchemists. The term Alchemy comes from the Arabic word Al-Chimia which again takes its origin from Chemi or Kimi. The word chemistry comes from this chemi. Alchemist Jabir Al Hiyan is the first scientist to hold chemical experiment in a laboratory. That is why he is sometimes called the father of chemistry. Jabir al Hiyan believed all matters are composed of four components- soil, fire, water and wind. Therefore, although experimented, Jabir was not very clear about the mysteries of chemistry. Scientists including Antony Lavorsiere, Robert Boyle, Sir Francis Bacon and John Dalton are the first school to start experimenting with chemistry understanding the real spirit of this science. Antony Lavorsiere is called the father of modem chemistry.

The branch of science that discusses the structure of matter, its nature and changes is called chemistry.

Table 1.01: Explanation of different incidents in every day life in terms of chemistry_

Subject	Analysis
A green mango is sour while a ripened mango is sweet	There remain various organic acids like succm1c acid, malloic acid etc. in a green mango which makes it sour. As it ripens, these acids transform into glucose and fructose in chemical reactions and turns the mango sweet.
Burning of kerosene, natural gas and wax	The main component of these elements is hydrocarbon which is a composite form of carbon and hydrogen. When we bum them, carbon and hydrogen react with oxygen of air and produce carbon-di-oxide, vapour and heat.
Taking antacid due to acidity in stomach	Acidity occurs in the stomach when excess hydrochloric acid is generated inside. Antacid contains aluminum hydroxide and magnesium hydroxide. These two compounds neutralize hydrochloric acid.

These incidents are sufficient to tell you that our life is irrevocably related to chemistry. Therefore, chemistry is one of the important branches of science.

1.2 The Scopes of Chemistry

Wherever there is element, there is chemistry. Various gaseous elements are there in the air. There are continuous chemical changes occurring in the air. The same is there in the soil we are living on . It is happening now, it happened in the ancient days too. The earth was highly heated at the moment of its creation. There was no wind, nor any animal. It took millions of years of chemical reactions for the creation of atmosphere, water and thousands of other elements. These altogether contributed to the habitability of the earth for animals. All animals including human beings, microscopic lives like bacteria, amoeba, huge trees and animals have bodies which contain various kinds of chemicals. Each body is a kind of chemical factory where chemical reactions are taking place every moment. We live because of these chemical reactions. Again, with the advent of civilization, humans have produced various necessary items and products by means of chemical reactions and put them to their use. For example, the dresses you put on, the paste you brush your teeth with, the comb you fix your hair with, the cosmetics you use on your skin- all are chemical products. Besides, soap, toilet cleaner, life saving drugs, all are chemicals too. We use fertilizers and insecticides in our field crops, use petrol, diesel etc. in vehicles. These are industrial products made out of chemical reactions. In fact, the scope of Chemistry is so vast that it cannot be summarized easily. The table below tries to present some of the scopes in brief:

Table 1.02: Some scopes of chemistry.

!substance	Element	Source and Chemical Change
Air	Mostly oxygen	When we inhale air, the oxygen in it reacts with the food substances inside our body and produces energy.
Drinking water	Hydrogen, oxygen and mineral salts	Water plays a role in the chemical reactions that take place inside our body. It also works as solvent of various substances in the body. The poisonous substances in the body mix with water and come out m the form of urme and sweat. Mineral salts such as calcium, magnesium etc. play a vital role for our body. People may die if there is a lack of water in the body (dehydration). This is the main cause of death of people in cholera.
Fertilizer	. Nitrogen, oxygen, carbon, phosphorous,	Just as we eat food, plants also need food. The main components of plant food are nitrogen, oxygen, phosphorus, carbon etc. Plants collect them from the soil. Besides, various fertilizers contain compounds of these elements. Different• fertilizers contain compounds of these substances. As a result, these fertilizers act as

	calcium, magnesmm, potassium etc.	nutrients and help get a good crop.
Paper	Cellulose	Paper is one of the most significant inventions of human civilization. Bamboo, the outer skin of sugarcane etc. contain huge amounts of cellulose. The paper mills tum these sources into paper by means of chemical reaction.

1.3 Relationship Between Chemistry and Other Branches of Science

There are various branches of science like chemistry, biology, physics, mathematics, environmental science, soil science etc. Each of these branches is related to the other branches. Very much like the other branches are related to chemistry, so is chemistry related to the other branches. Let us now check the relationship with some examples.

Relationship with Biology: All plants produce glucose on their green parts in the photosynthesis process. Photosynthesis is basically a chemical process. Plants take in carbon-di-oxide from air and water from the soil. Then it uses the chlorophyll of its green parts to produce glucose in the reaction between water and carbon dioxide. Animal bodies synthesize the proteins of animal's intake and produce glucose, amino acid etc. All animal bodies are indeed stuffed with various chemicals. Biology discusses these chemicals and chemical reactions that take place inside the bodies of plants and animals. That is where the two sciences are interrelated

Relationship with Physics: Physics discusses magnet, electricity, different machines etc. Battery used for getting electricity is contribution of chemistry. Energy gleaned by burning oil, gas or coal is the source for vehicles and electricity. Chemistry is also dependent on physics. Physical chemistry is a branch of chemistry, the theories of which are essentially dependent on theories and formulas of physics.

Relationship with Mathematics: Mathematics has a close relationship with chemistry. In various fields of chemistry, especially in calculations, from simple mathematical formulas to complex ones are used. For example, determining the concentration of a solution, determining the composition of a compound, determining the rate of a reaction, etc.

In the same way, chemistry is directly and indirectly related to the other branches of science too.

1.4 The Importance of Studying Chemistry

Imagine what happens on a typical day with you. You use toothpaste, once you get up from bed in the morning. Then you start reading your books. Your mother serves you biscuits and tea. After finishing that, you take your bath. When you enter the washroom, you find it a bit unclean. You use toilet cleaner to clean it and then have bath using scented soap and shampoo. You use lotions after bath. Then you take your breakfast and go to school. The teacher there uses chalk on the board to simplify your lessons. Now, do you see, all the things you are using, e.g. paste, biscuit, tea, toilet cleaner, soap, shampoo, chalk etc. are contributions of chemistry.

Not only that, we use fertilizers to increase fertility of fields, use insecticides to keep away insects from our crops, preservatives to store the food for a longer time. This way, the whole process of food and cultivation is dependent on chemistry.

Today, cholera, typhoid, tuberculosis etc. are curable diseases but they were once killer diseases-Thanks to chemistry, we have been relieved from the dreadfulness of recent corona. - How can you justify? Millions of people died of them in the ancient days. Humans have invented cures for them by means of their knowledge of chemistry. Nowadays, the field of medicine has developed so much that many people are cured of different cancers too.

Chemical wastes from industries, vehicles, consumer products etc. are doing harm to our environment. These contain carbon dioxide, carbon monoxide, sulphur dioxide, various acids, heavy metals like mercury, lead, arsenic, cobalt etc. When they come in contact with air, air is polluted, when they come in touch with water, water gets polluted. They enter human bodies and harm them. Again, use of excess chemicals is harmful for us. Insecticides help us save our crops but excess insecticide gets washed away to the water bodies, polluting the water.

Some of it gets vaporized and pollute the air. Chemistry tells you all these natural and life oriented facts.

By now you should have understood that chemistry plays a significant role in our advancement but excess of it is harmful for us and nature as well. Many diseases are still there which do not have cures. Our duty is to study chemistry and try inventing those drugs. Therefore, learning chemistry does not only benefit us by means of newer inventions, it also helps us realize how we are harming our nature. Your learning chemistry will take the world steps ahead. That is our expectation.

1.5 The Process of Research in Chemistry

The aim of science is the betterment of humanity. Scientists are constantly working with the same aim in their minds. The term scientist certainly rings the names of great scientists like Einstein, Newton, Archimedes, Lavoisier, Galileo etc. They are obviously great scientists. However, the meaning of the term scientist has the scope for you too to be called so. Indeed, science is that knowledge which is gleaned out of systematic experimentation. The process to glean knowledge by experimenting is known as research. One who carries out such research is a scientist.

Therefore, if you carry out research, you can also be a scientist. Experimenting through a perfect and systematic process in order to learn something is called research. It means, there is a certain procedure to carry out a research. Research in chemistry also follows some procedure. Now we shall learn the steps of this procedure.

In the first step of a research, you need to determine what you want to learn or what new thing you want to invent. Suppose, you want to learn whether heat will be produced or absorbed as ammonium chloride is dissolved in water. This is known as topic selection.

In the second step, you have to investigate the matter. At this stage, you will read some books or some papers from the internet and other sources in order to learn how such kind of an experiment was carried out by someone else and what result it did yield. Suppose, you have learned that another chemical compound calcium oxide, when dissolved in water, produces heat. You will also be able to learn what kind of apparatus, chemicals and steps were followed in this experiment. That will give you an idea about what things you will require to conduct the test yourself. Besides, you will have an idea about the probable result- in this case, if you dissolve ammonium chloride in water, heat will be produced.

Again, you will be able to decide what kind of materials you are going to use and what will be the steps of the experiment. You came to know that you would need a beaker, water, ammonium chloride, thermometer, glass rod, balance etc. First you will take water in the beaker. You will record the temperature of the water m the beaker with the thermometer. Then, you will weigh ammonium chloride using the balance and mix and dissolve that with the glass rod in the water, a number of times. Each time, you need to check the temperature of water. This is the procedure of your experiment. Now you can start your experiment.

Table 1.03: Dissolving ammonium chloride in water.

· Quantity of dissolved ammonium chloride in water of beaker	Temperature of the solution
Og (nothing dissolved)	25°(
5g	20°(
10g	15°(
15g	10°c

Take 250mL water in the beaker and check the temperature. Suppose, the present temperature is 25°C. Record it in your notebook. Now, with the help of the balance, weigh 5g ammonium chloride and mix it in the water. Use the glass rod to stir so that it gets dissolved. As soon as the chemical is dissolved, measure and record the temperature. Now the temperature is 20°C. Add, mix and dissolve another 5g of ammonium chloride in the beaker. See what the temperature is with IOg chemical in the water. Follow the same procedure again. Now the beaker's water has 15g of dissolved ammonium chloride and let's suppose the temperature is I0°C. Record the data in your notebook.

If you analyze the data shown above, you will see, the more ammonium chloride is dissolved in water, the less the temperature of water becomes. You will decide, since dissolving ammonium chloride in water decreases the temperature of water, ammonium chloride absorbs heat from water in order to get dissolved. The result is dissolving ammonium chloride in water results in absorption of temperature. The steps followed by you in the above experiment can be shown in the following flowchart:

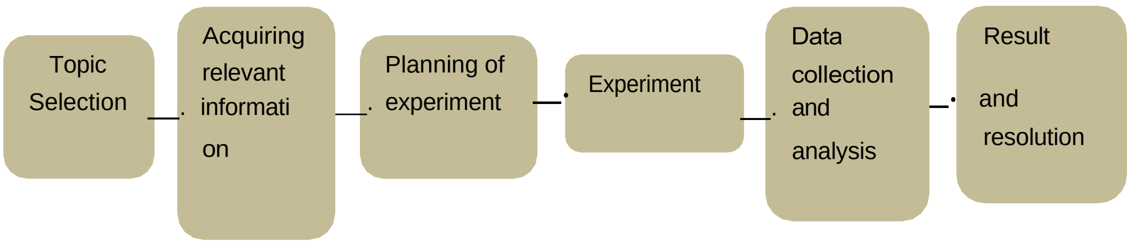


Fig 1.02: Steps in a research in Chemistry.

Whenever you are dealing with some research in chemistry, you are required to follow the same steps.

1.6 Safety Measures in Chemistry Laboratory and in use of Chemicals.

The place where scientific experiments are held is called the laboratory. Similarly, the place where experiments of chemistry are held is called Chemistry laboratory. It is understood, there will be various chemicals in a chemistry laboratory. Almost all chemicals are harmful to some extent for us as well as our environment. Some chemicals are prone to explosion, some are flammable, some harm our body directly and some are dangerous for nature. Most of the apparatus in a chemistry laboratory are made of glass. Therefore, we need to be cautious from the moment of entry into the laboratory to the moment we come out. Lack of caution may result in accidents, e.g. if acid falls on your body, you will get injured; if acid falls on your dress, the dress will be spoiled. Besides, there may be accidents including fire or explosion in a laboratory. Therefore, you need to wear an apron. The apron will be knee-long and the sleeves will be up to your wrist. Its colour will be white. You will use hand gloves and safety goggles on your eyes. Some of these safety measures are given in the following picture:

Below are some pictures of things that need to be used m the chemistry laboratory for self-protection.

Fig 1.03: Safe dresses and kits in a laboratory.

We need to learn the nature of a chemical before we start to use it. We need to know whether that is flammable or radio-active. These are made clear using some signs on the containers. To introduce a globally harmonized system about this, the United Nations organized a conference named Environment and Development. This conference gave a set of harmonized signs for different risky substances and their level of risk. The table below contains some signs and their explanations identifying risk, extent of risk and precautions.

Table 1.04: signs and their explanations identifying risk.

Sign	Risk, Extent of risk and precaution
 Explosive substance	We need to be very careful about these substances. We must keep in mind that friction and fire may cause serious explosion from these which will be harmful for our body as well as the laboratory. We need extreme caution in handling these. TNT, organic peroxide, nitroglycerine etc. are such kind of substances.
 Flammable substance	Alcohol, ether etc. are flammable. These may catch fire quickly. Therefore, we need to keep them away from fire or heat.
 Toxic substance	Substances with this sign are poisonous. Ifwe come in touch with them or inhale them, they may cause harm to our body. Benzene, chlorobenzene, methanol, etc. are such substances. We must wear apron, hand gloves and safety goggles when handling them.
 Irritant substance	Cement dust, light acids, base, nitrous oxide etc. cause irritation on skin, eyes and breathing system. We must wear aprons, hand gloves and safety goggles when handling them.
 Hazardous substance	Direct contact on skin or inhalation of such substances may cause short or long term harm to our health. They may affect our breathing system or even cause diseases like cancer. Benzene, toluene, xylene are such substance. We must wear aprons, hand gloves and safety goggles when handling them.

 Radioactive substance	These substances emit harmful rays which may cause diseases like cancer or disable somebody. We need to be extremely cautious in handling these. Uranium, radium etc. are of this kind.
 Dangerous for environment	Substances with this sign are dangerous for the environment, meaning, they harm both animals and plants. They require caution when in use. Again, they have to be gathered in a place after use. They have to be recycled as much as possible. That way, they cannot do much harm to the environment.
 Corrosive	These cause injury to body in contact. Inhalation of such substances may cause injury inside the body. Hydrochloric acid, sulfuric acid etc. are examples of this kind.

Exercise

Multiple Choice Questions

1. Which of the following substances is used for preserving processed food for a long time?

   a. preservatives b. vinegar

   c. ethylene d. acetylene

2. What does the following sign indicate?

a. explosive substance
b. flammable substance
c. radioactive substance
d. flame of fire

3. Which of the following signs indicate a radioactive substance?

a. 
b. 
c. 
d. 

4. Which of the following metals is melted and mixed with copper to produce bronze?

a. IfOn
b. zinc
c. tin
d. lead

Creative Questions

1.

A

Fig A: Boy taking pills

B

Fig B: Spraying insecticide in the agriculture field

a. What is research?

b. Why does ripe mango taste sweet?

c. How is the figure A related to chemistry- explain.

d. Which of the activities of the stern, when done in excess, 1s harmful for the environment- answer with reasons.

2.

Sign 1

Sign 2

Sign 3

a. What is chemistry?

b. Why do we take antacid for acidity in the stomach?

c. The substances containing sign 3 harmful for human beings- explain.

d. Chemical substances containing sign 1 and sign 2 are risky when in use - explain.

Chapter Two

States of Matter

Matter is a physical entity that has mass and occupies space. Chairs, tables, notebooks, pens, ice, water, air- are all matter. All matters may exist in three different states- solid, liquid and gaseous states. They have their own characteristics and properties in all three states. This chapter will focus on these issues.

By the end of the chapter we will be able to

- explain the physical properties of matter in terms of the postulates of kinetic theory of particles
- explain diffusion and effusion with the help of kinetic theory
- explain the relationship between physical state of a matter and heat
- demonstrate practically the increase in the rate of diffusion with the increase of heat
- describe melting and sublimation of solids and distillation of liquids
- demonstrate practically melting and sublimation of solids and distillation of liquids
- show interest in explaining the real happenings in nature in terms of chemistry
- use of chemical compounds and thermometer properly

2.1 Three States of Matter

Anything that has a certain mass and occupies space is matter. At normal room temperature some matters may exist as solids, some as liquids and some as gasses. For example, at normal room temperature sugar, edible salt, marble etc. exist as solids; water, oil, kerosene etc. exist as liquids and nitrogen, oxygen, carbon dioxide etc. exist as gasses. Again, changing the temperature, the same matter's state can be transformed into any of solid, liquid or gaseous states. Below is given a short discussion on the properties and characteristics of solids, liquids and gaseous matters.

[Question: When the temperature is changed, the same substance becomes solid, liquid and gaseous. Give examples.]

2.1.1 Solids

A solid matter has a specific mass, volume and shape. Molecules of all matters have a force of attraction. It is known as inter molecular attraction. This force is the most in the solid matters. As a result, the molecules in solids stay very close to each other in a fixed state and they take a fixed dimension which cannot be compressed with pressure. Again, a solid matter hardly changes shape when the temperature is raised. Particles of solids can not move or leave spece, but can vibrate in their own place.

2.1.2 Liquids

Liquids have a specific mass and volume but do not have a shape. Liquids take the shapes of their containers. Since the molecules of a liquid remain farther from each other than those of solids, the inter molecular force of attraction is also less than solids. Such matters do not change volume when force is projected on them but the volume increases with the rise of temperature. This change of volume is greater than that of solids.

[Question: Why are the particles of liquids spaced a little further apart than those of solids?]

2.1.3 Gases

Gases have specific mass but they do not have specific volume or shape. Whatever quantity of gas is put into any size of container, it takes over the full size of that container. The molecules in gases stay further than those of liquids or solids. The inter molecular force of attraction is also very low among them. A small quantity of pressure is enough to compress gases and in the same way, a small amount of temperature is enough to increase the volume of such matters.

2.2 Kinetic Theory of Particles

Every substance is made of small particles which remain together by means of an inter molecular force of attraction. These molecules also have a kinetic force in them. The attempt to prove the states of substances using inter molecular force of attraction and the kinetic force of the particles is known as the kinetic theory of particles. When the particles inside a substance remain in very high force of attraction, they stay together and cannot move that much. This is the solid state. When heat is applied on such a solid substance, the particles start to vibrate.

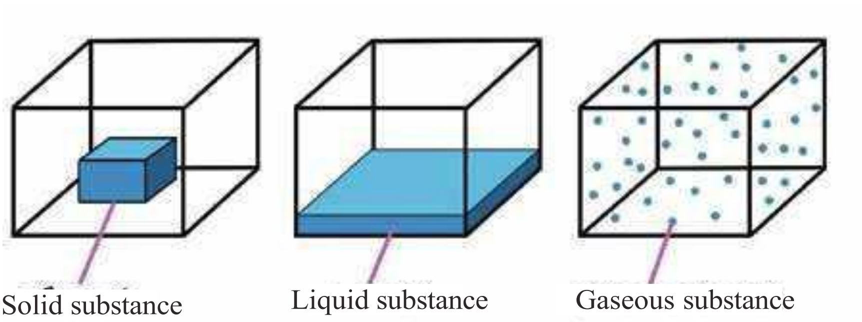


Fig 2.01: Kinetic Theory of Particles.

When more heat is applied, the particles lose some of their force of attraction and they start some movement. This state of matter is called a liquid. Liquid takes the shape of the container without changing their volume. When more heat is applied on this liquid state of the substance, the particles receive the heat and the kinetic force in them is increased. This kinetic force is increased to a level where they lose inter molecular force of attraction almost completely and start to move freely. This is the gaseous state. That is why gaseous matter has no absolute volume. The volume of the container in which it is kept is the volume of the gas. When more heat is applied to this state of the substance, the particles will only increase their speed of movement.

2.3 Diffusion

The tendency of solid, liquid or gas to spread spontaneously and uniformly in any medium is called diffusion. In diffusion process, solid, liquid or gas moves spontaneously from a place of higher concentration to lower concentration. Remember, what happens if you leave a perfume bottle with its lid open in the comer of a room? Within some time, you will find the whole room smelling of perfume. This is an instance of diffusion. If a matter takes lesser time to spread, its rate of diffusion is higher and vice versa.

Now, read through the following experiments.

Individual Task

Experiment 1

At room temperature, take some pure water in a glass jar. Add a small quantity of solid pink Potassium permanganate (K.MnO_4) into it. You will see, after sometime, the $KMnO_4$ grains are dissolving into a pink solution. Indeed, the $KMnO_4$ particles are getting motion and scattering freely in the water. In this case, some solid matter is diffused in water or liquid. The rate of diffusion of solid matters in water is slow, however, if heat is applied, the rate will increase.

Similarly, if we do the experiment of diffusion of Potassium permanganate in hot water, the water will tum into pink solution faster. In this case, the $KMnO_4$ particles will get added motion due to heat and scatter faster. This shows that the presence of heat increases the rate of diffusion of solids

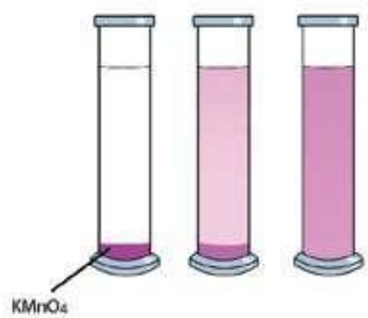


Fig 2.02:$KMnO_4$ solution in water.

Individual Task

Experiment 2

At room temperature, take some pure water in a beaker and add some liquid blue in it. Within a few moments, you will see that the water has turned blue. That means, the particles of blue solution or some liquid have diffused in the water. The temperature being the same, it has taken the liquid less time to diffuse in another liquid than solid $K.MnO_4$. That means, the rate of diffusion of liquid matter in another liquid is faster than in solid matter. The presence of heat will increase the rate. Just like solids and liquids, diffusion of gases takes place in the liquid medium. However, at a given temperature, the diffusion rate of gaseous substances is higher than that of solids and liquids in liquid mediums.

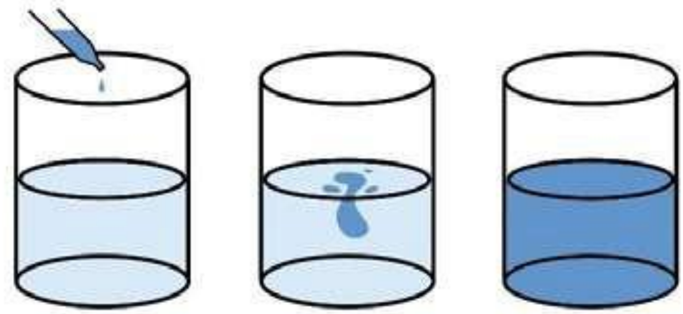


Fig 2.03: Diffusion of Liquid solution in liquid.

Individual Task

Experiment 3

Diffusion of two gases.

Take a glass tube with both faces open. Take two pieces of cottons. Soak a piece of cotton in concentrated hydrochloric acid (HCl) solution and soak the other in ammonium hydroxide (NH_4OH) solution. Now close the glass tube fixing each of the cottons to a side of it. Here hydrogen chloride gas from HCl solution and ammonia gas from NH_4OH solution will get diffused.

Within a few moments, you will see a white smoke filling up the tube. It is ammonium chloride (NH_4Cl), produced in the reaction between hydrogen chloride gas and ammonia gas. The white smoke will not be positioned in the centre of the tube; it will be nearer to the hydrochloric acid solution. That means at a same given time, hydrogen chloride gas has gone a lesser distance than ammonia. That also proves that ammonia gas spreads faster than hydrogen chloride gas because of its faster rate of diffusion. The reason behind it is the difference in their atomic masses. A gas with lesser atomic mass will have a better diffusion rate. Here ammonia gas (atomic mass 17) has spread faster than hydrogen chloride gas (atomic mass 36.5).

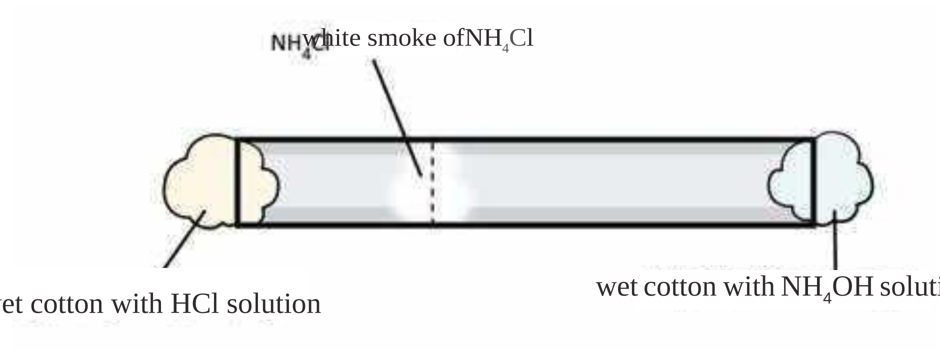


Fig 2.04: Diffusion of two gases.

Atomic mass of H_2, He, N_2, 0_2 and CO_2 gases are 2, 4, 28, 32 and 44 respectively. Since hydrogen is the gas with the least atomic mass, its rate of diffusion is faster than others while carbon dioxide's being the most, is the slowest.

2.4 Effusion

The passage of gases from a high pressure zone to a low pressure zone through a fine pore is called effusion.

Take a balloon and fill it with air or helium. Stick a piece of scotch tape on the balloon. Now, make a small pore on the balloon through the scotch tape and see what happens. The air from the balloon will come out through the hole with force (Don't try it without the scotch tape; the balloon will burst). Air pressure inside the balloon was higher than outside. So, when the air found the hole, the air from the balloon rushed towards the low pressure region. It is effusion. Like the rate of diffusion if heat is applied, the rate of effusion increases. If heat is applied, the rate of effusion increases very much like the rate of diffusion.

We use CNG (compressed natural gas) as fuel in our vehicles. Basically, it is compressed methane gas at high pressure. When we run our vehicle, this gas comes out of the cylinder with high pressure and runs the engine. This is also effusion of gas. Again, propane and butane gases are compressed at high pressure into liquid and put into cylinders to use them for cooking in the households. When we open the cylinder for cooking, it comes out in gaseous form with pressure. It is another example of effusion.

Effusion and diffusion are by nature, the same kind of actions. The basic difference between them is, effusion requires the presence of pressure but diffusion does not depend on pressure. In diffusion, solids, liquids or gases matter spread around in a suitable medium but in effusion, only gas comes out through a fine hole from the container. Ifwe open the cylinder but do not ignite our cooker, the gas from the cylinder will just come out and mix with air. This is effusion. Then, the gas that comes out would spread around the room, which is diffusion. Therefore, both the actions may take place one after another.

2.5 Burning of a Candle and the Three States of Wax

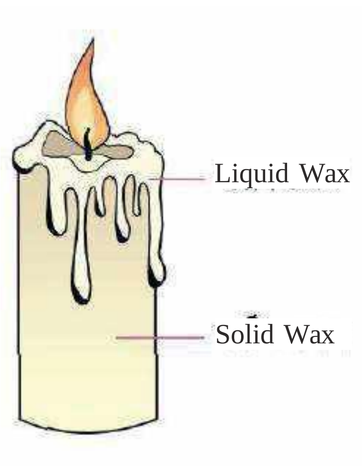


Fig 2.05: Burning of Wax.

Wax is a mixture of various hydrocarbons. Organic compounds made of hydrogen and carbon are known as hydrocarbons. In the burning of a wax, three states of matter can be observed simultaneously. There is a thin liner inside the wax. When we add fire to it, the hydrocarbon particles around the liner melt into liquid.The liquid wax absorbs heat and vaporizes first. Then the vaporized wax starts a reaction with oxygen of the air and produces carbon dioxide, water vapor, light and heat. A portion of the liquid wax remains and turns solid again. Thus, in the presence of heat we see three states of wax.

2.6 Melting and Boiling

The process of transforming a solid matter into liquid by means of applying heat is called melting. At normal pressure (1 atmospheric pressure), the temperature at which a solid matter turns into liquid state is called the melting point of that solid. Each pure solid matter has its own melting point, like the melting point of ice is 0°C.

The process of transforming a liquid matter into gas by means of heat is called boiling. At normal pressure (1 atmospheric pressure), the temperature at which a liquid matter turns into gaseous state is called the boiling point of that liquid. Each pure liquid matter has its own boiling point, like the boiling point of water is 100°C. The boiling process requires heat but solidification requires removal of heat.

Individual Task

Experiment 4

Suppose, we want to find out the melting point of urea, a solid matter. First, we need to put a net on a tripod, upon which we shall place a watch glass. Now we shall put some urea on the watch glass. Fix a thermometer with a liner on a stand and put the bulb of thermometer in the urea. Now start giving heat to the urea. You will find, the urea will start to melt at 133°C temperature and all the fertilizer will melt at the same temperature. This 133°C is the melting point of urea.

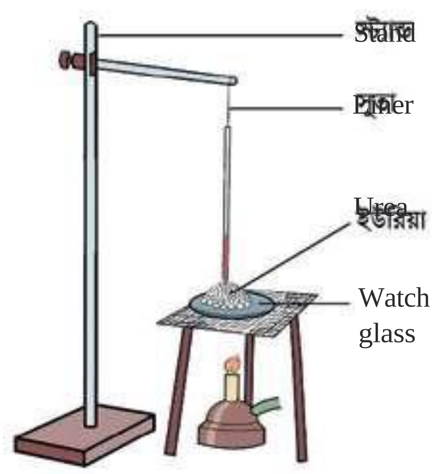


Fig 2.06: Melting point of urea.

Again, let's find out the melting point of an impure matter, wax. In order to find it out, first we need to tum the wax into powder. Collect the wax powder inside a glass tube with one side closed. Now fix a thermometer inside following the fig 2.07. Sink the glass tube in the beaker in such a way so that water can't get inside the tube. Now, start heating the beaker slowly. You will find the wax melting at a specific range of temperature instead of a fixed temperature. This range of temperature is the melting point of wax.

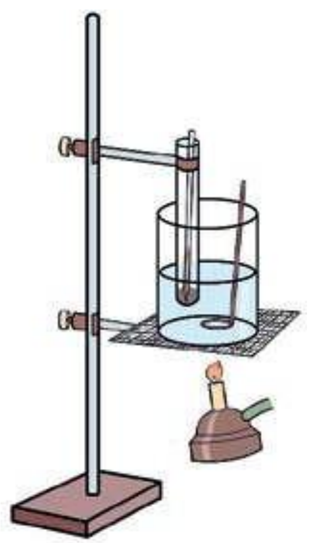


Fig 2.07: Melting point of wax.

Melting point of impure substances is lesser than that of pure substances. It is opposite in the case with boiling point. A mixed matter will have no fixed melting and boiling point. Since all pure solids have a specific melting point, they melt at that temperature. If a solid substance melts at any other temperature, the solid can be declared impure. Again, if it melts over a range of temperatures, it is impure too. For example: the melting point of sulfur at 1 atm is l15°C. But in an experiment, if sulfur melts at any other temperature or range of temperatures, the sample of sulfur can be declared adulterated. Therefore,finding the melting point can be a way to find the purity of solid substances.

Individual Task

Experiment 5

Boiling Point of Liquids

Some sample of the liquid (Example: water), the boiling point of which needs be determined, is taken in a beaker. The beaker is fixed with a thermometer. Now, the beaker will be heated carefully with a Bunsen burner. At a certain temperature, the water in the beaker will tum into vapor. That temperature is the boiling point of water. All the water in the beaker will vaporize at 100°C.

That sets the boiling point of water at 100° C (at 1 atm). Since each liquid matter has a specific boiling point, so a boiling point cannot be the same for two liquids. Again, if a liquid is adulterated, it will boil at a different temperature. For example, if we add some alcohol to water, it will boil at a different temperature than 100°C. So, boiling point can be a determiner of the purity of a liquid.

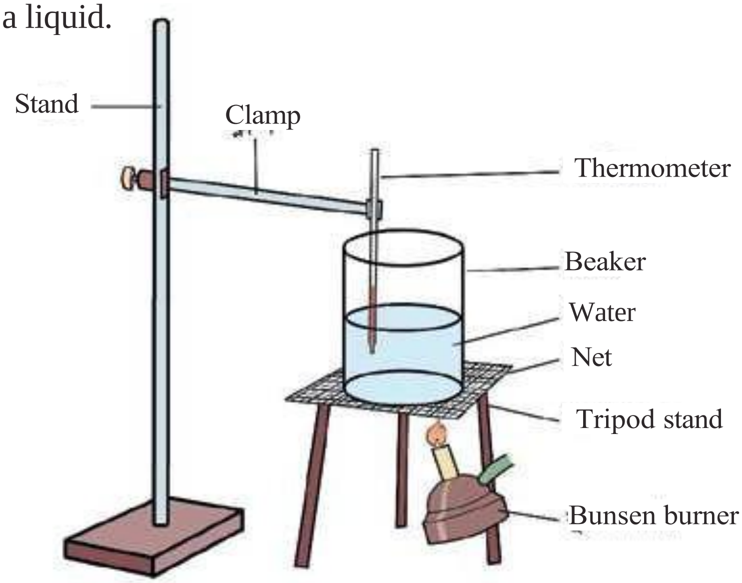


Fig 2.08: Boiling point of water.

You have learned, the heat used in boiling and melting does not change the temperature of the matter. It only transforms the state of the matter.

The experiment below will tell you what will happen if we apply heat on a solid to melt it and then heat more to boil it.

Individual Task

Experiment 6

Let us take some ice cubes in a beaker and heat it carefully. We shall keep watch on an attached thermometer throughout the process. Let's assume, the initial temperature of the ice was -40°C.

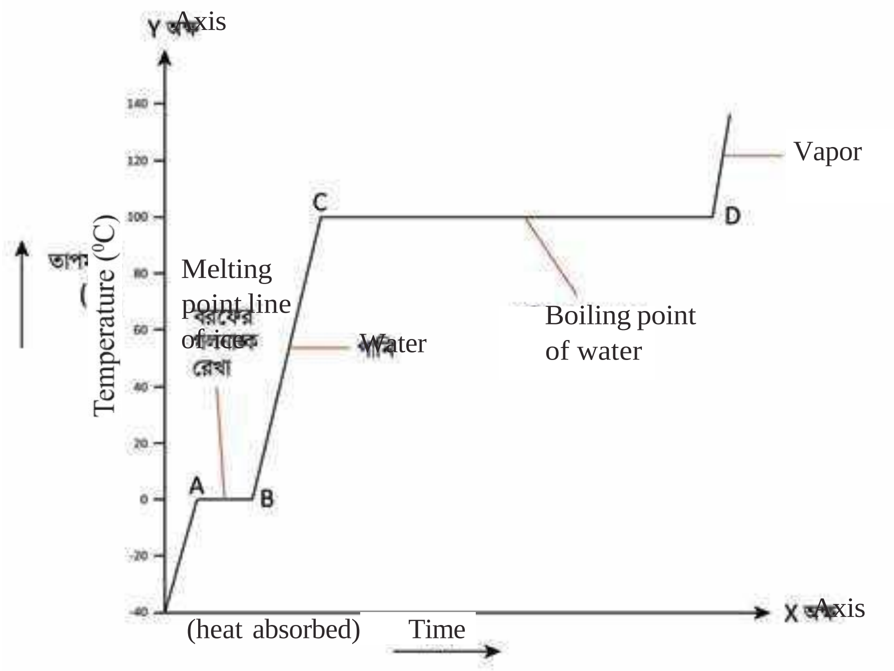


Fig 2.09: Graph of applying heat on ice.

When the temperature of the ice reaches 0°C absorbing the heat, they melt into liquid. The temperature remains stagnant at 0°C until all the ice cubes melt into the water. That proves 0° C as the melting point of ice. The straight line in the temperature is called the melting point line. In the fig 2.09, line AB is the melting point line. Both ice and water exist through the length of the line. If we apply more heat, the temperature of water starts to rise. When it reaches 100°C, you'll see more heat will not be able to raise the temperature of water anymore. Rather, the water transforms into vapor. All the water will vaporize at this 100° C temperature. If we apply more heat after that, the temperature of the water vapor will increase. The boiling point of water is 100°C. CD is the line of boiling point. Water and vapor co-exist at this line.

<ri

Again, collect the data of cooling the water vapor and set them on a graph sheet with X axis telling time and Y axis telling temperature. It will be like fig2.10.

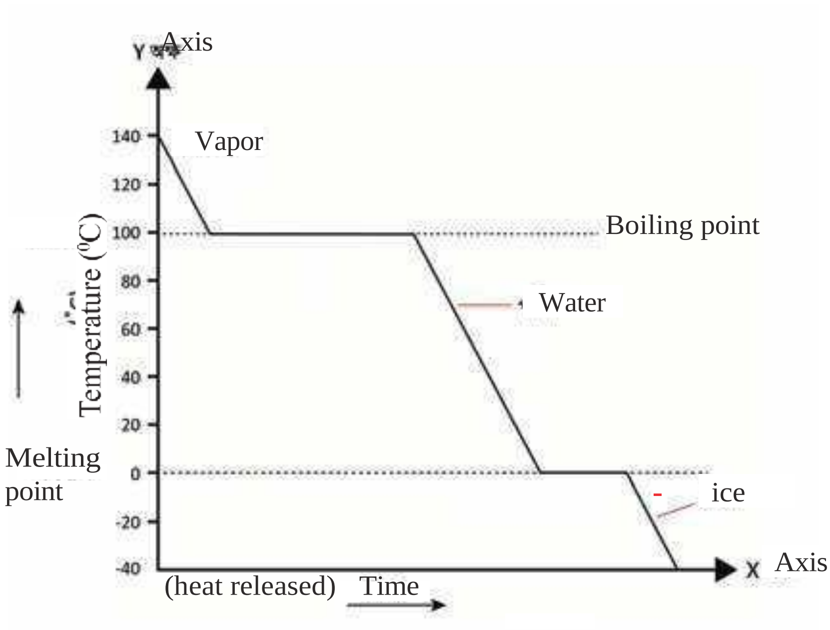


Fig 2.10: Cooling curve of vapor.

The graph shows the initial temperature of water vapor is 140° C. When in the process of cooling it to 100° C, the vapor starts to tum into water. It remains 100° C until all the vapor is turned into water. Further cooling starts to decrease the temperature of water. When it reaches 0°C, the water starts to transform into ice. It remains the same until all the water is turned into ice and then the temperature of ice decreases from 0° C. The fig 2.10 shows a decrease of temperature of ice to -40° C.

2.7 Distillation and Sublimation

The process of heating a liquid and turning it into gas is called evaporation or vaporization. When water from a hot tea is converted to vapors, that is an example of vaporization. Again ifwe cool that vapor, the vapor turns into liquid. This process is called condensation. For example, water vapor emits heat and turns into water, which is condensation. The process of heating a liquid into vapor and then retrieving the liquid from the vapor by cooling it is called distillation. That means,

$$\boxed{\text{Distillation } = \text{vaporization} + \text{condensation}}$$

Figure 2.11 shows the change of state of a volatile substance by applying heat.

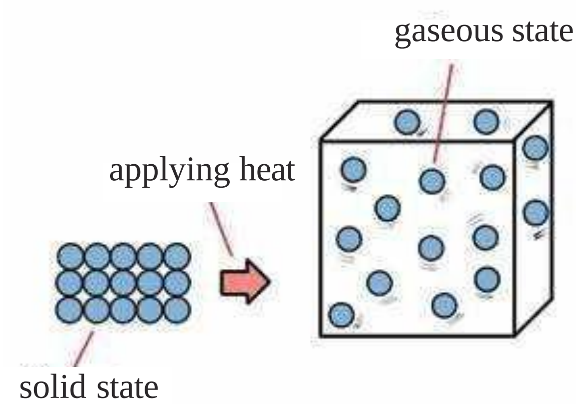


Fig 2.11: Sublimation of substance.

The process in which heating a solid directly turns that solid into a gaseous substance instead of a liquid, is called sublimation. Ammonium Chloride (NH_4Cl), camphor ($C_{10}H_{16}0$), Naphthalene ($C_{10}H_8$, solid Carbon dioxide (CO), Iodine (I), Aluminum Chloride ($A1Cl_3$)etc. are matters that do not tum liquid if heat is applied. Instead, they vaporize. These substances are called sublimated substances.

Experiment 7

Take some solid aluminum chloride salt in a beaker. Put a glass lid on its open face. Put some ice cubes on the lid. Now, apply heat slowly on the beaker. You'll see the solid $A1Cl_3$ is turning into gaseous form absorbing heat. This gaseous $A1Cl_3$ again reaches the lid and under the influence of ice, condenses itself underneath the lid.

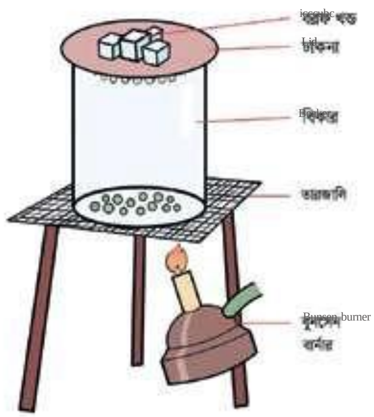


Fig 2.11: Sublimation of$AlCl_3$.

If a sublimated substance is mixed with some solid matter, it can be retrieved by means of the sublimation process. For example, if some ammonium chloride (NH_4Cl) is mixed with some edible salt ($NaCl$), it can be separated by the process of sublimation. If heat is continuously applied to a sublimated substance, it vaporizes. In iodized salt, iodine is a sublimated substance. If you apply heat to that salt, the iodine will be vaporized from there.

The vapor can be cooled into solid iodine. However, since the mixture of sand and glucose does not contain any sublimated substance, therefore, you cannot separate them by sublimation.

Exercise

Multiple Choice Questions

1. What kind of action takes place when hot tea is kept in a tea cup?

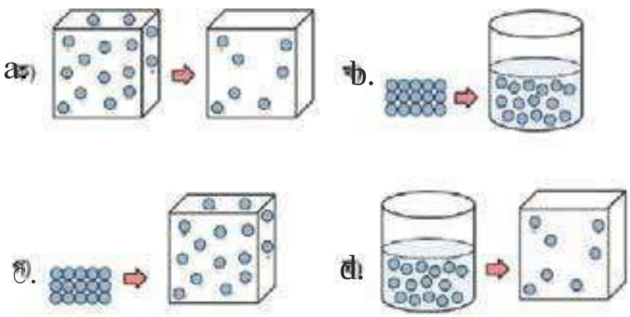
   a. vaporization b. sublimation

   c. diffusion d. effusion

2. What will happen to the particles when water vapor is condensed?

a. size will reduce
b. will remain in movement
c. will vibrate at the same position
d. energy will evolve

3. Which of the following pictures is applicable for sublimation?



4. Heating curve of unknown solid matter Z tells us:

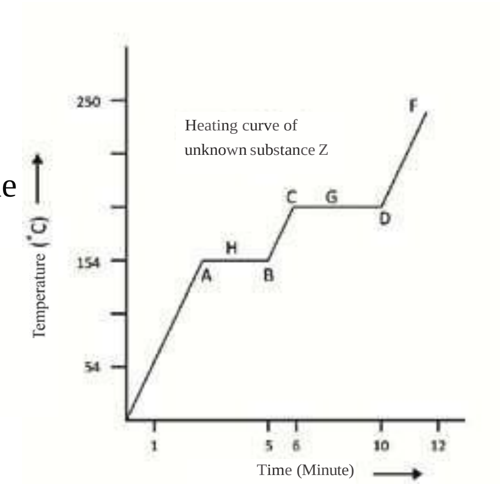
i. melting point of Z is 154◦ C

ii. Z is volatile

iii. AB and CD curves indicate the boiling and melting lines of Z

Which of the below is correct :

a. i and ii
b. ii and iii
c. i and iii
d. i, ii and iii



5. Which of the followings has the highest rate of diffusion?

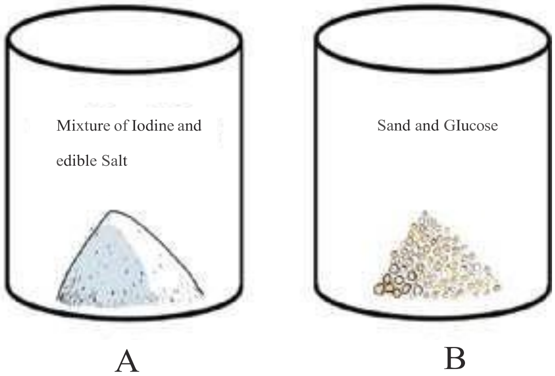
a. CO_2
b. NH_3
c. HCl
d. H_2SO_4

6. Which of the followings can be sublimated?

a. Iodine
b. Edible salt
c. Copper sulfate
d. Soda ash

Creative Questions

1.



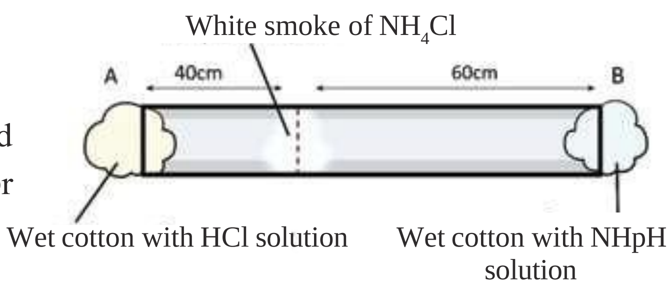
a. What is diffusion?

b. When you open the gas cylinder used for cooking, which action takes place first-diffusion or effusion?

c. If you increase heat, which of the matters in the stem will vaporize first? Explain.

d. Can you separate the elements of the two mixtures using the same process? Show reasons for your answer.

2.



a. What is effusion?

b. Why are melting point and boiling point different for the same matter?

c. What kind of change is the process of the stem? Explain.

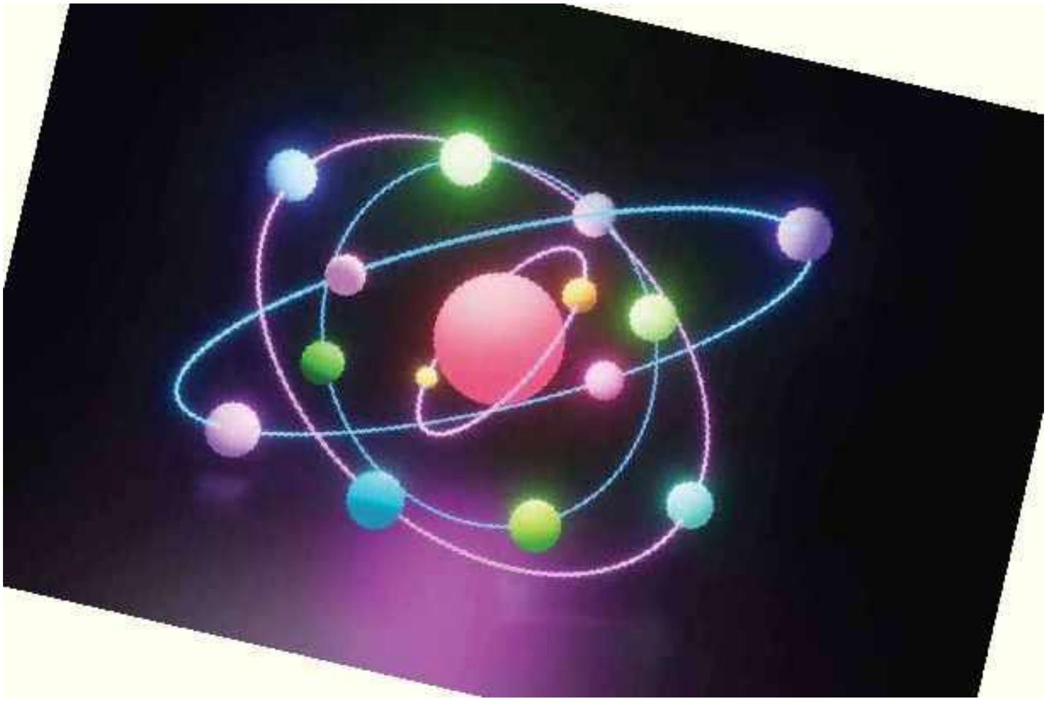
d. Why white smoke is produced at the end A of the tube? Explain with logic.

3. A beaker containing some ice cubes is slowly heated. With the passage of time, the changes in the state of ice are observed.

a. What is distillation?
b. What do you understand by diffusion and effusion?
c. Present the action of the stem on a graph sheet.
d. What will happen if you replace ice of the stem with naphthalene? Analyze.

Chapter Three

Structure of Matter



Electronic configuration in different energy level of hydrogen.

Have you ever thought what the things around us are made of? What 1s our body made of? Yes, like us, the ancient philosophers also used to think of these questions. The ancient Greek scholars used to think, there were four basic elements- soil, water, air and fire. All other things according to them were made of these four elements. Greek philosopher Democritus was the first to say that all substances have a unit which is very small and indivisible. He called it the Atom. This however did not get any recognition as it lacked any scientific proof. After 2500 years John Dalton, the British scientist, gave a theory on atoms in 1803 which was based on data collected from various experiments. He said, every matter of the universe is made of small, indivisible particles. He honoured the Greek philosopher by naming these particles Atom. Later on, it was proved that atoms are not indivisible. Any atom can be divided into electrons, protons and neutrons. This chapter will focus on various models of the atom, fundamental particles of atom, configuration of the electrons etc.

By the end of the chapter, we will be able to

- write symbols of elements from their English and Latin names
- describe the characteristics of fundamental and stable particles
- describe atomic number, mass number and relative atomic mass
- calculate the relative molecular mass from the relative atomic mass
- calculate the number of electrons, protons and neutrons of an atom
- explain the uses of isotopes
- describe the Rutherford and Bohr models of atom's structure
- explain whether the Rutherford or the Bohr model is more acceptable
- arrange electrons of atoms in orbits and different sub-orbits

3.1 Elements and Compounds

Elements

Certainly you have seen gold, silver or iron. No matter how far you divide pure gold, you will get nothing but gold. The same is applicable in the cases with silver or iron. When divided, the matter which does not yield anything but itself, is called element. Besides the above three, nitrogen, oxygen, phosphorus, carbon, helium, argon, magnesium, sulfur etc. are also elements. So far, a total of 118 elements have been discovered. Out of them, 98 elements are available in nature and the rest are made in the laboratory. The second group is known as artificial elements. Do you know that your body contains as many as 26 different elements?

Compounds

You have already known that an element yields the element only. If water is analyzed, we shall find two different elements- hydrogen and oxygen. The same way, if we analyze writing chalk, we get calcium, carbon and oxygen. The substances which, if divided, give away two or more elements are called compounds. In a compound, elements will always exist in the same ratio. For example, chemical analysis of any water sample collected from any place will show two hydrogens and one oxygen. That means, the ratio of hydrogen and oxygen atoms in water is 2:1. The characteristics of compounds are different from those of elements they are made of. Again, for example, at normal room temperature, hydrogen and oxygen are gaseous elements but when they make water, it is a liquid.

3.2 Atoms and Molecules

Atoms are the smallest particles of elements that contain the characteristics of the elements. For example: Nitrogen atoms contain the characteristic features of nitrogen while oxygen atoms contain the same of oxygen.

When two or more atoms remain connected with each other in a chemical bond, it is known as a molecule. You will learn about chemical bonds in detail in chapter five. Two oxygen atoms (0) bond to each other to form an oxygen molecule (OJ. Again, a carbon atom (C) bonds with two oxygen atoms (0) to generate a carbon dioxide (CO) molecule. When more than one atoms of a specific element bond each other, they produce that element's molecule, like 0_2. When atoms of different elements bond together to produce a molecule, it is called a molecule of the compound, like CO_2.

3.3 Symbols of Elements

The abbreviated form of English or Latin name of an element is called its symbol. Each element has its own symbol. There is a system of writing a symbol of an element.

Table 3.01: Symbols of Elements.

Element	Symbol
Hydrogen	H
Oxygen	O
Nitrogen	N

a. The first letter of an English name of an element is usually the symbol and that has to be written using capital letters. For example, the symbol of Hydrogen is (H),the symbol of carbon (C) and the symbol of oxygen (0) etc.

b. When the first letter of two or more elements is the same, one of them is expressed by the first letter. The other element(s) get the first two letters; the first letter is capitalized, followed by a small hand second letter.

Table 3.02: Symbols of Elements (First letter same).

Element	lSymbol	Element	Symbol
Carbon	C	Cobalt	Co
chlorine	Cl	Cadmium	Cd
Calcium	Ca	Chromium	Cr

c. Some elements have got their symbols from their Latin name.

Table 3.02: Symbols of Elements (Latin Name).

Element	Latin Name	Symbol	Element	Latin Name	Symbol
Sodium	Natrium	Na	Gold	Aurum	Au
Copper	Cuprum	Cu	Lead	Plumbum	Pb
Potass um	Kalium	K	Tungsten	Wolfram	W
Silver	Argentum	Ag	Iron	Ferrum	Fe
Tin	Stannum	Sn	Mercury	Hydrurgyrum	Hg
Antimony	Stibium	Sb			

Individual Task:

Collect names and symbols of some elements from the Periodic table given in chapter four and show it to your teacher.

3.4 Formula

One Hydrogen molecule is expressed as H_2. It means, there are two Hydrogen atoms in that molecule. Again, one molecule of water is expressed as H_20, meaning, it contains two Hydrogen atoms and an Oxygen atom. The following table shows formulas of some common molecules:

Table 3.04: Formula of Molecules.

Name of Molecule	Formula
Nitrogen	Nz
Ammonia	NH_3
Chlorine	Cl_2
Sulfuric Acid	H2S04
Hydrochloric Acid	HCl

3.5 The Fundamental Particles of an Atom

Each atom consists of three stable particles- electrons, protons and neutrons. These particles are called fundamental particles of atoms. Protons and neutrons remain in the nucleus at the center of the atom while electrons continue to move around the nucleus.

Electron: Electron is one of the fundamental particles of atom containing negative charge. The amount of this charge is -l.60x10-^{19} coulombs. It is expressed

through the symbol e. An electron has the mass of 9.11x10-^{23} g. The relative charge of electron is taken to be **-1** and the mass of electron is 1/1840 of proton and neutron. That is why, the relative mass of electron is taken as 0.

Proton: Proton is one of the stable particles of an atom containing positive charge. The charge is +1.60 x10^{-19} coulomb. It is expressed by p. The mass of proton is 1.67 x 10^{-24} g. The relative charge of proton is taken as +1 and relative mass is taken as 1.

The characteristic properties of fundamental particles of atoms are presented in the following list.

Table 3.05: Fundamental Particles.

Name of Particle	Symbol	Actual Charge	Actual Mass	Relative Charge	Relative Mass
Electron	e	-1.60 x 10^{-19} coulomb.	9.110 x 10^{-28} g	-1	0
Proton	p	+1.60 x 10^{-19} coulomb.	1.673 x 10^{-24} g	+1	1
Neutron	n	0	1.675 x 10^{-24} g	0	1

Neutron: Neutron is another stable particle of an atom containing no charge. Neutron prevails in atoms of all elements except hydrogen. Expressed by n, a neutron has a mass slightly more than a proton. Its relative charge is O and relative mass is 1.

3.5.1 Atomic Number

Atomic number of an element is determined by the number of protons present in the nucleus of that element's atom. For example: an atom of Helium (He) has two protons in its nucleus, so the atomic number of Helium is 2. Again, an Oxygen atom has eight protons in its nucleus, so the atomic number of Oxygen is 8. The atomic number denotes an atom.Therefore, the atomic number can also be called the ID number of an element. If the atomic number is 1, we understand it is Hydrogen, if the atomic number is 2, we understand it is Helium, if the atomic number is 9, we understand it is Fluorine. Thus, atomic number is the permanent identity of an atom. Proton number or atomic number is expressed by Z. Since all atoms are charge neutral, so they contain the same number of electrons as is the number of protons in its nucleus.

3.5.2 Mass Number

The mass number of an atom is denoted by the total number of protons and neutrons in its nucleus. The mass number is expressed by A. Since the mass number is the summation of neutrons and protons, we can get the number of neutrons in an atom by deducing its proton number from the mass number. The mass number of Sodium (Na) is 23, its proton number is 11; so the number of neutrons in sodium is (23 - 11) = 12.

The atomic number of an atom is written at the lower left comer of its symbol while its mass number is written at the upper left comer. In the case with Sodium (Na), it will be written as

Mass Number (A)

if Na

Atomic Number/
Proton Number (Z)

Table 3.05: Short Form of Different Elements.

Symbol	Atomic/Proton Number (z)	Mass Number A	Number of Electrons	Number of Neutrons (A -Z)	Short Form
H	1	1	1	0	$^{1}_{1}H$
He	2	4	2	2	$^{4}_{2}He$

Individual Task

Student Task: Find out the mass number, number of protons and electrons for Li and Be.

3.6 Atomic Model

3.6.1 Rutherford's Atomic Model

Rutherford has given a model on the structure of atom in 1911. The model states:

a. In the centre of an atom there is a positively charged dense central core. This core is called the nucleus of the atom. Protons and electrons are situated inside and out side this nucleus respectively. Since, compared to the whole mass of the atom, the mass of electron is zero, so protons and neutrons inside the nucleus determines the whole mass and positive charges of the atom.

b. The Nucleus is very small and most of the space inside an atom is void.

c. Electrons in an atom always move round the nucleus in different orbits like the planets revolve round the sun in the solar system. The number of electrons in an atom is same as the number of protons. Since the charge of an electron and proton in an atom are equal and opposite, therefore the overall charge of an atom 1s zero.

d. The electrons with negative charge are attracted to the positively charged nucleus. The force of this attraction is centripetal and due to this centripetal force, electrons move round the nucleus like our earth does a round the sun.

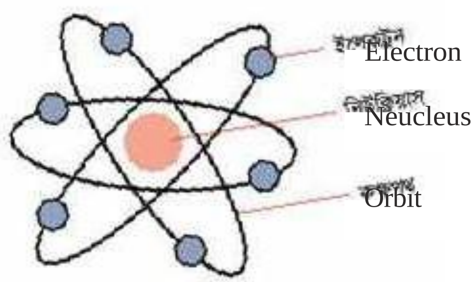


Fig 3.01: Rutherford's Atomic Model.

Rutherford's model is known as the solar system model for its continuous parallelism to the solar system. Again, since the Rutherford model first gave the idea of a nucleus, it is also called the nuclear model.

Limitations of Rutherford's Model

Rutherford is the first scientist to introduce the idea of a nucleus and orbits of an electron. Although his model is the first acceptable atomic model, it has some limitations. They are:

a. Rutherford's model did not give any idea about the size and shape of the orbits along which the electrons move.

b. Planets in the solar system are electrically neutral but electrons and nucleus are charged. A parallelism between some charge neutral elements and charged elements is not quite correct.

c. There is no satisfactory explanation regarding how the electron will move round the nucleus in the case of atoms having more than one electron.

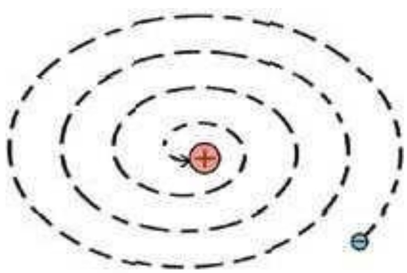


Fig 3.02: Electron falling on nucleus.

d. According to Maxwell's electromagnetic theory of radiation, any charged particle moving in a circular path, always emits energy and its radius will gradually grow smaller. At a stage, it is supposed to fall into the nucleus. That will be the end of the atom or at least its stability will be in trouble. However, that doesn't happen in nature; in other words, according to Maxwell's theory, Rutherford's atomic model is not correct.

3.6.2 Bohr's Atomic Model

Scientist Neils Bohr gave some corrections to Rutherford's atomic model in 1913. This corrected model is called the Bohr's atomic model. The main postulates of this model are:

a. The electron moves around the nucleus in a circular motion, about an axis. This circular motion is called an energy level or orbit. They are also known as shell or permanent orbit or principal energy level. Electrons do not absorb or emit any energy when they revolve round these fixed orbits. If we express the permanent orbit as n, then n = 1, 2, 3, 4 etc. In other words, if n = 1, the principal energy level is K, when n = 2, Lis the principal energy level, when n = 3, Mis the principal energy level, when n = 4, N is the principal energy level etc.

b. According to Bohr's model, the angular momentum of an electron in an energy level is mvr = nh/2n . Here,

m = the mass of electron (9.11x10-^{31} kg)
r = the radius of the orbit that the electron follows
v = the velocity of electron in the permanent orbit
h = Plank constant (h = 6.626xl0-^{34} m^2 kg/s)
n = principal energy level or principal quantum number (n = 1, 2, 3, 4, ...)

According to this, the energy level with a lesser value of n is the lower energy level and the energy level with a higher value of n is the higher energy level.

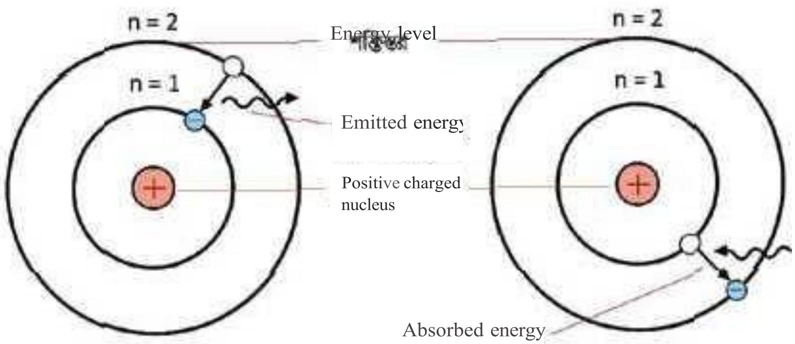


Fig 3.03: Bohr's Atomic Model.

When an electron moves a round in its principal energy level, it doesn't absorb or emit any energy. However, it absorbs energy when it moves from a lower to a higher energy level. The same way, an electron emits energy when it moves from a higher to a lower energy level. This absorbed or emitted energy is hv = he/).,. Here, c = velocity oflight ($3x10^8$ ms^{-1})

v = frequency of absorbed or emitted energy (unit s^{-1} or Hz)

"A= length of energy wave absorbed or emitted (unit m)

The light emitted when an electron moves from higher energy level to lower energy level creates an atomic spectra when it goes through a prism.

Success of Bohr's Model

a. Rutherford compared the orbits of electrons around nucleus to that of the planets in the solar system. It did not mention anything about the size of the energy levels. Bohr's atomic model specifies the circular size of the energy levels.

b. Rutherford's model does not mention about the changes in structure of atom when they absorb or emit energy. The Bohr model states that the electron moves from lower to upper energy level when the atom absorbs energy and it moves from upper to lower energy level when the atom emits energy.

c. The Rutherford model doesn't explain the atomic spectra but the Bohr model can explain the atomic spectra of hydrogen (H) atom with one electron.

Limitations of Bohr's Model

a. Although the Bohr model can explain the spectrum of hydrogen containing one electron, it cannot explain the spectrum of ions or atoms containing more than one electron.

b. When electrons are transferred from one energy level to another, according to Bohr, there will be a single line in the spectrum. But highly sensitive apparatus shows every line consists of several fine lines. Why each line is the summation of various lines is not explained.

c. The Bohr model specifies that orbits of electrons in an atom is circular. However, later on, it was proved that the orbits can be of oval shape too.

3.7 Orbital Electronic Configuration of Atoms

The Bohr model states about the principal energy level. Each principal energy level can contain $2n^2$ electrons at the highest, where n = **1,** 2, 3 etc. According to this formula:

For energy level K, n = 1, so, the highest number of electrons in K is $2n^2 = (2\times 1^2) = 2$.

For energy level L, n = 2, so, the highest number of electrons in L is $2n^2 = (2 \times 2^2) = 8$.

For energy level M, n = 3, so, the highest number of electrons in M is $2n^2 = (2\times 3^2) = 18$.

For energy level N, n = 1, so, the highest number of electrons in N is $2n^2 = (2\times 4^2) = 32$.

Table 3.06: Electron Configuration of Elements [H(1) – Zn(30)].

Atomic Number	Element	K	L	M	N
1	H	1			
2	He	2			
3	Li	2	1		
4	Be	2	2		
5	B	2	3		
6	C	2	4		
7	N	2	5		
8	O	2	6		
9	F	2	7		
10	Ne	2	8		
11	Na	2	8	1	
12	Mg	2	8	2	
13	Al	2	8	3	
14	Si	2	8	4	
15	P	2	8	5	

Atomic Number	Element	K	L	M	N
16	S	2	8	6	
17	Cl	2	8	7	
18	Ar	2	8	8	
19	K	2	8	8	1
20	Ca	2	8	8	2
21	Sc	2	8	9	2
22	Ti	2	8	10	2
23	V	2	8	11	2
24	Cr	2	8	13	1
25	Mn	2	8	13	2
26	Fe	2	8	14	2
27	Co	2	8	15	2
28	Ni	2	8	16	2
29	Cu	2	8	18	1
30	Zn	2	8	18	2

The atomic number of Hydrogen is **1,** meaning it has one electron which will reside in energy level K. The atomic number of helium (He) is 2. So, its electron number is also 2 and these two electrons will enter the first energy level known as the K-shell. The atomic number of lithium (Li) is 3. So, its electron number is also 3, and the first 2 of the 3 electrons will enter the K-shell. Since the principal energy level, K-shell cannot contain more than two electrons, its third electron will enter the second energy, L-shell.

In the same way, the atomic number of sodium (Na) is 11. So, its electron number is also 11. These electrons are arranged in the energy levels as follows: 2 electrons in the K shell, 8 in the L shell, and the remaining 1 electron in the M shell.

A careful look will tell you that the electronic configuration from Hydrogen to Argon follows the rule stated above. However it doesn't remain the same in the case with elements from Potassium (K) onwards. We know that the highest capacity of the third principal energy level (M) is 18. But the 19^{th} electron of Potassium and 19^{th} and 20^{th} electrons of Calcium enter the fourth principal energy level (N) even before fulfilling the third. In the case with Scandium (Sc), the 21st electron has returned to the third principal energy level after its 19^{th} and 20^{th} went to the fourth principal level. Beginning from the atomic number 19 onwards, two electrons enter the fourth level first and then the rest return to level three. Still, we find exception in the case with Cr and Cu. We need to understand the idea of sublevels of energy before we attempt to understand it.

3.7.1 Concept of Energy Sublevel

We have seen all energy levels are specified with n. These levels are again divided into sublevels which are expressed by 1. The value of 1 is from O to n-1. These sublevels are called orbitals. They are identified with s, p, d, f etc.. The value of *l* for different orbitals is shown below:

When n = 1, *l* = 0. There will be one orbital: ls.

When n = 2, *l* = 0, I. There will be two orbitals: 2s, 2p.

When n = 3, *l* = 0, I, 2. There will be three orbitals: 3s, 3p, 3d.

When n = 4, *l*= 0, 1, 2, 3. There will be four orbitals: 4s, 4p, 4d,4f.

When n = 5, *l* = 0, I, 2, 3, 4. There will be five orbitals. However, if all the electrons are configured in the 4s, 4p, 4d, 4f orbitals, then there won't be any necessity for the fifth. The same is the case with n = 6, 7, and 8.

The number of subshells in each principal energy level is calculated by the formula (2/ + 1). Each subshell has an electron-carrying capacity of 2. Thus,eaeh orbital contains $2(2l + 1)$ number of electrons. We already know each principal energy level has $2n^2$ number of electrons. Now we shall see that the summation of all orbitals tum into this $2n^2$:

Table 3.07: Electronic Configuration in Energy Levels (n = 1-4).

Energy Leveln	Value of sublevel *l* according to n	Orbital Name according to *l*	Orbital Symbol	Total Number of Electrons in Orbital 2(2/+1)	Total Number of Electrons in Energy Level $2n^2$
1	0	s	ls	2	2
2	0	s	2s	2	2 + 6 = 8
	1	p	2p	6	
3	0	s	3s	2	2 + 6 + 10 = 18
	1	p	3p	6	
	2	d	3d	10	
4	0	s	4s	2	2 + 6 + 10 + 14 = 32
	1	p	4p	6	
	2	d	4d	10	
	3	f	4f	14	

3.7.2 The Principles of Electronic Configuration in Atoms

there are three principles for electron arrangement in atoms: (1) Pauli's Exclusion Principle, (2) Aufbau Principle, and (3) Hund's Rule. You will find a detailed discussion of these principles in the higher secondary chemistry textbook. Here, we have provided a brief overview of these principles to explain electron configuration in an atom. Here the basic concepts of these principles and the electron arrangement of atoms are briefly discussed. Electron first enters the lowest energy orbital of an atom and then gradually goes into the highest energy orbital. That means, the electron will enter the lowest energy level first and the highest level later. The energy level of the orbital is determined by the summation of value of principal energy level (n) and value of energy sublevel *(l)*. The orbital that has a lesser value of (n + **1)** is of lesser energy level and it gets the first entry of an electron. The orbital that has a higher value of (n + 1) is of higher energy level and it gets the later entry of an electron.

For 3d orbital, n = 3 and 1 = 2, so the value (n + 1) becomes (3 + 2 = 5). Again, for 4s, n = 4 and 1 = 0, so the value (n + 1) becomes (4 + 0 = 4). It shows 4s orbital has lower energy than 3d orbital. Therefore, the electron will first enter 4s and then will go to 3d. Again, if the value (n + 1) of two orbitals are equal, then the orbital with lesser value of n has lower energy and the electron will enter here first. In the same way, the orbital with higher n gets the electron later for being higher in energy.

For example, the values (n+l) of 3d and 4p are 3+2 = 5 and 4+ I = 5 respectively. Here in this case, since the value of n in orbital 3d is lesser than orbital 4p, so it is lower in energy and orbital 4p, being higher energetically will get electrons later. According to this system, the gradual sequence of energy of orbital in receiving electrons will be:

ls < 2s < 2p < 3s < 3p < 4s < 3d < 4p < Ss < 4d < Sp < 6s < 4f < sd < 6p < 7s < sf < 6d < 7p < 8s

We can easily remember the sequence of energy level from the chart below:

We have seen, the orbital s can contain a maximum of two electrons, the orbital p can contain a maximum of six electrons, the orbital d can contain a maximum of ten electrons and the orbital f can contain a maximum of fourteen electrons. Following this, we can configure the electrons of the following elements.

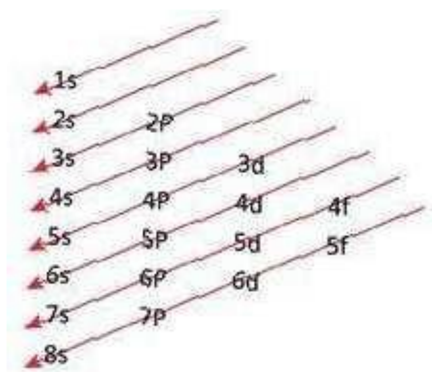


Fig 3.04: Sequence of Energy of Orbitals.

K(19)	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1$
Ca(20)	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$
Sc(21)	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^1\ 4s^2$
Ti (22)	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^2\ 4s^2$

Since the 4s orbital is lower in energy than the 3d orbital, so the 19th electron of Potassium enters 4s instead of3d. Again, in the case with Scandium, 19^{th} and 20^{th} electrons go inside 4s and then the 21st electron goes to the higher energy 3d orbital.

Always remember, when writing the electronic configuration, write down all orbitals of an energy level side by side; otherwise there is chance of making mistakes. For example: the configuration of Fe (26) will be

	n=l	n=2	n=3	n=4
Fe(26)	$1s^2$	2s2 2p6	1. s2 3p6 3d6	$4s^2$

Fe(26) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^6\ 4s^2$

3.7.3 Some Exceptions in Electronic Configuration

Commonly, if the orbital of the energy sublevel p and d are half full (p^3, d^5) or complete (p6, d'^0), that kind of electronic configuration is the most stable. That way, the electronic configuration of Cr(24) is supposed to be Cr(24) $1s^2 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^4\ 4s^2$. But the interest of 3d to be half full brings one electron from 4s.That way, the final configuration stands at Cr(24)$ls^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5\ 4s^1$

Individual Task

Do Yourself

The electronic configuration of Cu(29) is Cu(29) $ls^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10} 4s^1$ whereas it is supposed to be $ls^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^9\ 4s$. Explain the reason.

3.8 Isotopes

Atoms of the same element with equal number of protons but different numbers of neutrons and mass are called isotopes of each other. The three atoms in the table below have the same number of protons. Therefore, they are isotopes of each other. Hydrogen has seven isotopes ('H, ^2H, ^3H, ^4H, ^5H, ^6H, ^7H). Three of them are available in nature and the remaining four are laboratory made.

Table 3.08: Three Natural Isotopes of Hydrogen.

Name	Symbol	Proton Number Z	Mass Number A	Neutron Number A-Z
Hydrogen or Proteum	**iH**	1	1	0
Deuterium	$^{Z}_{1}O$	1	2	1
Tritium	$^{3}_{1}T$	1	3	2

3.9 Atomic Mass or Relative Atomic Mass

We already know that, the mass number of an element's atom is the summation of the number of protons and neutrons present in its nucleus. It certainly implies the idea that the mass number is an integer. But you will see the atomic mass of copper is 63.5 and the atomic mass of chlorine 35.5. How is that possible? Indeed, it is the relative atomic mass. What is it and why is it necessary?

The mass of an atom of Fluorine is 3.16x1Q-^{23} g

The mass of an atom of Aluminium is 4.482x10-^{23} g

It is really hard to use such small masses. That is why, 1/12 th of a Carbon 12 isotope is taken as a unit and then the atomic mass of other atoms are determined relative to that.

1/12 th atomic mass of Carbon 12 isotope is 1.66 xlQ-^{24} g

Therefore, the relative mass of the element:

$$\frac{\textit{mass of one atom of element}}{\text{iZ} \textit{ of mass of a Carbon 12 isotope}}$$

If we know the actual mass of an atom, we can determine its relative atomic mass. We have to divide the total real mass of an atom by 1.66×10^{-24} g to get the relative atomic mass. Example:

The real mass of an Al atom is 4.482×10^{-23}g

So, the relative atomic mass of an Al atom is $= \frac{4.482 \times 10^{-23} g}{1.66 \times 10^{-24} g} = 27$

The relative atomic mass is a ratio of two masses, so it doesn't have any unit.

3.9.1 Determining the Average Relative Mass of an Element from Percentage of Isotope

Most of the elements in nature have more than one isotope. We calculate the average relative mass of those elements having more than one isotope from their percentage of availability in nature. The steps in this calculation are:

Step 1: Multiply the mass numbers of all isotopes of that element with the percentage of natural availability of those isotopes.

Step 2: Get the summation of all the results of step 1.

Step 3: Divide the total of step 2 by 100. This will give the average relative mass of that element.

Suppose, an element A has 2 isotopes. If the mass number and natural availability of one of these isotopes are p and m respectively while the same of the other are q and n, then,

The average relative atomic mass of that element is $= \frac{p \times m + q \times n}{100}$

Example: There are two isotopes of chlorine in nature, ^{35}Cl and ^{37}CL

Naturally available percentage of $^{35}Cl = 75\%$

Naturally available percentage of $^{37}Cl = 25\%$

So, the average relative atomic mass of chlorine $= \frac{35 \times 75 + 37 \times 25}{100} = 35.5$

In the periodic table also, you will see that the average relative atomic mass is shown as 35.5. The periodic table displays the average relative atomic mass.

Example: If there are two naturally available isotopes of an element, then we can calculate the percentage of those isotopes available in nature from the average relative atomic mass.

Suppose, in nature ^{63}Cu is available in *x¾* and ^{65}Cu is available in (100- x) %

the average relati·ve atomi·c mass of Copper = $\frac{XX\ 63 + (100 - X) \times 65}{100} = 63.5$

or, $x = 75\%$

Naturally available percentage of ^{63}Cu = 75% and
Naturally available percentage of ^{65}Cu = 25%

3.9.2 Getting the Relative Molecuhr Mass from Relative Atomic Mass

We can get the relative molecular mass of an atom by taking the summation of the multiplied value of relative atomic mass of the atoms with their respective number of atoms. Generally, relative atomic mass is considered as atomic mass and relative molecular mass as molecular mass.

The atomic mass of Hydrogen (H) atom in a H_2 molecule is 1 and it has two atoms, so the relative molecular mass ofH_2 molecule is lx2 = 2.

Similarly, in a H_2SO_4 molecule, the relative atomic mass of H is 1 and number of atoms are 2. The relative atomic mass of Sulfur is 32 and number of atom is **1.** The relative atomic mass of Oxygen is 16 and number of atom is 4. Therefore, the relative molecular mass of sulfuric acid will be 1x2 + 32x1 + l6x4 = 98.

3.10 Radioactive Isotopes and Their Uses

We have already learned about isotopes in this chapter. There are some isotopes the nucleus of which spontaneously synthesize themselves and emit alpha (a), beta ( ) and gamma (y) rays. Isotopes of and element that emit radioactive rays are called radioactive isotopes. So far, scientists have gathered information more than 3000 isotopes. Some of them are natural and some are laboratory made. The physics book for your class discusses about various isotopes and their radioactivity in details. We will learn about their uses here.

Controlled use of radioactive isotopes has made many an impossibility possible. Presently, such isotopes are used in medical science, agriculture, preservation of food and seeds, electricity generation etc.

3.10.1. Medical Science

Medical science employs radioactive isotopes for various purposes.

Diagnoses

We can take pictures of a patient's affected area using radioactive isotopes. Technetium-99 (^{99}Tc) is injected inside the body in this system. When it gathers a particular isotope at a certain place inside the body, the isotope emits gamma rays. The gamma ray identification camera from outside can take the photo of that spot of the body. The lifetime of this isotope is 6 hours. Since it loses its radioactivity within a short time, it is safe.

Treating Diseases

Radioactive isotope was first used to cure thyroid cancer. The patient is made to drink a solution of ^{131}I . This isotope reaches the thyroid and emits beta rays which destroys the affected cells. Iridium isotope is used to treat brain cancer. ^{60}Co isotope is used to diagnose and treat tumors. The gamma rays emitted from this isotope destroys the cancer affected cell and tissue. ^{32}P isotope is used for treatment of leukemia.

3.10.2 Agriculture Sector

Nutrition of Crops

Sufficient fertilizers are required for nutrition of crops. The quantity of fertilizer is an important issue. Excess fertilizer costs more than necessary. It is also harmful for the environment. Again, less than necessary fertilizer won't be of any help. Radioactive isotopes help to determine the amount of Nitrogen and Phosphorus present in the soil. Plants absorb radioactive Nitrogen and Phosphorus via its roots which is then transferred to different parts of its body. Geiger Muller counters help to identify the presence of these isotopes and helps to determine the presence of the two elements in soil. Then we can determine the remedy too.

Getting Rid of Harmful Insects

Harmful insects are always a threat to a good crop. They not only lessen the production of crops but also they introduce various harmful microbes to the plants. We use insecticides to rid of these insects. These insecticides are harmful for our body and environment as well. These insecticides also manage to kill other insects that were of help for our crops. Insecticides enriched with radioactive isotopes have helped us to determine the standard of use of insecticides for a particular crop.

Development of Crops

Radioactive isotopes also play a significant role in developing hybrid varieties by bringing genetic changes in the original crop.

3.10.3 Generation of Electricity

A huge amount of heat is found in fission reactions or by breaking some atoms into smaller atoms. Driving this heat energy through generators, we can produce electricity. We call such power plants, nuclear power plants. The fourth chapter of your physics book discusses this in detail.

The government of Bangladesh is going to establish a nuclear power plant in Rooppur of Pabna. It is hoped that the power plant will be able to produce 2400MW electricity.

Fig 3.05: Rooppur Nuclear Power Plant.

3.10.4 Impact of Radioactive Isotope

It is true that radioactive isotopes are there for a good number of benefits. But at the same time, they have the potential to harm us too. The alpha, beta and gamma rays emitted from such isotopes can bring about genetic changes to cells which may cause cancer. The atom bombs used in Hiroshima and Nagasaki of Japan during the WWII killed lacs of people. The Chernobyl accident of 1986 in Russia has killed numerous people and has done harm to the adjacent environment.

Exercise

Multiple Choice Questions

1. Z is an element with its **111** protons and mass number 252. Which is the most appropriate expression for the atom?

a. mz b. $^{111}_{252}z$

C. 2s2z d. HiZ

2. What is the relative atomic mass of the element X? (Here, X is just a symbol, not an element)

Isotope	Percentage of Availability
	25
	75

a.148 b.150

c.152 d.153

3. If the real mass of an element is 4.482xI0-^{23} then its relative atomic mass will be-

a. 25 b.40

c.29 d.27

4. The formula $^{27}_{13}$Al Al shows that the element has

1. proton number 13
11. mass number 27
111. electron number I0

Which of the below is correct?

a. i and ii b. ii and iii

c. i and iii d. i,ii and iii

5. What is the atomic number of Potassium?

a.15 b.17

C. 19 d. 21

6. How many energy sublevels are there in N shell?

a. 1 b. 2

c. 3 d. 4

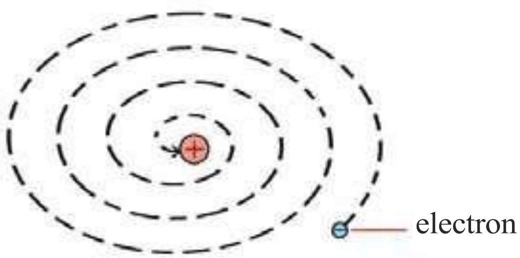
7. The atomic number of Sc is 21. Which is the correct electron configuration of Sc?

a. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1$ b. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$

c. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^1\ 4s^2$ d. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$

Creative Questions

1.Farid, a class 9 student drew the following picture as he was asked to draw an atom model.



a. What is the atomic number?

b. The nucleon number of $^{64}_{29}X$ and $^{64}_{30}Y$ atoms are the same but they differ in the number of neutrons- explain.

c. The picture drawn by Farid refers to the limitations of an atomic model. Describe that model.

d. The drawn picture shows that an atom will not be stable- elucidate.

2. Element A= ^{60}Co, element B = ^{32}P and compound C = H_2SO_4

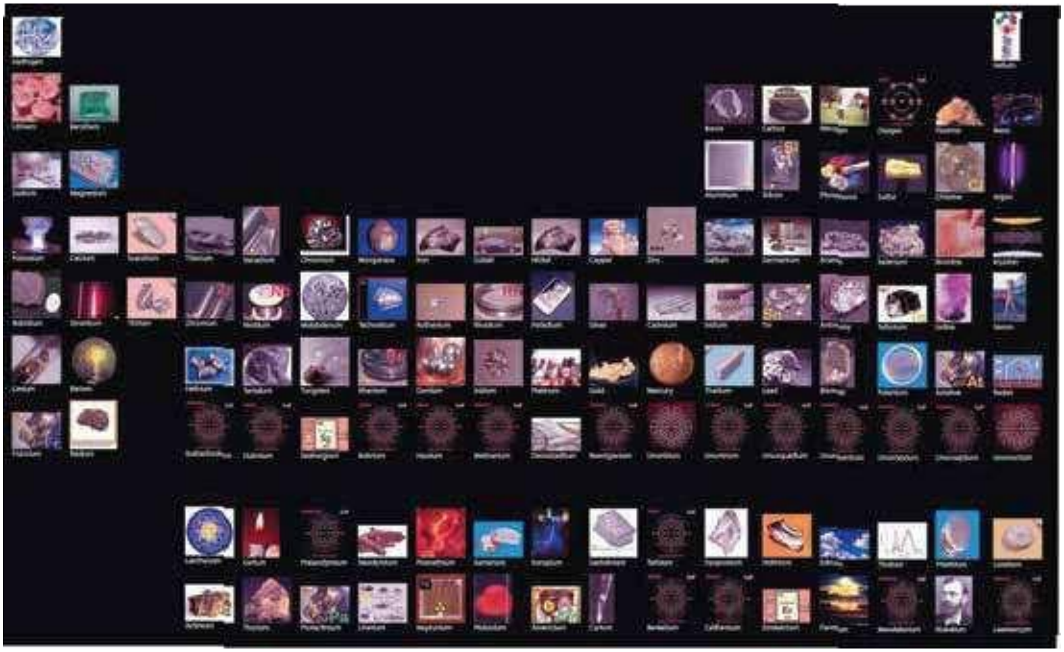
a. What is a symbol?

b. When is the spectra created in an atom? Discuss

c. Find out the relative molecular mass of compound C.

d. The isotopes of A and B play significant roles in our lives. Explain.

Chapter Four
Periodic Table



A special periodic Table.

A total of 118 elements are identified on earth up to the year 2016. Study and research in chemistry requires some idea about the physical properties and characteristic features of all these elements. Some of these elements among them show some common features. There had been efforts among the scientists for a long time to group such elements together and put all the elements in a chart. It took hundreds of years of efforts of various scientists, numerous changes and extensions to get us such a complete table so far, which is known as the Periodic Table. It is a significant achievement in chemical research. A sound knowledge of this periodic table and its features enables anyone with knowledge about not only the elements but also the compounds formed with them. This chapter will give you some introduction to this periodic table and properties and characteristics of elements in the table.

By the end of the chapter, we will be able to -

- describe the background of the development of periodic table
- determine the relation of the principal groups of elements of the periodic table with the electronic configuration of outermost energy levels
- determine the period of an element
- assume the physical and chemical properties of an element in relation to its position in the periodic table
- describe the reasons for special naming of elements
- explain the significance of the periodic table
- show that the compounds formed by the elements of the same group have similar properties.
- make proper use of glass apparatus at the time of experiments
- take precautions at the time of experiments
- show interest in assuming the properties of elements following the periodic table

4.1 Background of Periodic Table

Periodic Table is the outstanding collection of chemical concepts gathered over hundreds of years. It is not an achievement of one single scientist or a one day's effort. Various scientists have given their tireless effort after it to get the present state of the table.

In 1789, Antoine Lavoisier first divided the elements like Oxygen, Nitrogen, Hydrogen, Phosphorus, Mercury, Zinc, Sulphur etc. into metals and non-metals. Then on, there was constant effort to divide the elements in groups having the same characteristics.

In 1829, the scientist Dobereineir found that groups of three elements show the same kind of features. First, he organized the elements into threes according to their atomic mass. Then he marked that atomic mass of the second element is half or near about half of the summation of first and third's atomic mass. Dobereineir identified Chlorine, Bromine and Iodine as the first trio of chemical elements. It is known as Dobereineir's Law of Triads.

For the elements detected up to 1864, English scientist John AR Newlands gave a theory called Law of Octet. According to it, if elements are organized following a sequence of lower to higher atomic mass, there is evident similarity in physical and chemical properties of each eighth element.

In the year 1869, Russian scientist Mendeleev published a table in an attempt to contain elements with similar properties in the same group. Reviewing the physical and chemical properties, he theorized, "Physical and chemical properties of elements return periodically as atomic mass of elements increase."

Following this theory, he organized the 63 elements identified till then in eight vertical columns and 12 horizontal lines. Thus he proved that elements belonging to each column have the same physical and chemical properties and in each line, they change gradually as they progress from left to right. The table was named Periodic Table.

Legend	
Group number	6
Atomic number	24
Atomic mass	52
Symbol	Cr
Name of element	Chromium
Period number	4

Period	1	2	3	4	5	6	7	8	9
1	H Hydrogen								
2	3 7 Li Lithium	4 9 Be Beryllium							
3	11 23 Na Sodium	12 24 Mg Magnesium							
4	19 39 K Potassium	20 40 Ca Calcium	21 45 Sc Scandium	22 48 Ti Titanium	23 51 V Vanadium	24 52 Cr Chromium	25 55 Mn Manganese	26 56 Fe Iron	2 58 Co Cobalt
5	37 85.5 Rb Rubidium	38 88 Sr Strontium	39 89 Y Yttrium	40 91 Zr Zirconium	41 93 Nb Niobium	42 96 Mo Molybdenum	43 98 Tc Technetium	i4 101 Ru Ruthenium	45 103 Rh odium
6	55 133 Cs Caesium	56 137 Ba Barium	57 – 71	72 178.5 Hf Hafnium	73 181 Ta Tantalum	74 184 W Tungsten	75 186 Re Rhenium	76 190 Os Osmium	77 192 Ir
7	87 223 Fr Francium	88 226 Ra Radium	89 – 103	104 261 Rf Rutherfordium	105 262 Db Dubnium	106 263 Sg Seaborgium	107 262 Bh Bohrium	08 265 Hs Hassium	109 266 Mt Metrenium

Elements of Lanthanide series

57 139 La Lanthanum	58 140 Ce Cerium	59 141 Pr Praseodymium	60 144 Nd Neodymium	61 145 Pm Promethium	62 150 Sm Samarium	63 152 Eu Europium

Elements of Actinide senes

89 227 Ac Actinium	90 232 Th Thorium	91 231 Pa Protactinium	92 238 U Uranium	93 237 Np Neptunium	94 244 Pu Plutonium	95 243 Am Americium

Modern Periodic Table

10	11	12	13	14	15	16	17	18
								2 4 **He** Helium
			5 11 **B** Boron C<l@i1	6 12 **C** Carbon <fl1.f.T	7 14 **N** Nitrogen "Il dllljsr"l	8 16 **0** Oxygen	9 19 **F** Fluorine	10 20 **Ne** Neon f.rn.l
			13 27 **Al** Aluminium "!Jloffiif.rnl	14 28 **Si** Silicon	15 31 **p** Phosphorus	16 32 **S** Sulfur	17 35.s **Cl** Cholorine	18 40 **Ar** Argon '!i!l'Fl
28 59 **Ni** Nickel	29 63.5 **Cu** Copper <1'9fli:!	30 65 **Zn** Zinc <I'	31 70 **Ga** Gallium	32 73 **Ge** Germenium	33 75 **As** Arsenic	34 79 **Se** Selenium	35 80 **Br** Bromine	36 84 **Kr** Krypton @'9flT"il
46 106 **Pd** Palladium	47 108 **Ag** Silver	48 112 **Cd** Cadmium	49 115 **In** Indium	50 119 **Sn** Tin w-T	51 122 **Sb** Antimony <.!I	52 128 **Te** Tellurium	53 127 **I** Iodine	54 131 **Xe** Xenon
78 195 **Pt** Platinum	79 197 **Au** Gold c	80 201 **Hg** Mercury .nffl	81 204 **Tl** Thallium	82 207 **Pb** Lead	83 209 **Bi** Bismuth wmt0	84 209 **Po** Polonium c	85 210 **At** Astatine Jl>Ul&l "l	86 222 **Rn** Radon
110 269 **Os** Darmstadtiun 15l fc>U15Pirn	111 272 **Rg** Roentgenium 11 UliSff rn1	112 285 **Cn** Copernicium c1 ' 1	113 284 **Nh** Nihonium	114 285 **Fl** Flerovium	115 288 **Mc** Moscovium MIN>{ll	116 293 **Lv** Livermorium fo4"'111c 1fi'rn1	117 294 **Ts** Tennessine	118 294 **Og** Oganesson '8

64 157 **Gd** Gadolinium •1J1c151fo4f.lrn	65 159 **Tb** Terbium	66 163 **Dy** Dysprosium mm.r	67 165 **Ho** Holmium	68 167 **Er** Erbium	69 **169Tm** Thulium	70 173 **Yb** Ytterbium	71 175 **Lu** Lutetium
96 247 **Cm** Curium	97 247 **Bk** Berkelium	98 251 **cf** Californium g.JIMl<!'lf.fol	99 252 **Es** Einsteinium l "lc>\:f.1{11	100 257 **Fm** Fermium	101 258 **Md** Mendelevium C l<S/ftlNo{ll	102 259 **No** Nobelium	103 262 **Lr** Lawrencium "1li1"1Pl{ll

Another success of Mendeleev's table is his correct forecast about the existence of some elements. He kept some cells in his table blank as there were only 63 of them detected till then. Later on, these cells were accommodated by detected elements, proving Mendeleev correct.

There are some flaws in Mendeleev's table. According to his theory, elements with lesser atomic mass were supposed to be set before the elements with higher atomic mass. However, in Mendeleev's table, Argon with its atomic mass 40 is placed before Potassium with atomic mass 39. He did this to group according to similarity of physical and chemical properties. There are some other cases with similar flaws and other flaws in Mendeleev's table.

In 1913, scientist Mosley proposed to organize elements according to their atomic number instead of atomic mass. When the table was reorganized according to atomic number of elements, Argon (18) came automatically before Potassium (19) and thus the flaw in Mendeleev's table was corrected.

International Union of Pure and Applied Chemistry (IUPAC) has so far detected 118 elements. IUPAC supervises and controls different matters of chemistry and applied chemistry- like creating various rules and regulations, overseeing which of the escalating changes or inventions are to be accepted or discarded etc.

Lavoisier started with only 33 elements which became 63 detected and 4 undetected elements in Mendeleev's table. Now, that attempt has turned out to be the modem periodic table with 118 detected elements.

4.2 Characteristics of the Periodic Table

The periodic table is basically a table of elements. It also features columns and rows. In the periodic table, the rows from left to right are called Periods and vertical columns are called Groups. There are a total of 118 elements accommodated in the cells of the table, which is there for you at the beginning of this chapter.

The modem periodic table has some prominent characteristics. You can find these features if you take a closer look at the table.

a. There are seven periods (horizontal rows) and 18 groups (vertical columns) in the periodic table.

b. All periods start with group 1 at the extreme left and extend up to group 18 at the extreme right.

c. A small table of 2 horizontal rows and 14 columns displays the Lanthanide and Actinide elements beneath the main periodic table. These are part of period 6-7 of the main periodic table.

d. Period 1 contains only two elements. Periods 2 and 3 contain eight elements each. Period 4 and 5 contain 18 elements each. Periods 6 and 7 contain 32 elements each.

e. Group 1 contains 7 elements. Group 2 contains 6 elements. Group 3 has 32 elements. Groups 4 to 12 contain 4 elements each. Groups 13-17 have 6 elements each. Group 18 contains 7 elements.

Fifteen elements with atomic numbers 57 to 71 are called the Lanthanide elements. Fifteen elements with atomic numbers 89 to 103 are categorized as Actinide elements. Physical and chemical properties of elements belonging to each of these two categories are so close that they have been put separately in two separated rows.

Now consider the periodic table in terms of properties of elements.

1. Properties of elements change from left to right in the same period.
2. The physical and chemical properties of elements of the same group are almost similar.

4.3 Determination of the Position of Elements in the Periodic Table from Their Electronic Configuration

We can easily determine the group and period of an element from the electronic configuration of that element. The system of finding out the place of an element in the periodic table is discussed below:

Determining the Period Number

The number of the outermost main energy level in the electronic configuration of an element is the period number of that element. For example: the electronic configuration of Lithium is $Li(3)1s^2 2s^1$. Since the outermost energy level of Lithium is the second one, so the element belongs to the period 2 of the table. In the same way, the electronic configuration of Potassium is K(19) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$. Since the outermost energy level of Potassium is the fourth one, so the element belongs to the period 4 of the table.

Determining the Group

The group number of an element can be determined in a number of ways.

System 1: If the outermost energy level of an element consists of s orbital only, the total number of electrons in thats orbital is the group number of that element. The electronic configuration of Hydrogen is H(l)ls'. Since the outermost energy level of Hydrogen consists of s orbital and it contains only **1** electron, so the element belongs to the group 1 of the table.

System 2: If the outermost energy level of an element consists of s and p orbitals only, the total number of electrons in those s and p orbitals added with 10 is the group number of that element. The electronic configuration of Boron is B(5)-$1s^2 2s^2 2p^1$. Since the outermost energy level of Boron consists of sand p orbitals and they contain 2 + **1** = 3 electrons, so the element belongs to the group 3 + 10 = 13 of the table.

System 3: If the outermost energy level of an element consists of an s orbital which is preceded by a d orbital in the inner level, the total number of electrons in those s and d orbitals is the group number of that element. The electronic configuration ofFe is Fe(26)-$ls^2 2s^2 2p^6\ 3s^2 3p^6 3d^6 4s^2$. Since the outermost energy level of Iron consists of s and is preceded by a d orbital and they contain 6+2=8 electrons, so the element belongs to the group 8 of the table.

To make it easier for you to understand, the electronic configuration of the outer most energy level has been denoted by red colour.

Table 4.01: Electronic Configuration of Elements and their Groups.

Element	Electronic Configuration	Period Number	Group Number
H(l)	$1s^1$	1	1 (System 1)
He(2)	$1s^2$	1	18 (Exception)
Li(3)			
Be(4)			
B(5)	$1s^2\ 2s^2\ 2p^1$	2	2 + 1 +10 =13 (System 2)
C(6)			
N (7)	$1s^2\ 2s^2\ 2p^3$	2	2 + 3+10= 15 (System 2)
0(8)	$1s^2\ 2s^2\ 2p^4$	2	2 + 4+ 10=16 (System 2)
F(9)	$1s^2\ 2s^2\ 2p^5$	2	2 +5+10=17 (System2)
Ne(lO)	$1s^2\ 2s^2\ 2p^6$	2	2 + 6+10 =18 (System 2)
Na(ll)			
Mg(12)	$1s^2\ 2s^2\ 2p^6\ 3s^2$	3	2 (System 1)
A1(13)			
Si(14)	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^2$	3	2 +2+10=14 (System 2)
P (15)	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3$	3	2 + 3+10= 15 (System 2)
S (16)			
Cl(17)	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$	3	2 + 5+ 10 =17 (System 2)
Ar(18)	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$	3	2 + 6 +10 =18 (System 2)
K(19)	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6 4s^1$	4	1 (System 1)
Ca(20)	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6 4s^2$	4	2 (System 1)
Sc(21)			
Ti(22)	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^2\ 4s^2$	4	2 + 2 = 4 (System 3)
V(23)	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^3\ 4s^2$	4	2 + 3 = 5 (System 3)

Cr(24)	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5\ 4s^1$	4	1 + 5 = 6 (System 3)
Mn(25)	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5\ 4s^2$	4	2 + 5 = 7 (System 3)
Fe(26)			
Co(27)	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^7\ 4s^2$	4	2 + 7 = 9 (System 3)
Ni(28)	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^8\ 4s^2$	4	2 + 8 = 10 (System 3)
Cu(29)	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^1$	4	1 + 10 = 11 (System 3)
Zn (30)	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2$	4	2 + 10 = 12 (System 3)

Student Activity: Fill up the blank spaces of elements with atomic numbers 3, 4, 6, 11, 13, 16, 21, 26 of the above table with necessary information.

4.4 Electronic Configurations of Elements are the Main Basis of the Periodic Table

Electronic configuration serves to identify the group and period of an element in the periodic table. Again, elements having the same electron arrangement in their outermost orbit belong to the same group. On the other hand, elements with different configuration of electrons in their outermost shell belong to separate groups.

Table 4.02: Group and Electronic Configuration.

Groupl	
Element	Electron c Configurat on
H(l)	$1s^1$
Li(3)	$1s^2 2s^1$
Na(ll)	$1s^2 2s^2 2p^6 3s^1$
K(19)	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$

Group 2	
Element	lectron c Configurat on
He(2)	$1s^2$
Be(4)	$1s^2 2s^2$
Mg(12)	$1s^2 2s^2 2p^6 3s^2$
Ca(20)	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$

The elements with one electron in the outer shell generally tend to give away the electron and become positive ions. Sodium has one electron in its outer shell. So, it donates the electron and becomes a positive ion.

$$Na\ (1s^2 2s^2 2p^6 3s^1) \longrightarrow Na^+\ (1s^2 2s^2 2p^6) + e^-$$

Again, elements with seven electrons in the outer shell generally tend to accept an electron and become negative ions. Chlorine has seven electrons in its outer shell. So, it accepts one electron and becomes a negative ion.

$$Cl\ (1s^2 2s^2 2p^6 3s^2 3p^5) + e^- \longrightarrow Cl^-\ (1s^2 2s^2 2p^6 3s^2 3p^6)$$

So, electronic configuration helps us to determine the position of an element in the periodic table and explain their various characteristics as well. Therefore, electronic configuration is considered as the main basis of the periodic table.

4.5 Some Exceptions in the Periodic Table

a. The Position of Hydrogen: Hydrogen is a non-metal. However, the periodic table displays hydrogen alongside strong electropositive alkali metals like Na, K, Rb, Cs, Fr etc. in group 1. It is because the outer shell of H contains only 1 electron like the alkali metals. Besides, many properties of Hydrogen are similar to those of alkali metals. On the other hand, Hydrogen is also able to accept an electron like the Halogen elements (F, Cl, Br, I), meaning it has some similarities with Halogen in terms of properties. However, since most of the properties of Hydrogen have similarity with alkali metals, it is placed alongside the alkali metals.

b. The Position of Helium: The electronic configuration of Helium is He(2) + ls^2. According to its configuration, it was supposed to be positioned in group 2. But the elements of group 2 are strongly electropositive. They are called alkaline earth metals. On the other hand, Helium is an inert gas. Its properties are similar to other inert gases like Neon, Argon, Krypton, Xenon and Redon. And its properties are not at all similar to the alkaline earth metals. Therefore, Helium is placed alongside the inert gases in group 18.

c. The Position of Lanthanide and Actinide Groups: The Lanthanide elements are supposed to be set in the period 6 and group 3 of the periodic table. The original position of Actinide group is in period 7 and group 3. If they are placed in these positions, that hampers the beauty of the table. Therefore, to maintain the beauty of the table, these two groups of elements are moved to a separate table just beneath the main table.

4.6 Periodic Properties of Elements

The elements in the periodic table have some properties, like: metallic properties, non-metallic properties, atomic radius, ionization energy, electro negativity, electron affinity etc. These properties are called periodic properties

a. Metallic Property: Elements which are glossy, produce metallic sound when struck, and conductor to heat and electricity, we call them metals. Modem definition goes, the elements that tum into positive ions donating one or more electrons are metals. This property to donate electrons by the metals is called metallic property. The more an element is prone to donate electrons it is regarded to be endowed with more metallic property. Lithium (Li) is a metal as it donates an electron and becomes Li^+.

$$Li \quad Lt+ \quad e-$$

Any period in the periodic table has got the most metallic on the left and gradually elements are less metallic as the period extends to the right.

b. Non-metallic Property: Elements which are not glossy, don't produce metallic sound and non conductor of heat and electricity are called non-metallic. In the modern terminology, the elements which turn into negative ions accepting one or more electrons are called non-metallic elements. This tendency to accept electrons is called their non-metallic property. The more an element is prone to accept electrons it is regarded to be endowed with more non-metallic property. Chlorine (Cl) is a non-metal as it accepts an electron and becomes Cl^-.

$$cl + e- \quad c1-$$

Any period in the periodic table becomes more non-metallic as it extends to the right.

Some elements are there which sometimes behave like metals and sometimes behave like non-metals. They are called sub-metals. According to modem definition, elements that sometimes tend to donate electrons and sometimes accept electrons are called sub-metals. Silicon (Si) is a sub metal.

In the periodic table, the left periods are metals, middle periods are sub metals and the right side periods are non-metals.

c. Atomic Radius/ Size of Atom: The size of atom or the atomic radius is a periodic property. The more a period progresses from left to right, the size of atom/atomic radius decreases. Again, vertically in the periodic table, the lower we go from the upper part, the size of atom increases.

In a period, the more we move from left to right, the atomic number increases, but the shell number remains unchanged. As the atomic number increases, number of protons in the nucleus increases and so do the number of electrons. The attraction between the increased number of electrons and protons also increases, resulting in the electron containing shells getting closer to the nucleus. As a result, the atomic radius decreases.

Again, in a same group, the lower we move from the upper part, a new shell is added to the outer layer. These added shells increase the size of the atom.

Noteworthy that, newer shells increase the size of atom more than the added electrons and protons decrease the size. That is why, the lower part of the periodic table contains elements with bigger atoms.

The size of atom decreases from left to right of a period

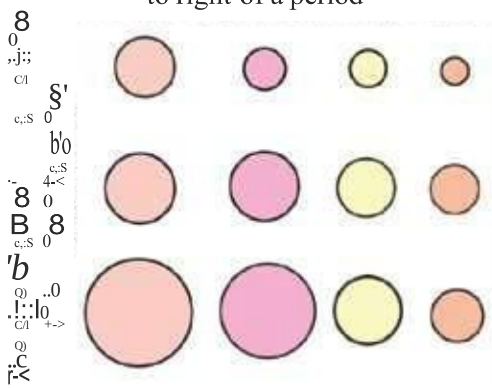


Fig 4.01: Periodic Property of Atomic Radius.

d. Ionization Energy: The energy that is required to transform an element into one mole positive ion removing one mole electron from its one mole atom in its gaseous state is called the ionization energy of that element. It is a periodic property. In the same period, elements of the left side have greater radius than those of the right side. When the atomic radius is less, the ionization energy 1s greater and vice-versa.

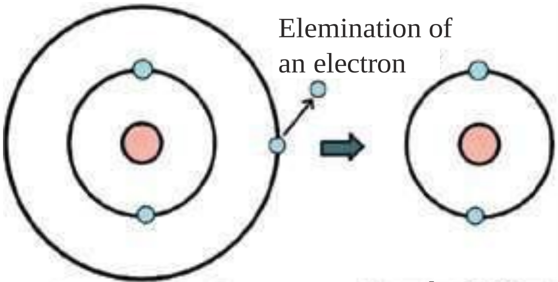


Fig 4.02: Ionization of Element.

Example:

The ionization energy of Si is greater than Na, Mg and Al because the atomic radius of Si is the smallest among all these elements. On the other hand, Na, having the biggest radius among them is endowed with the least ionization energy.

Of the alkali metals in group-1, i.e. Li, Na, K, Rb, Cs and Fr, Li has the smallest atomic radius and the highest ionization energy.

Again, of the elements in group-17, i.e. F, Cl, Br, I and At, F has the smallest atomic radius and the highest ionization energy.

e. Electron Affinities: The energy emitted when we try to transform an element in its gaseous state into one mole negative ion by injecting one mole electron into its one mole atom is called the electron affinity of that element. It is a periodic property. In the same period, elements of the left side have greater radius than those of the right side. When the atomic radius is less, the electron affinity is greater and vice-versa.

Individual Task

Problem: Of the elements Be, Ca, Sr, Ba, Mg and Ra, some display greater electron affinity and some lesser.

Solution: All these elements belong to group-2. Be among them has got the lowest atomic radius and that is why, its electron affinity is higher. Again, Ra among them has the highest radius and the least electron affinity.

Problem: Of the elements Na, Mg, Al, and Si, which has the strongest electron affinity and which has the least?

Solution: All these elements belong to period-3. Na among them has got the highest atomic radius and that is why, Sodium's electron affinity is the least. Again, Si among them has the least radius and the highest electron affinity.

f. Electronegativity: When two atoms tum into a molecule by covalent bonds, the atoms in that molecule attract the electrons towards themselves. This attraction is called electronegativity. It is a periodic property. In the same period, elements of the left side have a greater radius than those of the right side. When the atomic radius is less, the electronegativity is greater and vice-versa. For example, The Na atom in the period-3 of the table has the least electronegative attraction and Cl has the most.

4.7 The Special Names of Elements Present in Various Groups

Elements were bestowed special names at different times based on their physical and chemical properties. Apart from metals, non-metals and sub metals already discussed, there are also some others.

Alkali Metals: There are seven elements in Group-1 of the table. Apart from Hydrogen, the six other elements here (Lithium, Sodium, Potassium, Rubidium, Cesium and Francium) are called alkali metals. They are thus called since all of them are soluble in water and when dissolved in water, they produce Hydrogen gas and alkali.

Alkaline Earth Metals: The periodic table contains six elements- Beryllium, Magnesium, Calcium, Strontium, Barium and Radium in its Group-2. These elements are called alkaline earth metals. They are available as various compounds in soil and all of them produce alkali. That is why, they are grouped under alkaline earth metals.

Coin Metals:Copper, Silver, Gold and Rontzanium are four metals belonging to Group-11. The first three of them are called coin metals as they were used to produce coins from the ancient age and were used as a means of trade and commerce.

Halogen Group: Six elements of Group-17 are called Halogens. They are Fluorine, Chlorine, Bromine, Iodine, Astatine and Tennesine. The meaning of halogen is salt maker. Metals bonding with these elements produce salts, like Na and F bond together to produce Sodium Fluoride, Na and Cl together produce Sodium Chloride etc. The main source of halogens is the sea salt. They themselves form di-atomic molecules by sharing electrons, like Cl_2, 1_2 etc.

Inert Gas: Elements belonging to Group-18 are called inert gases. They are Helium, Neon, Argon, Krypton, Xenon, Redon and Oganeson. As their outermost energy level is filled with electrons, they do not show any tendency to form compounds by accepting, donating or sharing electrons. This inaction in chemical reaction or chemical bonds gives them their group name. They remain in gaseous form at normal temperature.

Transition Elements: Elements of Group-3 to Group-12 are known as transition elements. Compounds produced with these elements get some colour. These transition elements act as catalysts in chemical reactions. Nickel of Group-10 is an example of this kind which is used in various organic reactions.

Individual Task

Problem: Why is Ca called an alkaline earth metal?

Solution: Different compounds of the metal Ca are available in soil which makes it an earth metal. Again, Hydroxide compound of Ca, $Ca(OH)_2$ is an alkali. Therefore, it is also alkaline.

Problem: Why is He an inert gas? Explain.

Solution: He doesn't bond with the other elements of its group. Neither is it interested in bonding with other elements. So, Helium is an inert element. Since, at normal temperature, it remains in gaseous form, so we call it an inert gas.

4.8 Advantages of the Periodic Table

The periodic table is a highly significant contribution of various chemists of different ages. Practice of chemistry is not possible without the modem periodic table. Some of the advantages of this chart are presented below.

a. Simplifying Study of Chemistry: We know that a total of 118 elements have been identified till 2016. If we consider only four physical properties (melting point, boiling point, density and state of matter) and four chemical properties (reaction with Oxygen, water, acid and alkali), then that turns out 118 x (4 +4) = 944 properties for these elements. It is impossible to remember all this information. The periodic table has simplified that task. Ifwe know the common properties belonging to each group in the table, we will also be aware of the common properties of all these elements. Again, since we will be familiar with the common properties of elements, we will also know the properties of compounds made with them.

b. Detection of New Elements: there were some blank cells in the periodic table even some decades ago. The periodic table gave us prior idea about the elements that will be accommodating those cells and their properties even before they were detected. You have already known that, Mendeleev had mentioned about four elements in his periodic table which were later detected.

c. In Research: The periodic table has a large contribution in the field of research too. Suppose, a scientist is interested to invent a new matter to meet up a specific purpose. In that case, he must have some conception about what the properties would be of the new matter and what kind of elements will be able to produce the new matter. He will get this idea from the periodic table.

You will gradually come to know about the other advantages of the periodic table.

4.9 Reactions Occurring in the Elements of the Same Group

An experiment will tell you that elements of the same group exhibit the same kind of properties.

The gases F_2, Cl_2, Br_2, $\mathbf{1}_2$ etc. belonging to Group-17 react with Hydrogen and produce HF (g), HCl (g), HBr (g), HI (g) gases respectively.

Hz{g} + Fz{g} ZHF (g)
Hz(g) + Clz{g} 2HC1 (g)
Hz{g} + Brz{g} ZHBr (g)
Hz{g} + Iz{g} ZHI (g)

Again, if we dissolve these produced gases into water, they produce hydrohalide acids, i.e. Hydrofluoric acid, Hydrochloric acid, Hydrobromic acid, Hydroiodic acid.

HF(g) + H20 (1) HF (aq)
HCl(g) + H20 (1) HCI (aq)
HBr(g) + H20 (I) HBr (aq)
HI(g) + H20 (1) HI (aq)

These hydrohalide acids react with any carbonate salt and produce Carbon dioxide gas, e.g. Calcium Carbonate and Hydrofluoric acid produce Carbon dioxide:

$$CaCO_3 + 2HF\ (aq) \longrightarrow CaF_2 + H_2O + CO_2$$

The same kind of reaction will take place with Hydrochloric acid:

$$CaCO_3 + 2HC1\ (aq) \longrightarrow CaCl_2 + H_2O + CO_2$$

So, the above reactions convince you that the elements of Group-17 exhibit the same properties and reactions. Mg and Ca of Group-2 also exhibit the same properties and reactions.

Magnesium Carbonate ($MgCO_3$) in its reaction with light Hydrochloric acid produces Magnesium Chloride, water and Carbon dioxide gas. Calcium Carbonate ($CaCO_3$), in the same reaction produces Calcium Chloride, water and Carbon dioxide gas.

$$MgCO_3 + 2HC1 \longrightarrow MgC1_2 + H_2O + CO_2$$
$$CaCO_3 + 2HC1 \longrightarrow CaC1_2 + H_2O + CO_2$$

Experiment

Name of Experiment: Identifying Carbon dioxide gas m the reaction between Calcium Carbonate and light Hydrochloric acid.

Principle: Calcium Carbonate and light Hydrochloric acid produce Calcium Chloride, water and Carbon dioxide gas.

$$CaCO_3 + 2HC1 \longrightarrow CaCl_2 + H_2O + CO_2$$

Apparatus: a. one conical flask b. a thistle funnel c. a u-shaped delivery tube made of glass d. some gas jars e. cork with bore.

Chemicals: Calcium Carbonate, dilute hydrochloric acid and water

Procedure:

1. Take some small pieces of calcium carbonate in the round bottom flask.

2. With the help of the cork, put in the thistle funnel and the delivery tube inside the Wolf bottle.

3. Put in some water in the round bottom flask through the thistle

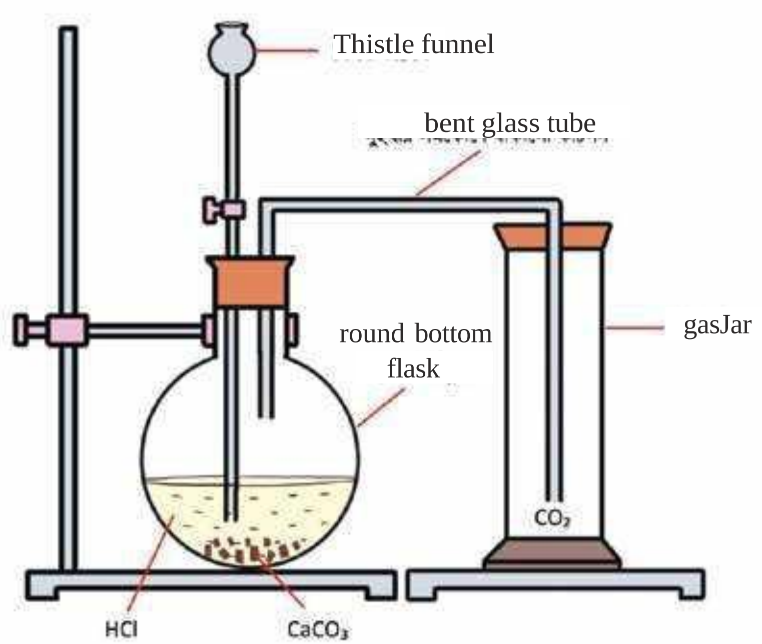


Fig 4.05: Preparation of Carbon Dioxide.

funnel so that the chemicals within and the edge of the thistle funnel remain submerged.

4. Set the other end of the exhaust tube inside a gas jar.

5. Now, slowly add dilute hydrochloric acid through the thistle funnel. You will see, the carbon dioxide gas bubbles produced in the reaction are coming out through the exhaust tube.

6. Let's preserve the carbon dioxide gas in the gas jar. Since the gas is heavier than air, it will gather in the lower part of the jar.

Checking the Properties of Carbon Dioxide Gas:

1. Let's check the colour of the produced gas in the jar. It is colourless like carbon dioxide.
2. Let's hold a lighted matchstick on the open face of the gas jar. It will be extinguished. It is decided that carbon dioxide helps to extinguish fire.
3. Let's pass the produced gas inside a test tube containing lime water or calcium hydroxide. First, a small quantity of gas will enter the tube and create white calcium carbonate residue at the base. The lime water will be dull. Now pass more carbon dioxide gas into the solution. This will produce calcium bicarbonate which will clear the lime water.

Caution:

1. Measures were taken so that the end of the thistle funnel was submerged in the water.
2. The round-base flask was fixed with a stand.

The same experiment can be done with snails, oysters, egg shells as substitute for calcium carbonate and vinegar substituting for hydrochloric acid.

Exercise

Multiple Choice Questions

1. What is the main basis of the modern periodic table?

   a. atomic number b. atomic mass

   c. relative atomic mass d. electronic configuration

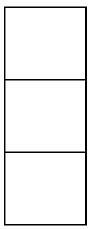
2. A $ls^{2}\ 2s^{2}\ 2p^{6}\ 3s^{2}\ 3p^{6}\ 3d^{3}\ 4s^{2}$. Which group of the periodic table does the element belong to?

   a. Group-2 b. Group-5

   c. Group-11 d. Group-13

Answer questions 3 and 4 from the following table:

It is an intersection of a group from periodic table :



Here X and V are symbols, they do not represent actual elements

3. Which period of the periodic table does the element belong to?

   b. 41h

   c. 51h d. 6th

4. The shown elements have-

   i. one electron in their outer shell

   ii. atomic radius decreases as we go from top to bottom

   iii. element Y is more active than element X

Which is correct?

   a. i and ii b. ii and iii

   c. i and iii d. i, ii and iii

Creative Questions

1.

			F
Na	Mg		Cl
			Br

Diagram of the stem is a part of the periodic table.

a. Write down the Triads Law.

b. Why is Barium called alkaline earth metal?

c. Which of the elements in the stem is the biggest in size? Explain

d. Analyze the electron affinity of the elements in the stem as we move periodically from left to right.

2:

	Group 1	Group 2	Group 3
riod 2			
riod 3			
riod 4	A	B	C

a. Write down the modern formula of the periodic table.

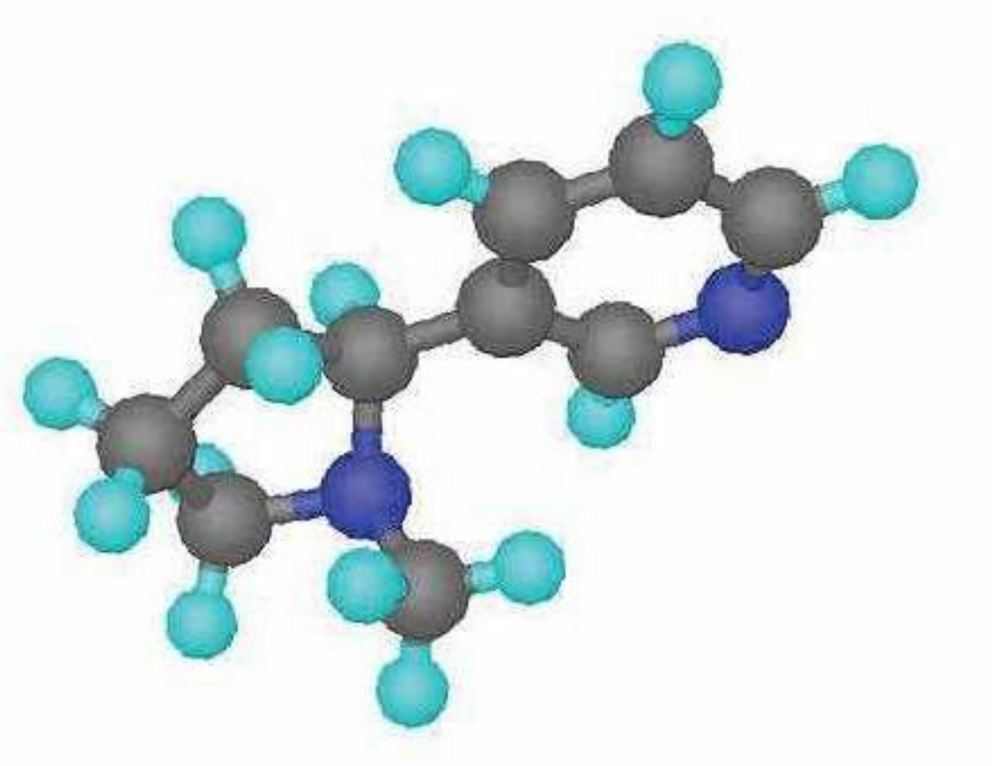
b. Why is B called an alkaline earth metal?

c. Explain the change in the size of atom from A to B.

d. Analyze the change in ionization energy as we progress from A to C.

Chapter Five

Chemical Bond



We know, all substances consist of molecules and atoms. Each of these matters has its own atoms. Out of these substances, atoms of one or more elements make a substance's molecule. Atoms do not remain scattered in the molecule of substances. They remain highly organized. The force of attraction that binds two atoms in a molecule is called chemical bond. This bond may be of various kinds- ionic bond, covalent bond or metallic bond etc. This chapter will focus upon compounds made of ionic bonds, covalent bonds or metallic bonds, their process of bonding and their properties.

By the end of the chapter, we will be able to-

- explain the concept of valence electrons
- write the symbols of elements, formula of radicals and the formula of compounds using their valency
- explain the stability of inert gases
- explain the concept of octet and duet rules
- explain chemical bonds and the causes of their formation
- explain how and why ions are formed
- explain the formation of ionic bonds
- explain the formation of covalent bonds
- explain properties like melting point, boiling point, solubility, electric conductivity and crystal formation with ionic and covalent bonds
- explain the concept of metallic bonds
- explain the electric conductivity of metals with metallic bonds
- identify ionic and covalent compounds among the easily available objects

5.1 Valence Electrons

The number of total electrons in the outermost principal energy level of an element is called the valence electrons of that element. For example, the electronic configuration of Potassium and Oxygen show OI and 06 electrons at their outermost energy level.

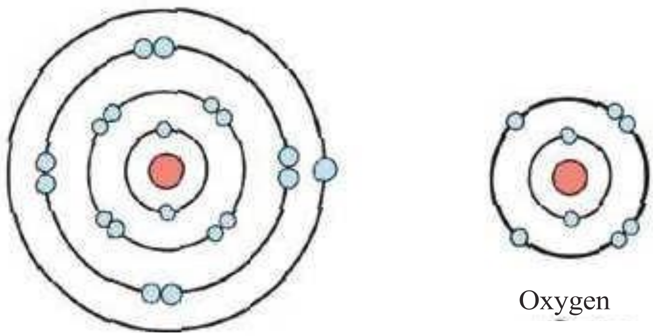


Fig 5.01: Valence Electron of Potassium and Oxygen.

Therefore, K has O I valence electron while O has 06 valence electrons. The following table shows the valence electron number of some elements from their electronic configuration:

Table 5.01: Valence Electrons of Elements.

Elemen	Electronic Configuration				Valence Electron
	K Orbit	L Orbit	M Orbit	N Orbit	
N(7)	2	5			5
F(9)	2	7			7
P(15)	2	8	5		5
C1(17)	2	8	7		7
Ca(20)	2	8	8	2	2

Here, Nitrogen has 2 electrons in its K orbit while 5 electrons in L orbit. L orbit is the outermost energy level of Nitrogen. So, Nitrogen has five valence electrons.

Individual Task

Student Activity: Find out the number of valence electrons of F, P, Cl and Ca.

5.2 Valency

You already know that, atoms of different elements donate, accept or share electrons of their outermost energy level with atoms of other elements to form molecules. The capacity of bonding of an atom with another atom of an element while forming a molecule is called valency.

Usually, the valency of Hydrogen is taken to be 1. Valency of an element is determined by the number of atoms of H or Cl can bond with one of its atoms.

An atom of Hydrogen bonds with another atom of Chlorine to form a HCl molecule. So the valency of chlorine is also **1.** Again, an atom of Oxygen bonds with 2 Hydrogen atoms to produce H_20. So valency of Oxygen is 2. **1** atom of Na bonds with 1 Cl atom to produce NaCl, therefore, the valency of Na is **1.**

The number of oxygen atoms that can be bonded with an atom multiplied by 2 determines the valency of that atom. Example: a calcium atom (Ca) bonds with one oxygen atom (0) to produce calcium oxide (CaO). Therefore, the valency of calcium is **1**x2 = 2.

Some elements have more than one valency. This kind of valency is called variable valency. For example, variable valency of Fe are 2 and 3. The difference between the highest valency of an element and its active valency is considered as latent valency. For example, in the compound $FeC1_2$, the active valency of Fe is 2 while its highest valency is 3. Therefore, the latent valency of Fe here is (3 - 2) = **1.** Again, in $FeCl_3$, the highest valency of Fe is used, which is 3. Therefore, in this case, there is no latent valency of Fe.

Table 5.02: Valency of Different Elements.

Element	Valency	Element		Element	Valency
H	1	Na	1	Fe	2, 3
F	1	K	1	Cu	1, 2
Cl	1	C	2, 4	Zn	2
Br	1	Mg	2		
I	1	Al	3		

Table 5.03: Valency and Compounds of Various Atoms.

Metallic and Non- metallic Atom	Symbol	Valency	Compound	Metallic and Non meta111c Atom	Symbol	Valency	Compound
Hydrogen	H	1	HCl	Silver	Ag	1	Agel
Lithium	Li	1	LiCl	Fluorine	F	1	NaF
Sodium	Na	1	NaCl	Chlorine	Cl	1	NaCl
Potassium	K	1	KCl	Bromine	Br	1	NaBr
Magnesium	Mg	2	MgCl2	Iodine	I	1	NaI
Calcium	Ca	2	CaCl2	Boron	B	3	$BC1_3$
Aluminum	Al	3	$AlC1_3$	Phosphorus	P	3	$PC1_3$
						5	$PC1_5$
Iron	Fe	2	FeC12	Copper	Cu	1	CuCl
		3	$FeC1_3$			2	$CuCl_2$
Zinc		2	ZnC12	Oxygen	O	2	H20
Lead	Pb	2	Pbcl2	Carbon	C		co
		4	$PbC1_4$			4	CH_4
Nitrogen	N	3	NH_3	Sulfur	S	2	H2S
		5	N20s			4	S02
						6	$S0_3$

5.3 Radicals and Their Valencies

Sometimes, a bundle of atoms from more than one element combine together, receive positive or negative charges and act as an ion of an element. They are called radicals.

Radicals may be of positive or negative charge. The number of charge of the radicals is their valency. For example, three H atoms and one H^+combine with one N atom to produce the radical named Ammonium (NH_4^+) ion. Since its number of charge is +1, so its valency is also 1. Charge may be positive or negative but valency is always the number only.

Table 5.04: Radicals and Their Valencies.

Radical	Formula	Charge	Valency
Ammonium	NH_4^+	+1	1
Carbonate	co/-	-2	2
Hydrogen Carbonate	HCO_3^-	-1	1
Sulfate	so/-	-2	2
Hydrogen Sulfate	HSO_4^-	-1	1
Sulfite	SO_3^{2-}	-2	2
Nitrate	NO_3^-	-1	1
Nitrite	No_2^-	-1	1
Phosphate	Po/-	-3	3
Hydroxide	OH^-	-1	1
Phosphonium	PH_4^+	+1	1

5.4 Chemical Formula of Compounds

The symbols and numbers belonging to the atoms that together produce a molecule of the compound are used to express a compound. For instance, two hydrogen (H) atoms and an oxygen (0) atom combine into a molecule of water

(H_20). Here, is the chemical formula of water's molecule. Therefore, a chemical formula is the way of expressing the compound molecule through the symbols, formulas and the numbers of atoms of elements and radicals. The numbers of atoms and radicals are written in subscript.

The System of Writing Chemical Formula

a. The number of atoms there are in an element's molecule has to be written in subscript after its symbol. Since nitrogen molecule has two atoms, its formula is $N_{2.}$ One molecule of Ozone has 3 oxygen atoms, so its formula is $0_{3.}$ Some elements, like all metals, do not form any molecule, which are expressed through their symbols only. That way, iron is written as Fe only. The same system is applicable to all inert gases too, as in Helium, He.

b. Sometimes, a compound's molecule is made of atoms of two different elements. If their valency is not divisible by a common number, then, the symbols of both the elements are written side by side and each is followed by the valency of the other. For example, valency of aluminum is 3 and oxygen is 2. These numbers are not divisible by a common number. In the case with any compound consisting of these two elements, first goes the symbol of aluminum (Al), followed by the valency of oxygen (2). Then the symbol of oxygen (0) comes followed by the valency of aluminum (3). An example is $Al_20_{3.}$ In the same way, valencies of calcium and chlorine are 2 and 1 respectively. The formula of calcium chloride is supposed to be $Ca_1Cl_{2.}$ Since, 1 doesn't need mention, so we write, $CaCl_{2.}$ Again, valencies of magnesium and phosphate are 2 and 3 respectively. Therefore, the formula of magnesium phosphate is $Mg_3 (P0_4)_{2.}$ Noteworthy that if a radical is there in a number more than 1, then the formula of the radical goes inside first bracket along with its number and the valency of the other element follows outside the bracket. For example, ammonium phosphate $(NH_4\backslash PO_{4,}$ aluminum sulfate $Al/SO_{4\backslash}$ etc.

c. If the valencies of the two elements are divisible by a common number, then the quotient after dividing will be written following the formula stated in rule b. For example, carbon dioxide is a compound made of carbon and oxygen. Valencies of carbon and oxygen are 4 and 2 respectively. Since they can be divided by 2, therefore, we have to write the quotients C,O_2. Again, since 1 is not necessary to mention, we will write, CO_2. In the compound ferrous sulfate, the valency of ferrous is 2 and that of sulfate ion (SO/) is 2. Therefore, after dividing them both with 2, the formula stands $FeSO_4$. Same way, valency of boron and nitrogen is 3. Therefore, the formula of boron nitride stands B_3N_3 = B,N, =BN.

5.5 Molecular Formula and Structural Formula

The formula of using symbols and the number of atoms of the kind/ kinds of element(s) that constitute the molecule of an element or compound is called the molecular formula or chemical formula. We have just learned about it. Again, the formula of expressing a molecule through the symbols and bonds of atoms, otherwise known as organization of atoms, is called the structural formula. For example, three carbon atoms combine with eight hydrogen atoms and produce propane (C_3H_8) molecule. This C_3H_8 is the molecular or chemical formula of propane. Again, the three carbon atoms here bond with each other like a chain and the rest valencies get completed with hydrogen. Thus, valency of each carbon becomes 4. The structural formula of propane is shown below:

```
  HHH
  | | |
H-C-C-C-H
  | | |
  HHH
```

Again, the molecular formula of water H_2O is written in structural formula:

```
 0
 /\
HH
```

$CH_{4,}$ which the molecular formula of methane is written in structural form:

```
  H
  |
H-C-H
  |
  H
```

Each line between carbon-carbon and carbon-hydrogen above is a bond. These are covalent bonds, you will learn about this bond in this chapter. The structural formula tells us how many atoms of which element are there in a compound and how they bonded with each other as well.

5.6 Octet and Duet Rules

All elements tend to make the electronic configuration of inert gases at their outermost energy level. All inert gases other than helium have 8 electrons at their outermost energy level. When constituting a molecule, an element obtains the electronic configuration of inert gases, holding electrons by means of donating, accepting or sharing electrons. This is known as the octet rule. The central atom C of CH_4 molecule has 8 electrons in its outermost energy level. Four of these eight electrons are carbon's own while the rest four comes from hydrogen (figure 5.02).

Due to some limitations of the octet rule, scientists have presented a new rule, which is called the "Duet rule". This new rule is more modem than the octet rule and it has better utility too. Very much like the inert gases having 2 or 8 electrons at their outermost energy level, when constituting a molecule, atoms will have one or more pairs of electrons at their outermost energy level.

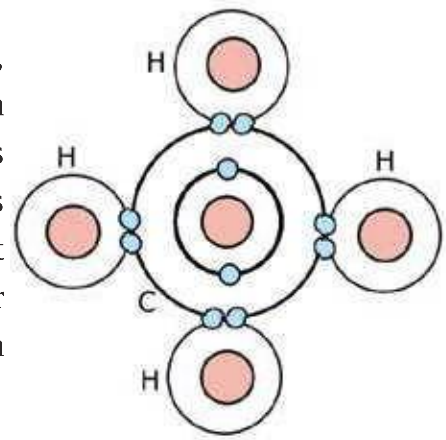


Fig 5.02: octed rule in Methane molecule.

This is the duet rule. This means, any molecule's atom will bear one or more pairs of electrons at their outermost energy level.

The Be atom at the centre of $BeC1_2$ has 2 pairs or 4 electrons at its outermost energy level. B atom at the centre of BF_3 has 3 pairs or 6 electrons at its outer most energy level. C atom at the center of CH_4 has 4 pairs or 8 electrons at its outermost energy level. Not only that, besides the central atom, other atoms like Cl will have 4 pairs or electrons at its outermost energy level. Likewise F will have 4 pairs and H will have 1 pair of electrons at their outermost energy level.

This proves, all atoms are following the duet rule. Noteworthy that, elements 1-20 in the periodic table basically follow the rules of octet and duet.

5.7 Inert Gases and their Stability

You have learned about the inert gases or Group-18 elements from the periodic table. Electronic configuration of these gases are presented again below for your convemence:

He(2)	$1s^2$
Ne(lO)	$1s^2 2s^2 2p^6$
Ar(18)	$1s^2 2s^2 2p^6 3s^2 3p^6$
Kr(36)	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6$
Xe(54)	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^{10} ss^2 5p^6$
Rn(86)	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^{10} 4f1^4 5s^2 5p^6 5d^{10} 6s^2 6p^6$

Helium has 2 electrons in its outermost energy level. Since it required this number of electrons to fulfill its outermost energy level, helium's electronic configuration is stable. Other inert gases have 8 electrons (ns^2 np^6) in their outermost energy level. Any element having 8 electrons in its outermost energy level has got the highest level of stability. Two electrons in the outermost energy level forms a duet while 8 electrons form an octet. Since these gases fulfill both the duet and octet condition, they are stable. This stability drives them not to donate any electron to other elements. They do not receive electrons from other elements either. Chemically, they lack affinity or become inert. No other element has this fulfilled electronic configuration at its outermost energy level. As a result, they are not that stable. They tend to fulfill the duet or octet rules at their outermost energy level. That is why, they donate, accept or share electrons with other atoms and create mutual bonds.

5.8 Chemical Bonds and the Causes of their Formation

Two hydrogen atoms mutually bond together into hydrogen (HJ molecule. Similarly, atoms of hydrogen and chlorine bond with each other to constitute hydrogen chloride (H-Cl) molecule. In hydrogen molecule, a kind of attractive force is effective among the two H atoms. In hydrogen chloride also, there is an attractive force working among the H and Cl atoms. Basically, this kind of attractive force is a chemical bond, meaning the attraction force that forces the atoms to stay together is called a chemical bond. This raises two questions- why didn't the atoms stay separate and why did they bond together to create the molecule?

We have already learned that all elements tend to form the stable electronic configuration of inert gases at their outermost energy level. When two atoms of the same element or different element stay close to each other, they donate, accept or share electrons in order to assume the electronic configuration of the nearest inert gas. Thus, they create the chemical bond among themselves. Therefore, it can be said that the reason of chemical bonds is the tendency of the atoms to assume stability of electronic configuration at their outermost energy level.

5.9 Cations and Anions

We know, in a normal situation, the number of positively charged proton in the nucleus of an atom is complemented by the same number of negatively charged electrons outside its nucleus. As a result, the atom becomes charge neutral. If one or more electron from the outer energy level is removed from such a charge neutral atom, its neutrality will no longer exist. Then, it will tum into an ion with positive charge. Such an ion with positive charge is called a cation. Usually, the elements or metals at the left side of periodic table donate one or more electrons from their outermost energy level to gain the electronic configuration of inert gases and become cations. For example, lithium atom donates one electron from its outermost energy level in order to get the configuration like helium and produces lithium cation (Li^+). The figure below shows it.

Similarly, the Na atom donates an electron from its outermost energy level in order to get the configuration like neon gas and produces the Sodium cation (Na+). (Fig: 5.04)

Can you tell why the metals donate electrons to produce cations?

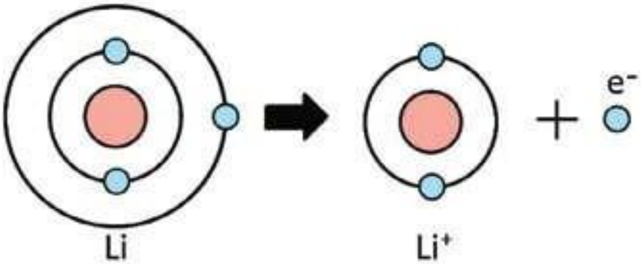


Fig 5.03: Formation of cation Lithium (Li+).

We know, in any period of the periodic table, elements gradually lose their metallic property as we progress from left to right. Simultaneously, the non-metallic property increases in them in this case. It means the elements on the left side of a period are metals and on the right side are non-metals. Again the more rightward we progress in a period; the size of atom also decreases. This is the reason why the metals are larger than other elements. The outermost energy level of metals usually contains 1, 2 or 3 electrons. Due to the bigger size of the metals, the outermost energy level is comparatively far from their nucleus which implies a weaker attraction force towards the nucleus or a weaker bond. As a result, their ionization energy is far lower. As a result, if a bit of force is applied, these metals donate one or more electrons from their outermost energy level and tum into cations.

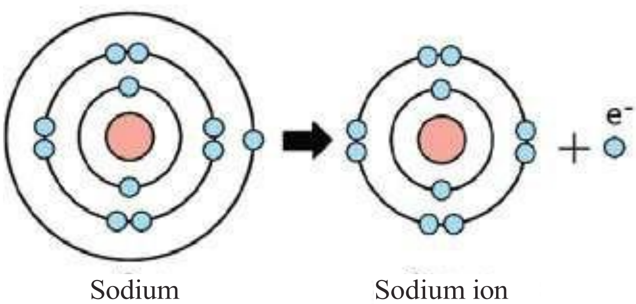


Fig 5.04: Formation of sodium cation (Na+).

On the other hand, the non-metals don't create cations. They are there at the right side of any period. They usually have 5, 6 or 7 electrons at their outermost energy level. Being smaller than metals in their size, the outermost energy level of these elements stay comparatively closer to their nucleus and undergo stronger attractive force. That means their ionization energy is also higher. It requires a stronger force to remove one or more electrons from such elements which is not there in a normal chemical reaction. That is why the non-metals do not create cations.

So, what kind of change occurs in the outermost energy level of the non-metals? Since their outermost energy level usually lacks 1, 2 or 3 electrons to become an octet, they easily accept them from other elements and assume the electronic configuration of their nearest inert gas. In other words, their electron affinity is high. This acceptance of electrons from other elements increases the number of electrons than protons in them and the negative charge in them as well. Thus, in general, the atoms of non-metals are negatively charged. These negative charge non-metal atoms are known as anions. For example, the Cl atom accepts one electron to reach the electronic configuration of argon (Ar) gas and thus produces chloride a (Cl-) ion. (Fig 5.05)

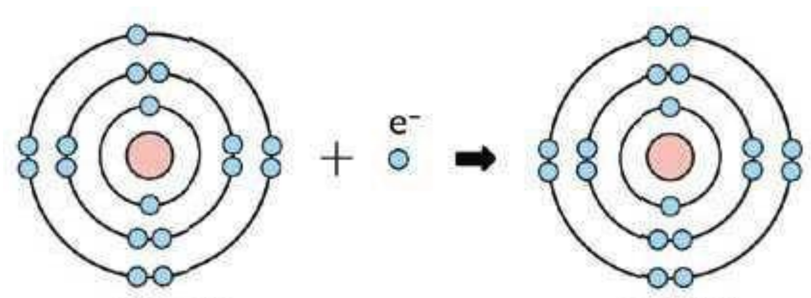


Fig 5.05: Formation of chloride anion (Cl-).

5.10 Ionic Bond or Electrovalent Bond

We have already learned that the metals having lower ionization energy easily give away electrons from their outermost energy level and tum into positive charge cations. On the other hand, the non-metals having higher ionization energy easily receive electrons into their outermost energy level and tum into negative charge anions. An electrostatic force remains effective on these oppositely charged cation and anion. This electrostatic or Coulomb force keeps them together. The attractive force by which cations and anions, formed by exchanging electrons,are held within the atoms of a compound is called the ionic bond. For example, Na atom donates one electron from its outermost energy level and forms the Na+cation with its 4 electrons in the outermost energy level. On the other hand, Cl atom receives one electron donated by Na in its outermost energy level and forms Cl- anion with its 4 electrons in the outermost energy level. These two mutually opposite charges are attracted towards each other in a bond of electrostatic force. This attraction force is the ionic bond. In other words, in the chemical bonding between a metal and a non metal, the bond that is enforced when the elements tum into positive and negative charge is called the ionic bond. The compound that has an ionic bond is called an ionic compound.

$$Na \longrightarrow Na^{+} + e^{-}$$

Cl+ e------------ c1-

Na+---- Na+ + cl- = NaCl

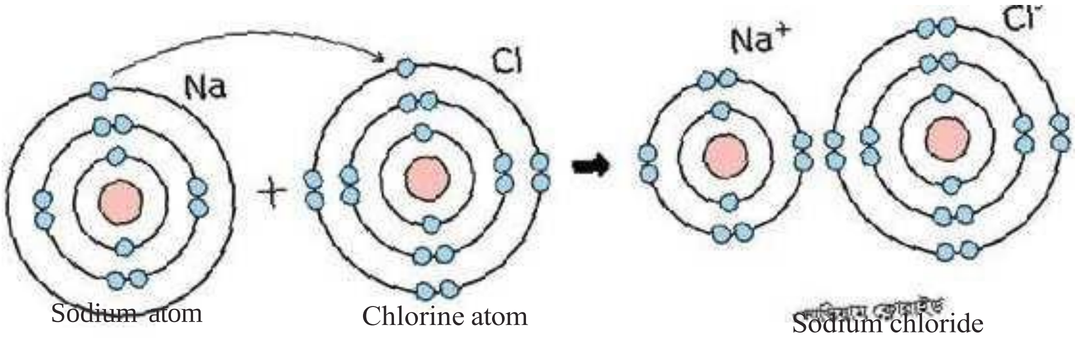


Fig 5.06: Formation of sodium chloride.

In the MgO molecule, Mg donates 2 electrons to get the electronic configuration of Ne and become $Mg^{2+}$with 8 electrons.

$$Mg \longrightarrow Mg^{2+} + 2e^{-}$$

The O atom accepts those 2 electrons to get the electronic configuration of Ne and become 0^{2-} with 8 electrons.

Now, $Mg^{2+}$and 0^{2-} come closer to form an ionic bond.

$O + 2e^- \longrightarrow O^{2-}$

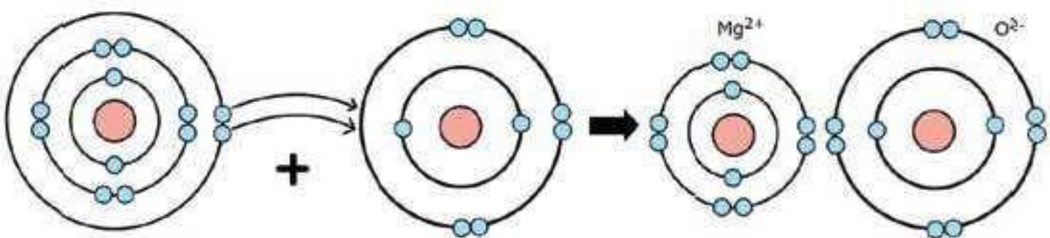


Fig 5.06: Formation of Magnesium oxide.

In the NaH molecule, Na atom donates an electron to get the electronic configuration of inert gas and becomes Na+with 8 electrons.

The H atom accepts that electron to get the electronic configuration of an inert gas and become H- with 2 electrons.

$$Na \longrightarrow Na^+ + e^-$$
$$H + e \text{ ------------ } H^-$$

Now, Na+ and H- come closer to form an ionic bond.

In the CaO molecule, Ca atom donates two electrons to get the electronic configuration of inert gas and becomes $Ca^{2+}$with 8 electrons.

$$Ca \longrightarrow Ca^{2+} + 2e^-$$

The O atom accepts those electrons to get the electronic configuration of inert gas and become **O-** with 8 electrons.

$$O + 2e^- \text{ --------------- } O^{2-}$$

Now, $Ca^{2+}$and 0^{2-} come closer to form an ionic bond.

Notably, the metals belonging to Group 1 and 2 and the non-metals of Group 16 and 17 of the periodic table usually commit themselves to ionic bonding. Each rule has some exceptions. Here in this case, Al of Group-13 commits itself to ionic bonding. Other elements do not show this tendency to donate or accept electrons as they have too many electrons at their outermost energy level. As ionic bonding takes place through electrostatic force, it is very strong.

5.11 Covalent Bond

You have just learned how a metal and a non-metal commit to ionic bonding in order to form compounds. That cannot be possible in the case of a reaction where both the elements are non-metals. So, how do they come together? Yes, two non-metal atoms can combine into a molecule too, like when two chlorine atoms are kept close, they bond chemically together into a chlorine molecule. But how is it possible for each of them has 7 electrons at their outermost energy level?

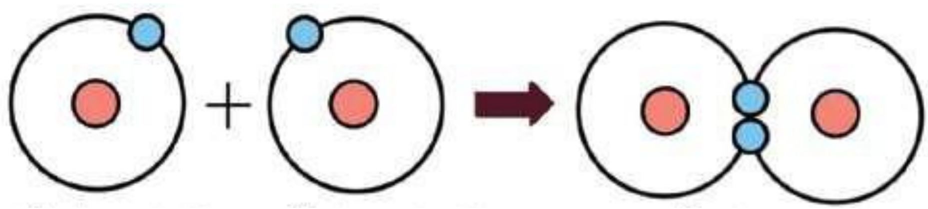
The electronic configuration of Chlorine is cl (17) $1s^2$ $2s^2$ $2p^6$ $3_5{}^2$ $3p^5$

Since it has 7 electrons at its outermost energy level, chlorine will tend to receive an electron instead of donating. But in the absence of a donor atom, the receiving will not happen also. Therefore, when two chlorine atoms come closer, 1 electron from the outermost energy level of each comes together as a pair and the pair of electrons positions itself in between the two nucleuses of the two atoms. This is known as electron sharing. Thus, both the atoms assume the electronic configuration of inert gas at their outermost energy level. The result is that the two nucleuses of chlorine cannot leave each other or remain in a bonding. This kind of bonding is called covalent bonding. Therefore, it can be said, in a chemical bonding of two non-metal atoms, the atoms create a pair of electrons by sharing one each from their outermost energy level. Both of the atoms continue to share the pair together in a bond which is called a covalent bond. The compounds that are endowed with covalent bonds are called covalent compounds. In each covalent bonding, two electrons participate. The covalent bonding is denoted by a line(-) and the electrons are denoted by dot(.) or cross (x) marks.

A chlorine molecule has two chlorine atoms and its formula is Cl_2. Many non-metals remain as molecules, like hydrogen (H_2), oxygen (0_2), nitrogen (N_2), sulfur (S_8), phosphorus (P_4), bromine (Br_2), Iodine (1_2), fluorine (F_2) etc.

Covalent Bond in Hydrogen: The electronic configuration of hydrogen is H(1) $1s^2$. When 2 H atoms come close, both of them share one electron from their outermost energy level each. That means, they create a pair of electrons which makes the configuration same as inert gases. This creates a (H-H) covalent bond.

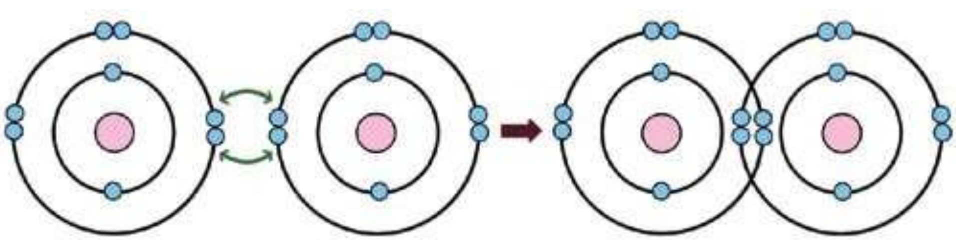
H·+ ·H ------------- H · · H



Hydrogen atom Hydrogen atom Hydrogen molecule

Fig 5.08: Formation of covalent bond in Hydrogen molecule.

Covalent Bond in O_2 Molecule:The electronic configuration of oxygen is O(8) $1s^2\ 2s^2\ 2p^4$ It lacks two electrons in its outermost energy level than that of inert gas. When two O atoms come close, both of them share two electrons from their outermost energy level each. That means, they create two pairs of electrons which makes the configuration same as inert gases. This creates a (O=O) covalent bond. Here the number of bond is two.



oxygen atom oxygen atom oxygen molecule

Generally,

O+O ———— O = O or, O_2

Fig 5.09: Formation of covalent bond in Oxygen molecule.

Covalent bond is also available in compound's molecule made of more than one non-metallic element. For example, in water's molecule, 0 atoms share one of their electrons from the outermost energy level with one electron of H atom. Thus two (0-H) covalent bonds are created and water's molecule is structured.

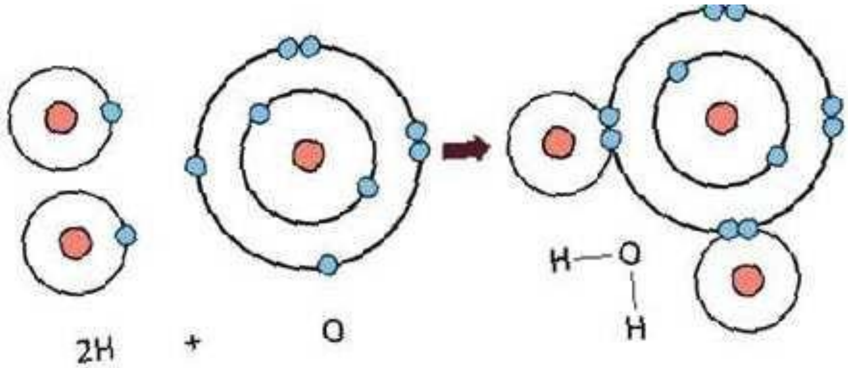


Fig 5.10: Two (O-H) covalent bonds in water molecule.

In the $H_2 0$ molecule, two pairs or 4 electrons of O atom do not participate in any bonding. However, if required, they can also create bonds which you will learn in higher classes.

An O atom is capable of participating in both ionic and covalent bonds. A Na atom however is never able to participate in covalent bonding; it always participates in ionic bonding only. An O atom can accept 2 electrons from other elements in an ionic bond and can share 2 electrons with another element in a covalent bond. Na atom, on the other hand is capable of only donating electrons to other elements in an ionic bond.

Molecules of elements with covalent bonds (N_2, 0_2, Cl_2, Br_2, 1_2 etc.) are called covalent molecules and compounds with covalent bonds (CH_4, CO_2, HCl, NH_3 etc.) are called covalent compound molecules. Many covalent molecules (CO_2, NH_3, 0_2, Cl) remain in gaseous state at normal temperature and pressure. Some of them remain in the liquid state ($H_2 0$, $C_2 H_5 0H$ etc.) in the same situation while some others ($C_{10}H_8$, S_8, I) are found in solid state. When two covalent molecules come close, a weak attraction force remains effective among them. This force is called Vander Wall's attraction force. The covalent molecules remain attached with each other due to this attractive force. That's why, it is easy to alienate them with a bit of force. Melting and boiling points of these molecules are also low. Again, Vander Wall's attraction force is hardly effective on gaseous covalent molecules. They remain as gaseous single molecules due to this.

5.12 Characteristics of Ionic and Covalent Bonds

(a) Melting Point and Boiling Point

The compound consisting of an ionic bond is called an ionic compound and the compound consisting of covalent bonds is called a covalent compound. The melting and boiling points of ionic compounds are higher than those of covalent compounds. Ionic compounds contain positive and negative charges which remain tightly connected with each other. Many such positive and negative charges are organized in an ionic compound in a three dimensional way to create a crystal. This results in a higher inter atomic force among them and that makes it tough to alienate from each other. Therefore, they require higher amount of heat energy to melt or to boil. Inter atomic force in covalent compounds is comparatively weaker as it is constituted because of Vander Wall's force. Therefore, they can be boiled or melted with a lower amount of heat energy. You can easily experiment this with ionic compounds like NaCl, $CuSO_4$, $NaNO_3$, KCl, $CaC1_2$ etc. and covalent compounds like glucose, sugar, or even water. All the experiments will prove that the boiling point and melting point of ionic compounds are higher than those of covalent compounds

(b) Solubility

Take some water in a beaker or a glass jar. Add some NaCl, an ionic compound and continue to stir it. Then, do the same thing with washing soda ($Na_2CO_3.10H_2O$), Copper Sulfate ($CuSO_4.5H_2O$) or some other ionic compounds; you'll find them all soluble in water. However, you'll not find the same result with silver chloride. That means apart from a few exceptions, ionic compounds are soluble in water. Try the same experiment with covalent cornpounds like naphthalene, mustard oil, kerosene etc. covalent compounds. You will find none of them soluble in water. Although there are few exceptions like sugar, glucose etc, most covalent compounds are not soluble in water.

Why are some covalent compounds soluble in water? The reason lies in the bond structure of water. Water is a covalent compound itself where two hydrogen atoms are connected with one oxygen atom by electron sharing. But since oxygen is more electronegative than hydrogen, the two electrons of the covalent bond of water move towards oxygen a bit. As a result, oxygen atom becomes a partially negative charge while hydrogen becomes a partially positive charge, meaning a partial positive and a partial negative end is created in water molecule. This kind of charged covalent compound is called polar covalent compound. So, water is a polar soluble. Remember, the attraction force of an atom when it tries to attract the electron pair of a covalent bonding to itself is called the electronegativity of an atom. The figure 5.10 uses +3 (plus delta) and -◊ (minus delta) to express positive and negative charges.

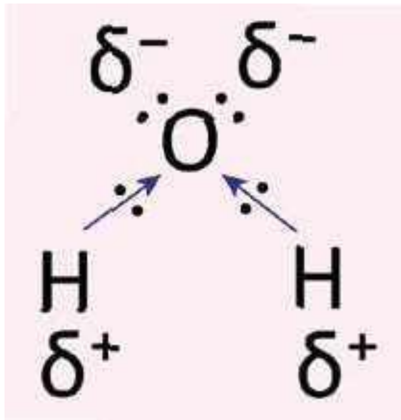


Fig 5.11: +Oand-◊ indicate partial positive and partial Negative charge.

When the ionic compound is added to water, the polar solvent, water molecule's cation attracts the anion of the ionic compound. The same action takes place between the anion of water molecule and cation of ionic compound's molecule. When this attraction force becomes greater than that between the cation and anion of the ionic compound, then they become alienated from each other and become surrounded by water molecule. Thus ionic compound is dissolved into water.

NaCl is an ionic compound and being so, it gets dissolved in the polar solvent, water. Methanol (CH_3OH) is a polar compound and so it gets dissolved in polar solvent, water. Since methane (CH_4) is neither an ionic compound nor a polar compound, it does not get dissolved in water.

On the other hand, there is no cation and anion in covalent compounds. They don't become attracted or distracted by cation and anion of water. As a result, they do not break down as ions in water or get dissolved.

However, partial polarity is seen in some covalent compounds like ethanol (C_2H_5OH). These covalent compounds only get dissolved in water.

(c) Electrical Conductivity

Take some water solution of edible salt (NaCl) in a beaker and some water solution of sugar in another. Now put two graphite rods or any other kind of metallic rod into each solution and finally connect battery and bulb to each of them accordingly as shown in the figure 5.12. You will see, the bulb in salt water solution is lit up while the one with sugar-water solution is not. That shows the salt water solution is able to conduct electricity while sugar water cannot.

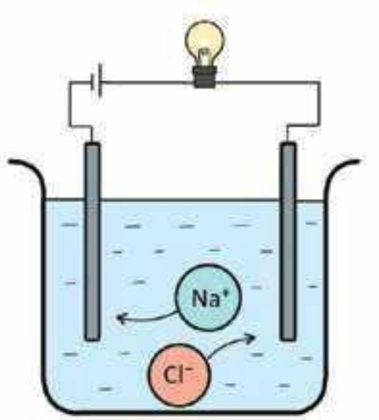


Fig 5.12: Electrical conductivity of water solution of edible salt (NaCl).

You may come to decide that ionic compounds in solution with water can conduct electricity while covalent compounds cannot.

You can also guess the reason very well. Electro-conductivity requires alienated positive and negative ions. In the salt water solution, Na+and Cl- act as positive and negative ions respectively and conduct electricity. As in water solution, ionic compounds remain as alienated cations and anions, therefore, all water solutions with ionic compounds are electro-conductive.

On the other hand, covalent compounds do not conduct electricity in water solution as they do not carry alienated ions.

In $CaC1_2$ solution, there is Ca^{2}+ and Cl-. HCl solution contains H+ and Cl-. Therefore they can conduct electricity. Glucose ($C_6H_{12}O_6$) does not carry any ion, so it does not conduct electricity.

Group Work

Fig 5.13: Crystals of salt and sugar.

Formation of Crystals

Each group will take two beakers. One beaker will have salt and another, sugar. Add water to both and heat them a bit to dissolve as much salt (NaCl) and sugar ($C_{12}H_{22}O_{11}$) as possible. Now preserve both beakers for some days along with a cotton liner hanging inside each. After some days, pick up the liners- you will find salt and sugar crystals have formed around them. Usually, all ionic compounds remain as crystals. On the other hand, though some form crystals, usually, covalent compounds are not available in crystal form.

5.13 Metallic Bond

We have seen that, a metal and a non metal element creates an ionic bond among themselves while two non-metal elements create a covalent bond among themselves. But when two metallic elements come closer together, there is created a metallic bond. It means, the attraction force that keeps the atoms in a piece of metal interconnected is called the metallic bond. You have obviously seen copper wire, knife, scissors, window grill or gold ornaments etc. Numerous atoms of the same element are interconnected by means of metallic bonds inside.

The outermost energy level of each metallic atom usually contains **1,** 2 or 3 electrons in its electronic configuration. Since their size is bigger than the non-metallic elements of the same period, the attractive force of the nucleus on them is less strong. As a result, atoms donate one or more electrons from their outermost energy level and tum into a positive ion. This positive ion is called the atomic core. These atomic cores are three dimensionally organized in a metal's lattice.

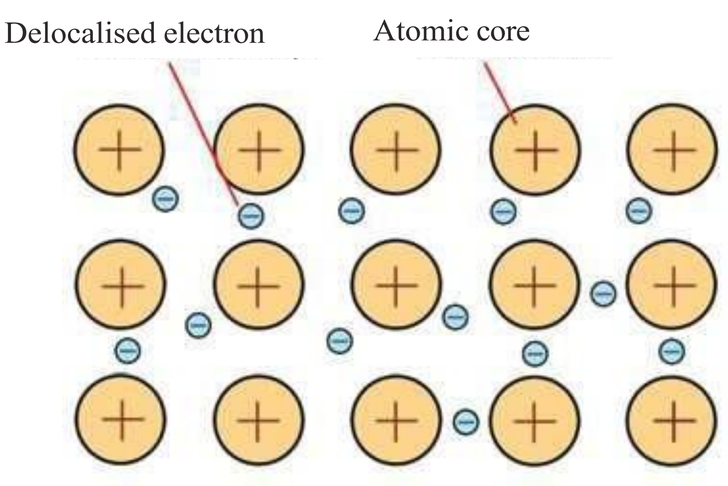


Fig 5.14: Metallic bonds.

In the metal lattice, the donated electrons come out of the orbit and move freely at the center of the atomic core. Such electrons are called Delocalized Electrons. They become electrons of all the metallic ions of that piece of metal instead of remaining under a particular atom. It can be said that the ions remain organized like a lattice in the sea of electrons. When a delocalized electron is situated amidst two metallic ions, both the ions are attracted towards the electron with an electrostatic force. This causes the two ions to remain connected, which is the basic feature of a metallic bond. These delocalized electrons are responsible for the conductivity of heat and electricity. Similarly, they are the reasons for the flexibility, brightness, and charge-resistance etc. features of a metal.

Electro Conductivity of Metals

All metals are electrical conductors. The delocalized electrons in the metal lattice are the carrier of electricity in them. Ifwe connect the two ends of a piece of metal to positive (+) and negative (-) edges of a battery, the electrons will rush from the negative edge to the positive edge. That means, there will be flow of electricity from positive end to negative end. Flow of delocalized electrons creats electricity. There would not have been any electricity flow in the absence of delocalized electrons.

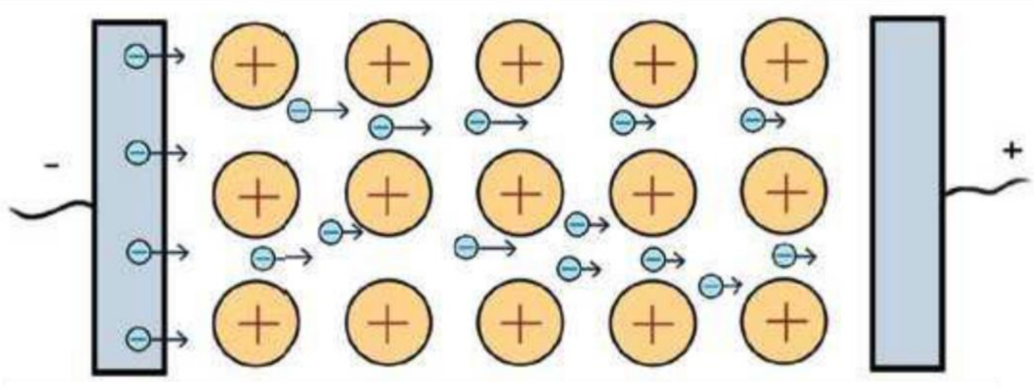


Fig 5.15: Mechanism of electrical conductivity of Metal.

Heat Conductivity of Metals

When you heat an end of a piece of metal, you'll find that the other end is also getting warm fast. It means, metals are heat conductors too. The reason is again delocalized electrons. When heat is applied, these electrons receive energy and increase their velocity. They rush from the heated end towards the comparatively cooler end. Thus heat is conducted in a metal.

Individual Task

Identifying ionic and covalent compounds among locally available products.

Put edible salt, kerpoor, naphthalene, washing soda etc. in different beakers containing water. Stir them with a glass tube and mix them properly. Those which got dissolved in water are ionic compounds and those which did not are covalent compounds. You can divide all compounds into two categories by the same process

Exercise

Multiple Choice Questions

1. What is the name of the attraction force which keeps the atoms bonded in a molecule?

a. Electron affinity b. Electronegativity

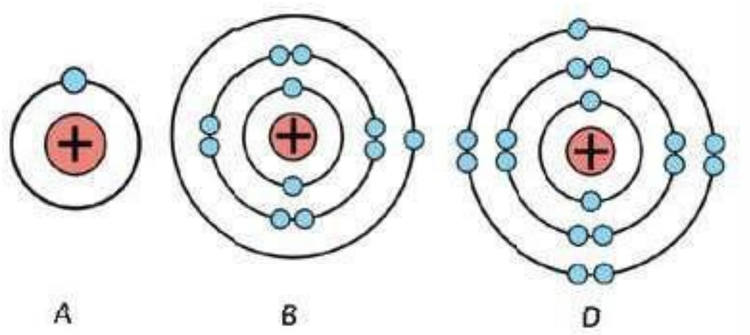
c. chemical bond d. Van Der Waals force

2. The formation of which molecule below attains the electronic configuration of neon?

a. KF b. CaS

c. MgO d. NaCl

Answer the questions 3 and 4 on the basis of the following electronic configurations:



3. Which valency is impossible for the element marked by D?

a. 2 b. 3

c. 4 d. 6

4. The element B-

i. forms two types of bonds

ii. donates electron to A

iii. Dissolves in water combining with A

Which of the following is correct?

a. 111 b. ii and iii

c. i and iii d. i, ii and iii

5. Which of the following denotes the formula of aluminum sulfate?

a. Alz(S04)3 b. $AlSO_4$

C. Al(S04)3 d. Al_2SO_4

6. What kind of compound is calcium oxide?

a. covalent b. ionic

c. metallic d. polar

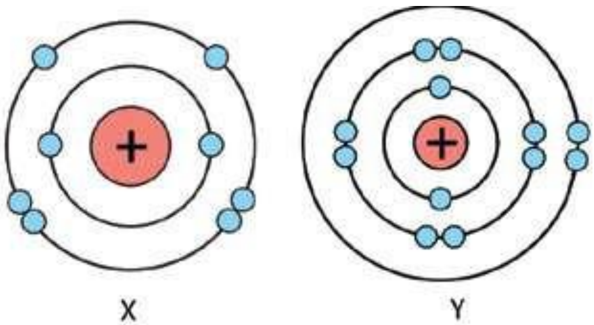
7. Which of the following compounds 1s not electro conductive in water solution?

a. NaCl b. $Cacl_2$

c. HCl d. $C_6H_{12}O_6$ (Glucose)

Creative Questions

1.



(Here X and Y are symbolic. Not symbols of any element)

a. What is a covalent bond?

b. Why is there a difference in the size between Na and Na+ ions?

c. What kind of bond is there in the compound YX of the stem? Explain.

d. Though X is capable of forming both covalent and ionic bonds, element Y never goes into covalent bonds - Explain with logic.

2. Read the following stem and answer the questions

(a) CH_4 (b) NaCl (c) $CC1_4$ (d) CH_3OH

a. What is a covalent bond?

b. Why is water a polar compound? Explain.

c. Which compound of the stem forms a crystal? Explain

d. The compound (b) of the stem is soluble in water but compound (c) is not. Analyze

Chapter Six

Concept of Mole and Chemical Counting

Chemistry basically deals with two kinds of analysis- qualitative analysis and quantitative analysis. Identification ofan element and its properties is qualitative analysis whereas determining the amount of a substance is known as quantitative analysis. Quantitative analysis deals with calculations which altogether are denoted by the term chemical counting. These calculations usually use mole as the unit to determine the amount of a substance. In this chapter, we will discuss what is a mole, how to use moles in calculations, how to determine the cubic measurements from moles etc.

By the end of the chapter, we will be able to:

- do the simple mathematical calculations using the concept of moles
- prepare solutions of certain concentrations
- determine the percent composition of elements present in the compounds using the given data
- determine the empirical and molecular formula using the percent compositions
- write chemical equations and balance the equation using symbols, formula and valency of elements and radicals
- solve mass related mathematical problems of reactants and products from the quantitative significance of chemical reactions
- calculate the percent composition of lattice water of copper sulphate
- do measurements of chemical substances using a balance

6.1 Mole

The word mole is the unit of any chemical measurement. Suppose,

12 nos of 0_2 = 1 dozen ofO_2
100 nos of 0_2 = 1 hundred of 0_2
1000 nos of 0_2 = 1 thousand of 0_2
Similarly, 6.023×10^{23} nos 0_2 = 1 mole 0_2

1 mole atom contains 6.02×10^{23} atoms
1 mole molecule contains 6.02×10^{23} molecules
1 mole ion contains 6.02×10^{23} ions

Therefore, the number 6.02×10^{23} is used in the case with atoms, molecules and ions etc. This number is called the Avogadro number.

The amount of a chemical substance that contains as many as the Avogadro number (6.02×10^{23}) of molecules, atoms or ions is called the mole of the substance. For example, 12 grams ofC contains 6.02×10^{23} number of C atoms.

The expression of atomic mass of atoms and the molecular mass of molecules into gram unit is called one mole of a chemical substance.

Therefore,

12 grams ofC = 1 mole C atom.

Again, 18 grams of H_2O contains 6.02×10^{23} number of H_2O molecules. Therefore,

18 grams ofH_2O = 1 mole H_2O.

The Process of Determining the Molecular Mass of a Molecule

The summation of atomic masses of all atoms that constitute a molecule denotes the molecular mass of the molecule. Cl_2 molecule, for example, has two Cl atoms.

Therefore, the molecular mass of Cl_2 = atomic mass of Clx 2 = 2 x35.5 = 71

tr,

One mole Cl_2 = 71 g Cl_2.

A NaCl molecule has **1** Na atom and 1 Cl atom. Therefore, the molecular mass of NaCl= atomic mass of Na + atomic mass of Cl= 23 + 35.5 = 58.5

One mole of NaCl= 58.5 g NaCl

$CuSO_4.5H_2O$ contains 01 Cu, 01 S, 09 0 and 10 **H** atoms. Therefore, the molecular mass of $CuSO_4.5H_2O$ = atomic mass of Cu x **1** + atomic mass of S x 1 + atomic mass of Ox 9 + atomic mass ofH x 10

$$= 1 \times 63.5 + 1 \times 32 + 9 \times 16 + 10 \times 1$$

$$= 249.5$$

A mole of $CuS0_4.5H_20$ = 249.5 g $CuS0_4.5H_20$

Examples

Problem: What is the mass of 1 H_2O molecule?

Solution: We know, 1 mole H_2O = 18 g H_2O = $6.023xl0^{23}$ no of H_2O molecule

Here, the molecular mass of $6.02x10^{23}$ H_2O molecules= 18 g

Therefore, the mass of **1** H_2O molecule = $\frac{18}{6.023X10^{23}}$ g = 2.99 x 10-^{23}g

Problem: How many H_2SO_4 molecules are there in lg H_2SO/

Solution: We know, **1** mole H_2SO_4 = 98 g H_2SO_4 = $6.023xl0^{23}$ no of H_2SO_4 molecule

Here, 98 g H_2SO_4 = $6.023xl0^{23}$ no ofH_2SO_4 molecules

Therefore, the mass of lg H_2S0_4 = $\frac{6\ 023X10^{23}}{98}$ = $6.14xl0^{21}$ H_2SO_4 molecules.

Problem: Calculate the mole of H_2O present in 5g H_2O.

Solution: We know, **1** mole H_2O = 18g H_2O = $6.023xl0^{23}$ no of H_2O molecules.

Here, 18 g H_2O = 1 mole H_2O

lg H_20 = $\frac{}{18}$ mole H_2O

Therefore, 5 g H_2O = $\frac{1}{18}$ xS = 0.277 mole H_2O.

Individual Task: Determine the number ofH, Sand O atoms in 1 g H_2SO_4

6.1.1 Molar Volume of Gas

The volume that 1 mole of a gaseous substance occupies is called the molar volume of that gas. 0°C temperature and 1 atm pressure together is called the standard temperature and pressure or the standard condition. The volume of 1 mole gas in this standard condition is 22.4 liter.

If n = mole number
w = mass m gram
V = Volume in liter
N = Number of molecules
M = Molecular mass

$$n = \frac{w}{M}$$

Or, $$n = \frac{V}{22.4}$$

Or, $$n = \frac{N}{6.023 \times 10^{23}}$$

Example

Problem: How many molecules are there m 1 liter CO_2 gas at standard temperature and pressure?

Solution: 1 mole CO_2 = 44 g CO_2 = 6.023×10^{23} no CO_2 molecules= 22.4 liter CO_2 gas at standard temperature and pressure

At standard temperature and pressure 22.4 liter CO_2 gas contains= 6.023×10^{23} no CO_2 molecules

Therefore, 1 liter CO_2 gas contains= $\frac{6.023 \times 10^{23}}{22.4} = 2.69 \times 10^{22}$ molecules

Individual Task: How many H atoms are there in 5 liter CH_4 gas at standard condition?

Problem: What is the volume of 5 mole CO_2 gas at standard temperature and pressure?

Solution: Here, it is given, mole n = 5, we require to find out volume V = ?

We know $n = \frac{V}{22.4}$

Or $5 = \frac{V}{22.4}$

Therefore V = 5x 22.4 = 112 liter

Individual Task: What is the volume of 5 CO_2 molecules at standard condition?

Problem: What is the volume of 10 g Hydrogen gas at standard condition?

Solution: Here, it is given, mass w = 10 g, molecular mass of H_2, M = 2. We require to find out volume V = ?

$$n = \frac{w}{M} = \frac{V}{22.4}$$

$$\frac{10}{2} = \frac{V}{22.4}$$

Therefore V = 22.4 x 22.4 liter= 112 liter

6.1.2 Mole and Molecular Formula

There is a relation between mole and molecular formula. The quantity in gram determined when we express the molecular mass of a substance gotten from its molecular formula is called 1 mole of that substance. For example, molecular formula of water is H_2O and its molecular mass is 18. Therefore 18 gram is called 1 gram molecular mass water or 1 mole water. It is clear here that, mole is also the gram molecular mass.

Molecular formula provides some other information too. For example, in the case with H_2O:

1. H_20 is water.
2. The formula of 1 molecule water is H_2O.

3. The formula of 1 mole water is H_2O.

4. 1 molecule H_2O contains 2 hydrogen atoms and an oxygen atom.

5. 1 mole H_2O molecule contains 2 mole hydrogen and 1 mole oxygen atoms.

6. In 1 mole H_2O molecule, the mass ofH atom is lx2 = 2 g and the mass of O atom is 16xl =16 g. Therefore, the total mass of 1 mole H_2O molecule is 2 + 16 = 18 g.

7. In 1 mole H_2O molecule, the number of H atoms are $6.023 \times 10^{23} \times 2 = 1.20 \times 10^{24}$ and the number of O atoms are $6.023 \times 10^{23} \times 1 = 6.023 \times 10^{23}$ and the number of H_2O molecules are 6.023×10^{23}.

6.1.3 Molar Solution

Suppose a solute is dissolved in a solvent. At a fixed temperature, if one mole solute is dissolved in 1 liter solution, then that solution is called molar solution or 1 molar solution. If 2 mole solute is dissolved in 1 mole solution, that solution is called 2 molar solution.

An example can make us differentiale between solute, solvent and solution. Take about half a glass of water. Add some edible salt to the water and mix it with a spoon. You will see the salt is no more visible in the water, after a while. This mix of salt and water is a solution. Here water is the solvent and salt is the solute.

Liquids such as water, acid, alcohol etc. are necessary in preparing solutions. In this chapter, chiefly we shall use water as the solvent. When water is used as solvent in a solution, the solution is called water solution.

Solution = Solute + Solvent

You may come across the terms Dilute Solution and Concentrated Solution frequently. 10 gram salt mixed in 250 mL

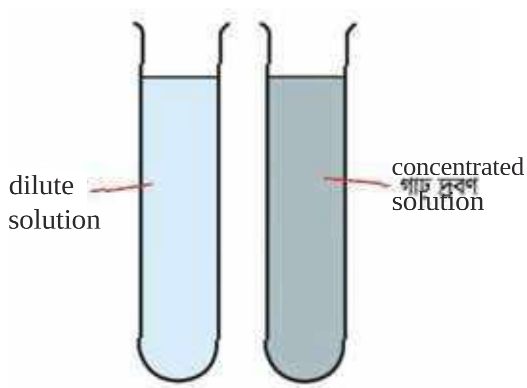


Fig 6.01: Dilute and concentrated solution.

water is a solution. Again, 15 gram salt in 250 gram water is also a solution. The one with lesser amount of salt is a dilute solution while the other is a concentrated solution. Again, 10 gram salt is mixed in two glasses containing 250 mL and 200 mL water each. The solution containing more water is a dilute solution while the one with less water is a concentrated solution. Similarly in the laboratory, smaller amounts of solute in a fixed amount of solvent creates a dilute solution and greater amounts of solute in the same amount of solvent creates a concentrated solution. Actually, there is no specific rule to determine which is dilute and which is a concentrated solution .

The number of moles dissolved in every liter of solution at a certain temperature is called the molarity of the solution. If 2 mole solute is dissolved in a one liter solution at a fixed temperature, then the molarity of that solution is 2. When there is 0.5 mole solute in 1 liter solution, that is a semi-molar solution and when that same 1 liter solution has 0.1 mole solute, that is called a decimolar solution. The molarity of a decimolar solution is 0.1 while 0.5 is the molarity of a semimolar solution.

Preparation of Solutions with Different Molarity

There is necessity of preparing molar, semimolar and decimolar solutions in the laboratory. It can be done easily following various steps. Firstly, you need to select a volumetric flask. Secondly, you need to weigh the substance that you are interested to prepare the solution of and put it in the flask. Thirdly, you need to add some water and shake the flask to prepare the solution. Then, you need to fill water to a certain mark in the flask. There is relationship in between molarity of solution, volume of solution, mass and molecular mass of the solute.

$$Mass\ of\ solute\ in\ gram\ unit$$
$$= \frac{molarity\ of\ solution \times volume\ of\ solution\ in\ milliliter\ unit \times molecular\ mass}{1000}$$

Here, if we take $Mass\ of\ solute\ in\ gram\ unit = w$

Molarity of solution = S

$volume\ of\ solution\ in\ milliliter\ unit = V$

$$molecular\ mass\ of\ solute = M$$

$$\text{Then } w = \frac{SVM}{1000}$$

To solve the molarity related problem, we can use the above equation

Example

Problem: How will you prepare 0.2 molar NaCl solution in a volumetric flask of250 mL?

Solution: Given, a volume of solution V = 250mL, molarity of solution S = 0.2 molar, molecular mass of NaCl= 23 + 35.5 = 58.5

Therefore, 1 mole NaCl= 58.5 g

0.2 molar NaCl solution in 1 liter or 1000mL requires 58.5x 0.2 = 11.7 g

250 mL solution requires $= \frac{11.7 \times 250}{1000} = 2.925$ g

Add 2.925 gram NaCl in a 250 mL volumetric flask. Pour 250 mLwater inside the flask. That will complete the preparation of 0.2 molar solution.

Alternative Solution

We know, $w = \frac{SVM}{1000}$

Therefore, $w = \frac{0.2 \times 250 \times 58.5}{1000} = 2.925$ g

Now, follow the procedure of adding the solute and solvent to complete the preparation.

Problem: How much Na_2CO_3 is there in a 2 liter 0.1 molar Na_2CO_3 solution?

Solution: Molecular mass ofNa_2CO_3 = 23x2 + 12 + 16x3 = 106

Therefore, the amount of Na_2CO_3 necessary in a 1 liter 1 molar solution = 106 g

the amount ofNa_2CO_3 necessary in a I liter 0.1 molar solution= 10.6 g

the amount ofNa_2CO_3 necessary in a 2 liter 0.1 molar solution= 10.6 x2g = 21.2 g

Alternative way

$$w = \frac{SVM}{1000}$$

$$w = \frac{0.1 \times 2000 \times 106g}{1000}$$

$$w = 21.2g$$

Problem: What is the molarity of the solution when there is 20 g Na_2CO_3 in 250 mL solution?

Solution: Molecular mass of Na_2CO_3 = 23 x 2 + 12 + 16 x 3 = 106

1 molarity in 1 liter solution requires 106 gram

1 molarity in 250mL solution requires $\frac{106 \times 250}{1000} = 26.5$ gram

26.5 g Na_2CO_3 in 250mL makes the molarity 1 molar

1 g Na_2CO_3 in 250mL makes the molarity $\frac{1}{26.5}$ molar

20 g Na_2CO_3 in 250mL makes the molarity $\frac{1 \times 20}{26.5} = 0.75$ molar

Alternative Way

$$w = \frac{SVM}{1000}$$

$$20 = \frac{S \times 250 \times 106}{1000}$$

$$S = 0.75 \ molar$$

Problem: What is the volume of the solution m mililiter when 20 g Na_2CO_3 is dissolved in 0.75 molar Na_2CO_3 solution?

Solution: Given here, S = 0.75 molar, w = 20 g, M = 23 x 2 + 12 + 16 x 3 = 106, V =?

We know, $w = \frac{SVM}{1000}$

$$20 = \frac{0.75 \times 106}{1000}$$

$$V = \frac{1000 \times 20}{0.75 \times 106} = 250ml$$

Problem: A 250 mL solution has 20g substance dissolved in it and its molarity is 0.75. What is the molecular mass of the solute in the solution?

Solution: Given here, w = 20 g, V = 250mL, S = 0.7 molar, M =?

We know,

$$w = \frac{SVM}{1000}$$

$$20 = \frac{0.75 \times 250 \times M}{1000}$$

$$M = \frac{1000 \times 20}{0.75 \times 250} = 106$$

Problem: How will you prepare 200mL semimolar Na_2CO_3 solution?

Solution: V = 200mL, S = 0.5 molar, M = 23x2 + 12 + 16x3 = 106

We know,

$$w = \frac{SVM}{1000}$$

$$= \frac{0.5 \times 200 \times 106}{1000} g = 10.6 g$$

Now, take 10.6 g Na_2CO_3in a pot and pour 200mL water in it. Thus we can prepare the solution.

Individual Task

Task: Find out the molarity of the solution when there is 4 g NaOH in a lO0mL solution.

Task: Find out the molarity of the solution when there is 4 g HCl in a 100mL solution.

6.2 The Percentage Composition of Elements in Compounds

The gram measurement of an element present in a 100 gram compound is called the percentage composition of that element. The molecular formula of a compound is the source to determine the percentage composition of various elements in the compound.

Percent composition of an element in a compound

$$= \frac{\textit{atomic mass of element} \times \textit{number of atoms} \times 100}{\textit{molecular mass of compound}}\%$$

Example: The percent composition ofH and Cl in HCl is shown below:

Molecular mass of HCl = 1 + 35.5 = 36.5

In 36.5 gram HCl the amount of H = 1 gram

In lgram HCl the amount ofH $= \frac{1}{36.5}$ gram

In 100 gram HCl the amount ofH $= \frac{1 \times 100}{36.5} = 2.74$ gram

So, the percent composition of Hin HCl is 2.74%.

Again,

In 36.5 gram HCl the amount of Cl= 35.5 gram

In lgram HCl the amount of Cl= $\frac{35.5}{36.5}$ gram

In 100 gram HCl the amount of Cl= $\frac{35.5 \times 100}{36.5} = 97.26$ gram

So, the percent composition of H in HCl is 97.26%.

It can also be calculated that the percent composition of Cl is (100-2.74) = 97.26%.

Examples

Problem: Find out the percent composition of H and O in H_2O.

Solution: The mass of 1 mole H_2O = 2 + 16 = 18 gram

In 18 gram H_2O the amount of H = 2 gram

In 1gram H_2O the amount of H = $\frac{2}{18}$ gram

In 100 gram H_2O the amount ofH $= \frac{2}{18} \times 100 = 11.11$ gram

So, the percent composition of H in HCl is 11.11%.

Again, the percent composition of O is (100-11.11) = 88.89%.

We can determine the same percent composition applying values m the formula of percentage composition.

$$\text{Percent composition of an element in a compound} = \frac{\text{atomic mass of element} \times \text{number of atoms} \times 100}{\text{molecular mass of compound}} \%$$

The molecular mass ofH_2SO_4= (lx2 + 32xl + 16x4) = 98

Here, atomic mass of H is 1 and the number of H atoms is 2

Therefore, the percent composition ofH $= \frac{1 \times 2 \times 100}{98} \% = 2.04\%$

Atomic mass of Sis 32 and the number of S atoms is 1

Therefore, the percent compos1·t1·0n of S $= \frac{32 \times 1 \times 100}{98} \% = 32.65\%$

Atomic mass of O is 16 and the number of O atoms is 4

Therefore, the percent composi·ti·on of O $= \frac{16 \times 4 \times 100}{98} \% = 65.3\%$

Problem: Find out the percent composition of aluminum, sulfur and oxygen in Al2(SO4)3

Solution: The molecular mass of Ab(SO4)3 = 27x2 + (32x1 + 16x4) x3 = 342

the percent composi·ti·on of Al= $\frac{27 \times 2 \times 100}{342} \% = 15.78\%$

the percent composition of S $= \frac{32 \times 3 \times 100}{342} \% = 28.07\%$

the percent composi·ti·on of O $= \frac{16 \times 12 \times 100}{342} \% = 56.14\%$

Do it Yourself

Task: Find out the percent composition of Na and Cl in NaCl.

6.2.1 Percent Composition and Empirical Formula

We are already familiar with the term Molecular Formula as we have learned what it is and have applied it to determine the number of atoms of elements in a molecule. The idea of an empirical formula has been introduced to express the ratio of various atoms in a molecule. For example, there are two H atoms and two O atoms in hydrogen peroxide (H_20_2). Therefore, the ratio of the atoms in this compound is 1:1. That means, the empirical formula of H_20_2 is HO. The formula that shows the ratio of the number of atoms of different elements present in a molecule is called the empirical formula. We can easily determine the empirical formula of a compound if we know the percent composition of elements in it and its relative atomic mass.

Determining of Empirical Formula from the Percent Composition

The steps required to determine the empirical formula from the percent composition are described below:

Step 1: The percent composition of the elements is to be divided by its atomic mass.

Step 2: Use the smallest quotient to divide the other quotients and then multiply these new quotients with the common nearest number to tum them into integers.

Step 3: Apply these integers to the right of respective symbol of elements. That forms the empirical formula.

Step 4: Do not write anything if the integer obtained is 1.

Suppose, **in** a compound, the percent compositions of carbon and hydrogen are 92.31% and 7.69% respectively.

First, let's divide the percent compositions with their atomic masses.

$$C = \frac{92.31}{12} = 7.69$$

$$H = \frac{7.69}{1} = 7.69$$

Now divide the quotients with the smallest of quotients:

$$C = \frac{7.69}{7.69} = 1$$

$$H = \frac{7.69}{7.69} = 1$$

Now write these values alongside the symbols of the elements and that gives you the empirical formula. Thus, the empirical formula of this compound is C,H, = CH.

Example

Problem: The percent composition of elements in a compound are given as H = 2.04%, S = 32.65% and O = 65.30%. Determine the empirical formula of the compound.

Solution: First, we'll divide the percent composition of the elements by their respective atomic masses:

$$H = \frac{2.04}{1} = 2.04$$

$$S = \frac{32.65}{32} = 1.02$$

$$0 = \frac{65.30}{16} = 4.08$$

Now, we'll divide the quotients by the small quotient above:

$$H = \frac{2.04}{1.02} = 2$$

$$S = \frac{1.02}{1.02} = 1$$

$$0 = \frac{4.08}{1.02} = 4$$

Now, we'll write the empirical formula of the compound: $H_2S_10_4 = H_2S0_4$

Problem: There is hydrogen and oxygen in a compound whose percent compositions are **11.11**% and 88.89% respectively. What is its empirical formula?

Solution: First, we'll divide the percent composition of the elements by their respective atomic masses:

$$H = \frac{11.11}{1} = 11.11$$

$$0 = \frac{88.89}{16} = 5.55$$

Now, we'll divide the quotients by the small quotient above:

$$H = \frac{11.11}{5.55} = 2$$

$$0 = \frac{5.55}{5.55} = 1$$

Now, we'll write the empirical formula of the compound: $H_2O_1 = H_2O$

Do It Yourself

An experiment showed that a compound consists of 3 gram carbon atom and 8 gram oxygen atom. Determine the empirical formula of the compound.

6.2.2 : Determining the Molecular Formula of a Compound from Percent Composition

If we want to determine the molecular formula of a compound from its percent composition, we need to determine the empirical formula first. If the total mass of the empirical formula of that compound is equal to its molecular mass then the empirical formula itself is also the molecular formula. But when the empirical formula and molecular mass of the compound varies from each other, then we need to find out how many times greater the molecular mass is from the empirical formula.

If molecular mass is n times greater than the empirical formula, then

$$\text{Molecular Formula} = (\text{Empirical Formula})n$$

Here, $n = \dfrac{\textit{Molecular Mass of Compound}}{\textit{Mass of Empirical Formula}}$

Suppose, percent composition of a compound is C = 92.31%, H = 7.69%. The molecular mass of the compound is 78. Determine its molecular formula.

Let's divide the percent composition of elements with their respective atomic masses:

$$C = \frac{92.31}{12} = 7.69$$

$$H = \frac{7.69}{1} = 7.69$$

Now, we'll divide the quotients by the small quotient above:

$$C = \frac{7.69}{7.69} = 1$$

$$H = \frac{7.69}{7.69} = 1$$

So, the empirical formula of the compound: C_1H_1 $=CH$

Since the empirical formula is CH, the molecular formula will be $(CH)n$ = CnHn

The mass of empirical formula of the compound stands = 12x**1 + 1 x 1** = 13 and its molecular mass= 78

$$\text{Therefore } n = \frac{\textit{molecular mass of compound}}{\textit{mass of empirical formula}} = \frac{78}{13} = 6$$

Thus, the molecular formula of the compound is C_6H_6

Determining Molecular Formula from Empirical Formula

The molecular formula of a compound can be the base to determine its empirical formula. Suppose, we need to find the empirical formula of glucose (C6H1206).

A glucose ($C_6H_{12}O_6$) molecule consists of 06 C atoms, 12 H atoms and 06 0 atoms.

The ratio of atoms C: H: 0 = 6: 12: 6 = **1** : 2: **1**

Therefore, the empirical formula of glucose is $C_1H_2O_1 = CH_2O$

Sometimes, the empirical formula and molecular formula are similar. For example, the molecular formula of water is H_2O, its empirical formula is H_2O too. Both the formulas for sulfuric acid is H_2SO_4.

Usually, the compounds, all the atoms of which can be divided by a certain number, have different molecular and empirical formulas. The molecular formula of benzene is CH Since the number of atoms here are divisible by 6, therefore, its empirical formula will be C,H, = CH. Similarly, the molecular formula of ethene is CH Therefore, its empirical formula is CH = CH

6.3 Chemical Reactions and Chemical Equations

Chemical Reactions

The change which causes a substance to get a new set of properties giving up its own properties and features is called a the chemical change. The process that brings the change is called a chemical reaction. Chemical equation is the short expression of a chemical process by using symbols, formula and sign.

The substances that are used to begin a chemical reaction are called reactants. The substance or substances with new properties that are formed at the end of the reaction are called products.

There are some rules observed to write chemical equations in order to express chemical reactions. The rules are:

1. In a chemical equation, the reactants are written on the left side and the products are written on the right side; an equal (=) sign or an arrow ( ) mark is placed in the middle.

2. The reactants and products are written by means of their symbols and formulas. If there are more than one reactants and products, they are written with plus sign.

3. The number of atoms of different elements on the left side and the number of atoms of the same elements on the right side need to be equalized. This is called balancing of the chemical equation.

2H2 + 02   2H20

2H2 + 02 = 2H20

4. Sometimes reactions are not balanced in the equations. In such cases, the arrow mark is used instead of the equal sign.

$$H_2 + O_2 \quad \text{———}$$

5. Sometimes, the physical states of both reactants and products are also mentioned in an equation. It is written on the right side of the element or compound in first brackets ( ). If the physical state of the substance is a solid, we write (s), if the state is liquid, we write (1), if gaseous, we write (g). When the

substance is in the form of an aqueous solution, we write (aq). In the above reaction, the reactants are gases and the product is liquid water. So we write:

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

The main objective of a chemical equation is to express which elements have participated in the reaction to form which product. That is why, it is not always necessary to balance a chemical equation.

6. However, if an equation is to show how much heat has been produced or absorbed in a reaction, it has to be balanced and the physical states of reactants and products are to be written.

Solid substance carbon reacts with oxygen gas and produces carbon dioxide (CO) gas. The equation will be as shown below:

$$C(s) \quad + \quad O_2(g) \quad \text{———} \quad CO_2(g)$$

Solid calcium carbonate reacts with aqueous solution of hydrochloric acid to produce calcium chloride, gaseous carbon di oxide and liquid water.

CaCOis) + HCl(aq) ——— CaClz(aq) + CO2 (g) + H20(l)

calcium carbonate hydrochloric acid calcium chloride carbon dioxide water

Some reactions are there that require heat to be applied. The heat is expressed with a delta ( ) sign above the arrow mark. For example, if heat is applied to solid magnesium nitrate, it produces magnesium oxide, nitrogen dioxide gas and oxygen gas.

$2Mg(NO_3)_2(s)$ ——— 2MgO(s) + 4NOz(g) + oz(g)

6.3.1 Balancing Chemical Equations

Chemical reactions are briefly expressed through chemical equations. Though reactants and products are different substances, they are composed of the same elements. That is why the conservation of mass rule is followed. When both the left and right sides of an equation has the same number of atoms of the same elements, we call that a balanced equation. See the example below:

Mg + HCl __ MgC12+ H2

It is true that we get magnesium chloride and hydrogen when magnesium and hydrochloric acid react; therefore, the reaction is okay. However, the equation is not balanced as the number of hydrogen and chlorine atoms on both sides are not equal.

The Process of Balancing Equations

To make the number of atoms of different elements equal, the formula of reactants and products are multiplied by suitable numbers (2, 3, 4). There is no specific rule to balance equations, but some strategies are followed in this regard. They are:

1. The equation is written using the correct formula of reactants and products.

2. If the reactants and products are compound substances, that is, if the atoms of more than one element are present in the formula, balance the equation, multiplying the reactants or products or both with the required numbers.

3. First the number of atoms present in the molecules of compound substances are balanced. Then come the number of atoms of elements.

4. When the number of atoms of each and every element present in the reaction on both the sides are equal, then the balancing of the equation is done.

Let us examine some examples in this regard.

Example 1

$$Mg + HCl \longrightarrow MgCl_2 + H_2$$

In the above reaction, the number of Cl atom in the compound HCl on the left is one while in the compound $MgC1_2$ there are two Cl atoms. It is understood that the number of Cl on both sides are not equal. The same way, on the left, there is one H atom while on the right, there are two H atoms. H atoms are also not balanced. Mg atom on both sides are equal as there is only one on each side.

First, let us balance the Cl atom. For this, let us multiply HCl on the left side with 2:

$$Mg + 2HC1 \text{ --- } MgC1_2 + H_2$$

Now, a brief check will tell us that all atoms of various elements present on both the sides of the equation are equal. Therefore, the balancing of the equation is done. When the balancing of the equation is done, it can be written with equal (=) sign too.

$$Mg + 2HC1 = MgC1_2 + H_2$$

Example 2

$$Na_2CO_3 + HCl \longrightarrow NaCl + H_2O + CO_2$$

This is not a balanced equation as the left side has two Na while the right has one. Therefore, we multiply NaCl with 2:

$$Na_2CO_3 + HCl \text{ —— } 2NaCl + H_2O + CO_2$$

Still it is not balanced. Now the right has two Cl while the left has one Cl. Multiply HCl on the left with 2:

$$Na_2CO_3 + 2HCl \longrightarrow 2NaCl + H_2O + CO_2$$

Now, number of atoms of every element on both sides are equal.

$$Na_2CO_3 + 2HCl = 2NaCl + H_2O + CO_2$$

Example 3

Aluminum oxide reacts with hydrochloric acid and produces aluminum chloride and water.

$$Al_2O_3 + HCl \longrightarrow AlCl_3 + H_2O$$

To strike a balance of Al on both sides, let us multiply $A1Cl_3$ with 2

$$Al_2O_3 + HCl \longrightarrow 2AlCl_3 + H_2O$$

To balance the number of Cl, multiply HCl on the left with 6:

$$Al_2O_3 + 6HCl \longrightarrow 2AlCl_3 + H_2O$$

Still balance is lacking as the number of O on the left is 3 while on the right is 1. There is a difference between the numbers of H too. So, let us multiply H_2O with 3:

$$Al_2O_3 + 6HCl \longrightarrow 2AlCl_3 + 3H_2O$$

Now, there is balance.

$$Al_2O_3 + 6HC1 = 2AlC1_3 + 3H_2O$$

6.3.2 Mole and Chemical Equation

Certain amounts of a reactant reacts with a certain amount of another reactant and produces a certain amount of product or products. The branch of chemistry that deals with measurements of products from amounts of reactants and measurements of reactants from amounts of products is called Stoichiometry. The information that can be gathered regarding mole from a chemical equation is the Stoichiometry of that reaction.

Analyzing the Stoichiometry, we can tell how many reactants reacted to produce how many products, how many moles of reactants formed how many moles of products, how many grams of reactants participated in the reaction to produce how many grams of products.

2Mg(s)	+	Oz(g)	——	2MgO(s)
Magnesium		Oxygen		Magnesium Oxide

According to stoichiometry, we can write

2Mg(s)	+	Oz(g)	2MgO(s)
2 mole Mg atom		**1** mole 0_2 molecule	2 mole MgO molecule
$2x6.023x10^{23}$ no of Mg atom		$6.023xl0^{23}$ no of 0_2 molecule	$2x6.023x10^{23}$no ofMgO molecule
2 x24 = 48 g		**1** x 32 = 32 g	2 x 40 =80 g

These accounts presented below a balanced equation of a chemical reaction are called its Stoichiometry. When both reactants and products are gaseous substances, in the Stoichiometry, under standard conditions, 1 mole gaseous substance has the volume of 22.4 liter.

Example:

Problem: How much oxygen is necessary for 5 gram magnesium to react and produce magnesium oxide completely?

Solution: Magnesium reacts with oxygen and produces magnesium oxide. The balanced equation of this reaction along with its Stoichiometry is shown above. Accordingly with this Stoichiometry:

48 gram magnesium reacts with 32 gram oxygen

1 gram magnesium reacts with $\frac{1 \times 32}{48}$ gram oxygen

5 gram magnesium reacts with $\frac{1 \times 32 \times 5}{48}$ = 3.33 gram oxygen

---

Problem: How many grams of magnesium oxide will be produced if we put the necessary amount of oxygen with 2 gram magnesium metal?

Solution: According to the Stoichiometry of the reaction:

48 gram Mg metal produces 80 gram magnesium oxide

1 gram Mg metal produces ! gram magnesium oxide

2 gram Mg metal produces $\frac{2 \times 80}{48}$ = 3.33 gram magnesium oxide

---

Problem: How much oxygen is necessary alongside the required amount of magnesium metal to produce 10 gram magnesium oxide?

Solution: According to the Stoichiometry of the reaction:

80 gram magnesium oxide is produced from 32 gram oxygen

1 gram magnesium oxide is produced from ! gram oxygen

10 gram magnesium oxide is produced from $\frac{32 \ xlO}{80}$ = 4 gram oxygen

Problem: How many NH_3 molecules will be produced from 5 N_2 molecules?

Solution:

Nz(g)	+ 3 H_2(g)	———	2NHig)
$6.023xl0^{23}$ no of molecules	$3x6.023xl0^{23}$ no of molecules		$2x6.023x10^{23}$ no of molecules

From the equation:

$6.023xl0^{23}$ no of molecules of N_2 produces $2x6.023xl0^{23}$ no of molecules ofNH_3

1 no of molecules of N_2 produces $\frac{2x6.023 \ x10^{23}}{6.023 \ xlO^{23}}$ = 2 no of molecules of NH3

So, 5 no of molecules ofN_2 produces 2 x 5 = 10 no of molecules ofNH_3

Do it Yourself

Task: How many moles of 0_2 is necessary to produce 6 moles of water?

Task: How much NH_3 in liter will be formed out of 4 liter N_2 at standard temperature and pressure? Here, both reactants and products are gaseous.

6.4 Limiting Reactant

If there is more than one reactant in a chemical reaction, it is not always possible to supply all the reactants in the required amounts when supplied after weighing. As a result, some reactants complete the reaction and none of it remains at the end while another reactant was also there in the reaction but some residue of it remains at the end. The reactant that finished itself during the reaction is called the limiting reactant. In a chemical reaction, the limiting reactant is determined by its amount. The amount of a limiting reactant will tell us how much of which reactant will react in the reaction, how much residue will be left and how much of which product will be produced.

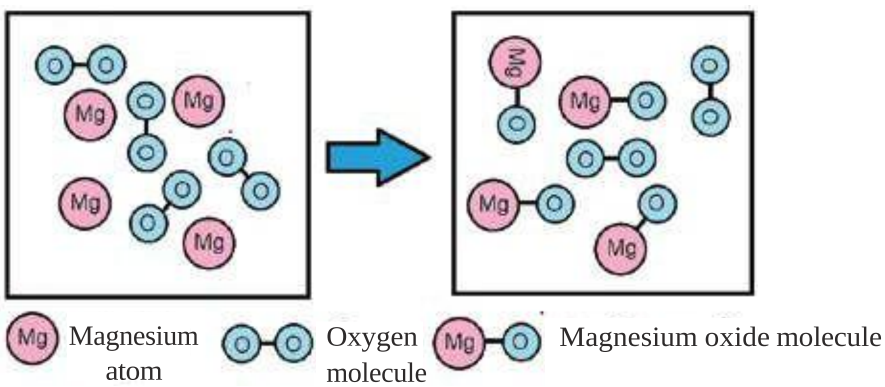


Fig 6.02: Here magnesium metal is the limiting reactant.

Example

Problem: 4 oxygen molecules are put into 4 atoms of magnesium metal. Which is the limiting reactant here?

2Mg + ——— 2Mg0

$2x6.023xl0^{23}$ no of atoms $6.023xl0^{23}$ no of molecules $2x6.023xl0^{23}$ no of molecules

Solution: The above equation tells us that, 1 0_2 molecule is necessary to react with 2 metallic atoms of Mg. So, 2 0_2 molecules are necessary to complete the reaction with the given 4 Mg atoms. That means, (4-2) = 2 molecules of oxygen will be left over when all the given magnesium atoms will finish themselves in the reaction. Here the magnesium atoms do not remain anymore at the end of the reaction. Therefore, the magnesium is the limiting reactant in this reaction.

What would have happened if 30 molecules of oxygen were mixed with 70 atoms of magnesium metal?

Since one 0_2 molecule reacts with 2 Mg atoms, 70 Mg atoms would require (70...,...2)=35 0_2 molecules to finish themselves in the reaction. But the given number of 0_2 is only 30. Therefore, oxygen will finish itself in the reaction and it is the limiting reactant here.

Problem: 75 g chlorine gas is mixed with 5 g hydrogen gas. Which is the limiting reactant here? How much of which reactant will be left over at the end of the reaction?

ZHCl

2 gram 2x35.5g = 71 gram 2 x 36.5g = 73 gram

Solution: The equation of the reaction tells:

2 gram hydrogen gas needs 71 gram chlorine in the reaction

So, 5 gram hydrogen gas needs in the reaction $\frac{71 \times 5}{2}$ = 177.5 gram chlorine

Since only 75 gram chlorine is given for the reaction, so Ch will finish itself earlier and it is the limiting reactant.

Do it Yourself

Task: Find out how much H_2 is left over in the above reaction.

6.5 Calculation of the Percentage of Yield

The reactants used in chemical reactions are not always found as 100% pure.The purest chemical substances / reactants are called Analar or Analar grade substance. Analar substances are 99% pure. The impure substances are purified through crystallization, distillation, fractional distillation, chromatography etc processes which you will learn about in higher classes.

Many a times, one or more purification process fails to yield 100% pure products. When the reactant is not 100% pure, the reaction does not yield the amount of product that was calculated from the amount of limiting reactant.

The amount of product from a chemical reaction, m percentage, can be determined following the formula below:

$$\text{Percentage of yield} = \frac{\text{Amount of Product Obtained from Reaction} \times 100}{\text{Calculated Amount of Product from Reaction}}$$

Exampie

Problem: 2 gram metallic magnesium reacts with the necessary amount of oxygen to yield 3.25 gram magnesium oxide. What is the percentage of the yield?

2Mg(s)	+	Oz(g)	---	ZMgO(s)
2 x 24 = 48 g		1 x 32 = 32 g		2 x 40 = 80 g

Solution: According to the equation:

48 gram magnesium yields 80 gram MgO

So, 2 gram magnesium yields $\frac{2 \times 80}{48}$ = 3.33 gram MgO

The actual yield after the reaction is 3.25 gram magnesium oxide.

Therefore, percentage of the yield = $\frac{3.25 \times 100}{3.33} = 97.6\%$

Do it Yourself

Task: When heat is applied to 80 grams of $CaCO_3$, it yields 39 grams of CaO. Determine the percentage of the yield. The atomic mass of Ca, C and O are 40, 12 and 16 respectively.

Experiment

Name of Experiment: Preparation of 0.1 molar sodium carbonate solution in a 250mL volumetric flask.

Principle : Sodium carbonate (Na_2C0_3) is a primary standard substance because it is found in pure and dry state, it can be directly weighed on a balance, its molar solution is long lasting. To prepare 0.1 molar sodium carbonate solution in a volumetric flask, the following calculation is necessary:

Here, V = 250mL, S = 0.1 molar, M = 23x2 + 12 + 16x3 = 106, w =?

$$w = \frac{SVM}{1000}$$

$$w = \frac{0.1 X 250 X 106}{1000} \text{ gram}$$

$$w = 2.65 \text{ gram}$$

Ifwe weigh and put 2.65 grams ofNa_2C0_3 inside a volumetric flask and fill the flask with 250mL water, the 0.1 molar sodium carbonate solution will be prepared. However, this molar solution preparation is very tough as to weigh 2.65 gram sodium carbonate is really tough. Therefore, the solution is made at a nearer molarity.

Necessary Instruments: 250mL volumetric flask, funnel, weighing bottle, chemical balance, wash bottle.

Chemicals: Pure sodium carbonate, water

Procedure

1. A funnel is inserted in the mouth of a clean 250mL volumetric flask.

2. A dry weighing bottle is weighed on the chemical balance.

3. Now, pour some sodium carbonate into the weighing bottle in a way so that the total weight of the bottle is 2.65gram higher than the previous weight.

4. Pour the sodium carbonate from the weighing bottle inside the volumetric flask through the funnel.

5. Pour the distilled water slowly from the wash bottle inside the volumetric flask. After pouring half the water, fix a cork on the mouth of the volumetric flask and shake it so that the sodium carbonate is dissolved fully into the water. Now, add the rest of the water to fill up 250 mL.

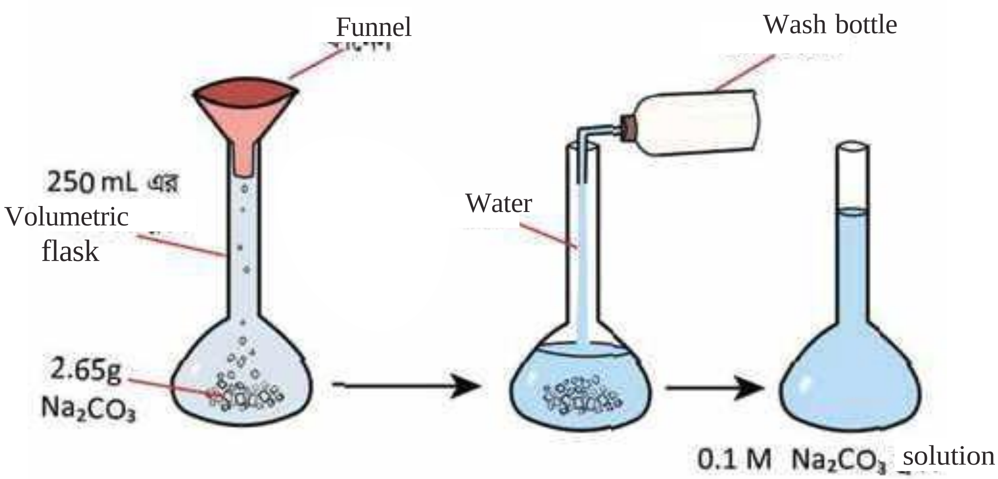


Fig 6.03: Preparation of 0.1 molar sodium carborate solution.

Caution

1. Take dry and pure sodium carbonate

2. Ensure the weighing bottle is dry

3. Add distilled water only

Task for Learners: According to your data and statistics from the above experiment, prepare a 0.1 molar sodium carbonate solution in a 250mL volumetric flask.

Experiment

Determination of percent composition of lattice water of hydrated copper sulphate.

Principle: Blue vitriol's chemical name is pentahydrate copper sulphate. Its formula is $CuSO_4.5H_2O$. Blue vitriol consists of copper sulphate and 5 molecules of water. It is a blue colored crystal lattice. There are five moles water in it. If heat is applied, that water vaporizes and its colour turns into white. These five moles of water are called crystal water.

$$CuS0_4 .5H_20 \quad ———— \quad CuS0_4 + \quad 5H_20$$

Ingredients: Copper sulphate, desiccators, chemical balance, ceramic bowl, tripod stand, net, Bunsen burner/spirit lamp

Procedure

1. Weigh the porcelain bowl on the balance. Suppose, the weight is a gram. Now take some copper sulphate in the bowl and weigh it again. Let's say, the weight now is b gram. Therefore, the mass of copper sulphate is (b-a) gram.

2. Fix the net on a tripod stand and put the bowl containing copper sulphate on it. Heat it with a Bunsen burner or spirit lamp.

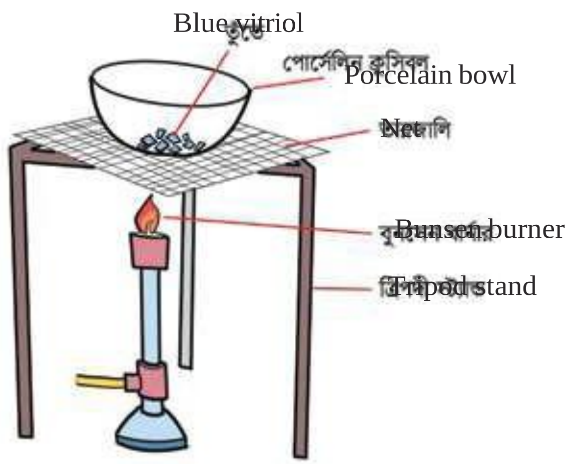


Fig 6.04: Determination of lattice water in Blue vitriol.

3. Keep marking the copper sulphate as heat is applied. The blue colour will gradually tum white. Since the water in the blue vitriol is vaporizing, it is transforming its colour.

4. When the transformation of colour is complete, stop the heating.

5. Swiftly take the bowl to the desiccators and weigh it again after cooling. If it isn't done fast, the copper sulphate will again absorb water and tum blue. Let's assume, this new weight is c.

That mean, after the vaporization of water, copper sulphate's mass is (c-a) gram. The mass of vaporized water from the blue vitriol is (b-a) - (c-a) gram. = (b-c) gram

Calculation

Mass of removed water from (b-a) gram copper sulphate= (b-c) gram

So, mass of removed water from 100 gram copper sulphate= $\frac{(b-c)}{(b-a)}$ x 100 gram

The percent composition of crystallized water in copper sulphate is $\frac{(b-c)}{(b-a)}$ x 100 %

Caution

The heating has to be slow and careful so that the heat reaches all the spots. After the removal of water, the weighing has to be quick.

Task for Learners: Carry out a task to determine the percent composition of water in copper sulphate.

Exercise

C. Multiple Choice Questions

1. What is the volume of 2 grams of hydrogen at standard conditions?

a. 2.24 liter b. 11.2 liter

c. 22.4 liter d. 44.8 liter

2. Which of the following is the formula of calcium phosphate?

a. CaP04 b. Ca(P04)2

c. Caz(P04)$_3$ d. CaiP04)2

Answer questions 3 and 4 in the light of the following stem:

5 gram hydrogen gas is passed on to 75 gram chlorine gas.

3. How many chlorine atoms are used in the reaction of the stem?

a. l.27x10^{24} b. 2.54x10^{24}

c. 6.02xl0^{23} d. 6.36x10^{23}

4. Which of the following is collected as remains **in** the reaction?

a. 1.44 mole $\mathbf{H}_2$ b. 1.44 mole Cl_2

c. 2.89 mole $\mathbf{H}_2$ d. 2,89 mole Cl_2

5. What is the volume of 17 grams of ammonia gas at standard conditions?

a. 24.2 liter b. 22.4 liter

c. 12.2 liter d. 11.4 liter

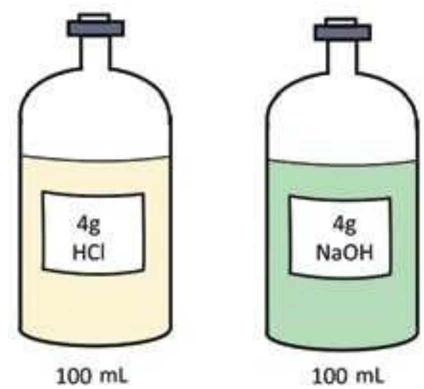
6. How many molecules are there in 10 grams of CaCO/

a. 6.02xl0^{23} b. 6.02xl0^{21}

c. 6.02xl0^{22} d. 2.58x10^{22}

Creative Questions

1.



a. What is a mole?

b. What do you understand by empirical formula and molecular formula?

c. Determine the composition of the salt that can be formed by combining the solutions shown in the stem.

d. Will the molarity of the shown solutions be the same? Give a mathematical explanation.

2. 4.4 g carbon dioxide and 5g calcium oxide are mixed to prepare 10 g $CaCO_3$.The expected yield is not met after the reaction is over.

a. What is the chemical equation?

b. Explain the molar volume of carbon dioxide.

c. Determine how many moles of carbon dioxide were used in the reaction.

d. Give a logical explanation of the lesser yield than expected in the reaction of the stem.

Chapter Seven
Chemical Reactions

We know, properties, characteristics and changes of substances are the topics discussed in chemistry. The elements in nature are constantly changing. Transformation to a different state is called a physical change while changing into a new element with new properties is called a chemical change. These changes occur due to certain physical and chemical reactions. This chapter will discuss elaborately on kinds of reactions, rates of reactions etc.

By the end of the chapter, we will be able to:

- differentiate between physical changes and chemical reactions
- identify chemical reactions by analyzing the changes in a substance
- classify the chemical reactions- redox/non-redox, reversible/ irreversible, endothermic/exothermic and detect the types of reactions
- explain the amount of products gained through chemical reactions in terms of Le Chatelier's principle
- detect the type of redox-nonredox reactions by analyzing the change
- explain many reactions taking place in various fields of real life
- find out ways to prevent or control the harmful reactions in real-life situation (like, ways of prevention of rusting on iron made materials)
- explain and compare concerned reaction rates
- examine and compare the reaction speed or rate by using various materials
- show consciousness in using metal substance in our daily life
- show the differences in the reaction rate through experiments
- demonstrate the acid-base neutralization reaction and precipitation reactions

7.1 Changes of Matter

The substances existing in nature undergo changes due to heat, pressure and contact with other substances. There are two types of changes: physical change and chemical change.

7.1.1 Physical Change

All chemical substances consist of one or more elements. Sometimes, changes occur only in physical conditions of a substance leaving their chemical structure unchanged. This is called a physical change. For example, a solid piece of ice, if kept at room temperature, absorbs heat from the environment and gradually melts into liquid water. Again, heating liquid water up to 100 °C will see the water vaporize into air. Here, the molecular formula of all three- water, ice and vapor is the same- H_20. That means each molecule of them has the same two hydrogen and one oxygen atoms in them. Therefore, all three substances are the same, only their physical states are different- ice is solid while water is liquid and vapor is gaseous. This kind of change is called a physical change.

$$\underset{\text{(solid)}}{\text{ice}} \; \underset{\substack{\text{cold}\\ \text{(-heat)}}}{\overset{\text{+heat}}{\rightleftharpoons}} \; \underset{\text{(liquid)}}{\text{water}} \; \underset{\substack{\text{cold}\\ \text{(-heat)}}}{\overset{\text{+heat}}{\rightleftharpoons}} \; \text{gas}$$

7.1.2 Chemical Change

Sometimes, due to the change of external temperature or pressure and contact with some other substance, some substances change completely into newer substances with newer percent composition of the existing elements. This kind of change is called a chemical change. That means, the kind of change that forms newer substances with newer set of properties is called a chemical change. The new substance formed through chemical change gets the same molecules that were there in the original elements. Isolated ions or atoms are formed out of the dissociation in the bond of the previous element. These isolated ions or atoms later constitute new bonds among themselves and create new molecules. As a result, chemical change also implies dissociation of old bonding and formation of new bonding too. The gas we use for cooking basically consists of methane (CH_4). When methane gas is burnt in oxygen, carbon dioxide, water vapor and heat energy is produced. This is a chemical change.

$$CH_4(g) + O_2(g) \longrightarrow CO_2(g) + H_2O(l)$$

Similarly, calcium carbonate reacts with hydrochloric acid and produces calcium chloride, carbon dioxide and water. This is also a chemical change.

$$CaC0_3\ (s) + 2HC1\ (aq) \longrightarrow CaCl_2\ (aq) + CO_2\ (g) + H_2O\ (l)$$

7.2 Classification of Chemical Reactions

We can classify the chemical reactions on the basis of following way:

7.2.1 Direction of Reaction

According to direction of reaction, chemical reactions are of two kinds: Irreversible reactions and Reversible reactions.

Irreversible Reactions

In irreversible reactions, only the reactants convert to products. Products cannot be converted to reactants by a reaction if any one of the products from the reaction is removed from the reaction medium. For example, calcium carbonate, when heated in a container breaks into solid limestone and gaseous carbon dioxide. If the carbon dioxide gas is removed from the container, then too, the limestone will not convert back to calcium carbonate. Thus, it is an irreversible reaction. Irreversible reactions are written in equations with a right faced arrow (----+) mark in the midst of reactants and products.

$$CaC0_3\ (s) \xrightarrow{\text{heat}} Cao\ (s) + COig)$$

Reversible Reactions

In a reversible reaction, the reactants react and convert to products and the products react again and revert to reactants. In reversible reactions, two reactions continue simultaneously. In one reaction, the reactants react and produce the product, which is called a forward reaction. In the other one, the products react again and convert to the reactant, which is called a backward reaction. Reversible reactions are written in the equation with double headed half arrow marks in the midst of reactants and products. For example, ethanol and ethanoic acid react in the presence of hydrochloric acid and produce ethyl ethanoate ester and water. Conversely, ethyl ethanoate ester and water react with each other and produce ethanol and ethanoic acid. In an equation, it can be shown as,

$$\underset{\text{Ethanol}}{C2H_50H} + \underset{\text{Ethanoic acid}}{CH_3COOH} \xrightleftharpoons{HCl} \underset{\text{Ethyl ethanoate ester}}{CH_3COOC2H_5} + \underset{\text{Water}}{H20}$$

Similarly, hydrogen and iodine react and produce hydrogen iodide as a product and this product again converts into hydrogen and iodine. This is also a reversible reaction.

$$H_2 + I_2 \qquad 2HI$$

Indeed, all reactions are reversible reactions, but m some reactions, the backward reaction is of so slow rate, that they appear to be irreversible reactions.

7.2.2 Heat Change and Reactions

You have already learned that heat change is a factor in chemical reactions. According to absorption of heat and generation of heat, reactions are classified into two categories: exothermic reactions and endothermic reactions.

Exothermic Reactions

When heat evolves at the time of producing the products from the reactants, the reaction is called an exothermic reaction. For example, 1 mole nitrogen and 3 moles hydrogen in the Heber process produce 2 mole ammonia and 92 kilojoules of heat. The reaction is:

$$+ \quad 3H_2\,(g) \xrightleftharpoons[\substack{200\text{-}250\ \text{atm} \\ 450°(\text{-}550°(}]{Fe} 2NH_3\,(g) + 92\ kJ$$

Here, ground Fe acts as the catalyst. According to the balanced equation, the heat change during a reaction is called reaction heat. It is denoted by H. If heat is evolved during a reaction, its value is negative.

$$+ \quad 3H_2\ (g) \quad \xrightarrow[\substack{200\text{-}250\ \text{atm} \\ 450°(\text{-}550°(}]{Fe} \quad 2NH_3\ (g) \qquad H = -92\ kJ$$

Endothermic Reactions

When heat is absorbed at the time of producing the products from the reactants, the reaction is called an endothermic reaction. 1 mole nitrogen and **1** mole oxygen react and produce 2 moles nitric oxide. When they do so, they absorb 180 kJ heat. This is an endothermic reaction.

$$Nz(g) + Oz(g) + 180\ kJ \longrightarrow 2NO(g)$$

Here also, we can use the symbol of heat H. In endothermic reactions, the value of absorbed heat is positive.

$$N_2(g) + O_2(g) \longrightarrow 2NO(g) \qquad H = +180\ kJ$$

7.2.3 Electron Transfer

Depending on electron transfer, reactions can be divided into two types: redox reactions and non redox reactions.

Redox Reactions

The term Redox combines the initial part of Reduction, Red and the initial part of Oxidation, Ox. It means oxidation-reduction. In redox reactions, there occurs an electron transfer in the reaction. A reactant donates an electron and the other reactant receives that electron. That means, a redox reaction is divided in two parts. In one part, the donation of the electron takes place which is called oxidation half reaction. In the other half, the other reactant accepts the donated electron, which is called the reduction half reaction. The reactant which donates the electron in such a reaction is called reductant and the one which accepts the electron is called oxidant.

$$Na + \frac{1}{2} Cl_2 \longrightarrow NaCl$$

Here, Na is donating an electron as it is a reductant substance and conversely, Cl is accepting that electron as it is an oxidant substance.

The reaction in which electron donation of an atom occurs or positive charge of that atom increases or negative charge of that decreases is called an oxidation reaction.

$fe^{2+} \quad fe^{3+} + e^-$ [oxidation reaction]

$Na^0 \quad Na^{1+} + e^-$ [oxidation reaction]

The reaction in which an atom accepts an electron or the positive charge of an atom decreases or the negative charge of an atom increases is called an reduction reaction.

$cl^0 + e^- \quad cP^-$ [reduction reaction]

$cu^{2+} + e^- \quad Cu^{1+}$ [reduction reaction]

Oxidation Number: Atoms in molecules or radicals sometimes tend to donate electrons and sometimes tend to accept electrons. The tendency to donate an electron of an atom is denoted by a number added with a plus (+) mark and the tendency to accept an electron of an atom is denoted by a number added with a minus (-) mark. In any molecule or radical, this number with plus or minus mark is the oxidation number.

The oxidation number of neutral atoms like Na, Mg, Fe etc. are taken to be zero (0). Similarly, atoms in molecules that consist ofhomogenous atoms like H_2, 0_2, N_2, Cl_2, Br_2 etc. are regarded to have oxidation number of zero.

The oxidation number of Fe in $FeSO_4$ is +2 while the oxidation number of the same atom in Fe metal is 0.

Determining Oxidation Number: In a compound the oxidation number of an element depends on the oxidation numbers of other elements of the compound. To determine the oxidation number of an element in a compound, standard oxidation numbers of other elements is used.

Table 7.01: Oxidation Number of Atoms in Different Compounds.

Rule of Oxidation Number	Formula of Compound	Element and Oxidation Number
Oxidation number of metals is positive and oxidation number of nonmetals is negative	Nacl	Na= +1 Cl = -1
Oxidation number of a neutral or free element is zero	Fe, H_2	Fe= 0 H=O
Total oxidation number of atoms of a neutral compound is zero	H^20	H = +1 0 = -2 cm'i, = 0
Total Oxidation number of atoms of a charged ion is equal to their charge	SO_4^{-2}, $\overset{+}{N}H_4$	so/-= -2 NH/= +1
Oxidation number of alkali metals is +1	KCl, K2C03	K = +1
Oxidation number of alkaline earth metals is +2	Cao, MgS04	Ca= +2 Mg= +2
Oxidation number of halogen in metal halide is -1	$MgC1_2$, LiCl	Cl = -1
In most compounds, Oxidation number of hydrogen is +1 but Oxidation number of hydrogen in metal hydride is -1	NH_3, $LiAlH_4$	H = +1 H = -1
In most compounds (oxides), Oxidation number of oxygen is -2 but Oxidation number of oxygen in peroxide is -1 and Oxidation number of oxygen in superoxide is -1/2 (i.e.- 0.5)	K_20, Cao K_202, H_202 Na02· K02	0 = -2 0 = -1 0 =- 2

1. Let us suppose the oxidation number of the atom in a compound or ion that is to be determined is x.

2. Oxidation numbers of all elements in the compound or ion are to be multiplied with their respective number of atoms and then their total is to be found.

3. In the case of molecules, the total will be zero (0) and in the case with ions, it will be equal to its number of charges added with the marks. For example, we need to determine the oxidation number of central atom Mn in $KMnO_4$. Suppose, the oxidation number of Mn is x, oxidation number of K is +1 and 0 is -2. The total in the formula presented above will be equal to the oxidation

number of$KMnO_4$. $KMnO_4$is a charge neutral molecule, therefore, its charge is 0. So,

$$(+1)x1 + xx1 + (-2)x4 = 0$$

$$\text{Or, } x = 7$$

The oxidation number of Mn is +7.

4. Apart from metal hydride (like LiH, LiAlH4) the oxidation number of hydrogen is generally +1. Apart from the exceptions mentioned in table 7.01, the oxidation number of oxygen is -2.

Determining the oxidation number of S in H_2SO_4

Suppose, the oxidation number of S = x

Therefore, (+l)x2 + x + (-2)x4 =0

Or, x = 6

The oxidation number of S in H_2SO_4 is +6

Do it Yourself

Find out the oxidation number of the elements written in red colour among the following compounds: $CuSO_4$, HNO HlO_4 , MnO KCrO NaSO Cul.

Given: Oxidation numbers of Cu= +2, 0 = -2, H = +1, K = +1, Na= +1, I= -1.

Oxidation number and valency are not the same. Oxidation number is the number of charges in an atom or ion along with its sign. It may be positive or negative, integer or fraction. The oxidation number of an element may vary in different compounds. On the other hand, valency is the capacity of an element to bond with other elements. It is always an integer and is never positive or negative. Only, in the case of inert gases, the valency is zero.

Oxidation-reduction is a simultaneous process: You already know what is oxidation and what is reduction and what is an oxidant and what is a reductant. Oxidation-reduction reactions takes place simultaneously. Let us consider the reaction below:

$$Na + \frac{1}{2} Cl_2 \longrightarrow NaCl$$

Here, the reduction agent Na has donated one electron from its outermost shell to complete the oxidation half reaction. The oxidant Cl
has accepted that electron and completed the reduction half reaction.

Oxidation half reaction $Na^0 \quad Na^+ + e^-$

Reduction half reaction $cl^0 + e^- \quad cl^-$

If we add these two half reactions, we get the oxidation-reduction reaction.

$$Na^0 + Cl^0 \quad Na^+ + cl^- = NaCl$$

It is clear here that the reduction agent has donated the electron to the oxidation agent. If oxidation agent Cl wouldn't accept the electron, the reduction agent Na would not have been able to donate the electron. So, it can be said, oxidation and reduction will occur together. They are simultaneous processes.

Since the reductant donates an electron and the oxidant accepts that electron, therefore, oxidation-reduction is actually the transfer of electrons.

There are some reactions where oxidation-reduction occurs. They are:

1. Addition Reaction

2. Decomposition Reaction

3. Substitution or Displacement

Reaction 4.Combustion Reaction

1. Addition Reaction: A reaction in which a new compound is formed by combination of two or more elements or molecules is called an addition reaction. For example, chlorine adds with ferrous chloride and produces ferric chloride:

2FeClz{aq) + Clz(g) ———— FeCliaq)

Similarly, hydrogen gas combines with nitrogen gas and forms ammonia gas:

$$N_2 + 3H_2 \longrightarrow$$

However, the addition reaction where two or more elements combine together to form a new compound is called synthesis. According to this definition, the reaction for ammonia gas is also a synthesis.

2. Decomposition Reaction: The process in which a compound breaks into one or more elements or molecules is called a decomposition reaction. For example, when heat is applied on phosphorus pentachloride, it decomposes into phosphorus trichloride and chlorine.

$$PC1_5 \xrightarrow{\text{heat}} \qquad +$$

Similarly, one water molecule decomposes to produce two different molecules on electrolysis. Hydrogen and oxygen are produced in cathode and anode.

$$2H_20\,(l) \xrightarrow{\textit{electrolysis}} 2H_2\,(g) + O_2\,(g)$$

3. Substitution or Displacement Reaction: The process in which an element or radical displaces another element or radical from a compound and takes its place is called a substitution reaction. For example, zinc metal displaces hydrogen from sulfuric acid to form zinc sulfate and hydrogen gas:

Zn(s) + $H_2SO_4(l)$ ———— ZnSOiaq) + Hz(g)
zinc sulfate

4. Combustion Reaction: The process in which any compound or element is burnt in the presence of atmospheric oxygen and converts to oxides of its elements is called a combustion reaction. Usually heat is evolved in combustion reactions. This process also involves electron exchange. For example, natural gas or methane reacts with oxygen of air and produces carbon dioxide and water.

Fig 7.01: combustion of fuel.

$CH_4(g) + 2O_2(g) \longrightarrow$ CO2 (g) + 2H20(g) + Heat

Similarly, S, C, Mg and H_2 produce their oxides and heat evolves when they are burnt.

S(s) + 0z(g) ——— soz(g) + Heat
C(s) + 0z(g) ——— coz(g) + Heat
2Mg(s) + oz(g) ——— 2Mg0(g) + Heat
2Hz(g) + oz(g) ——— 2H20(g) + Heat

In all combustion reactions, oxygen accepts an electron donated by the other element or compound. Therefore, this kind of a reaction belongs to the oxidation-reduction type.

Non Redox

There are some reactions where electron exchange does not occur. These reactions are called non-redox reactions. In this kind of reaction, there is no involvement of increase or decrease of oxidation number of any reactant because there is no electron exchange. Some of these kinds of reactions are discussed below: (1) Neutralization reaction (2) precipitation reaction etc.

1. Neutralization Reaction: An acid and a base react with each other and neutralize into salt and water, in some reactions, which are known as neutralization reactions. They are also known as acid-base reactions. NaOH and HCl, for example neutralize each other and convert to NaCl salt and water:

HCl(aq) + Na0H(aq) ————→ NaCl(aq) + H20(1)

Heat always evolves from neutralization reactions. That is to say, neutralization reactions are exothermic. When both the acid and base are strong, the evolved heat amounts to H = -57.34kJ. In this kind of a reaction, the acid provides the hydrogen ion (H+) while the base provides the hydroxide ion (OH} These two ions then react and produce water. In NaCl solution, sodium ion is Na+ and chlorine ion is CL

$$H^+ + Cl^- + Na^+ + OH^- \longrightarrow Na^+ + Cl^- + H_2O$$

In this solution, the two ions Na+,Cl- do not participate in the reaction. They are called spectator ions. The actual equation of a neutralization reaction is:

$$H^+ + OH^- \longrightarrow H_20 + 57.34 \text{ kJ}$$

Finally, neutralization reaction is the water producing reaction by means of H+ and OH- ions. Whatever the strength of both the acid and the base we take in this kind of reaction they will provide the same ions and produce water. The amount of heat that evolves to produce I mole water is called neutralization heat. Calculation tells us that it evolves 57.34 kJ heat.

Experiment

Demonstration of the Neutralization Reaction.

Take 10 mL NaOH solution in a beaker. Take HCl solution in another beaker. Dip a blue litmus paper in the solution. Now use your left hand to pour HCl solution with a dropper in the NaOH solution. Simultaneously use a glass tube in your right hand to stir and mix the solutions. The moment the blue litmus paper turns red, you will understand HCl has neutralized the NaOH solution.

$$HCl(aq) + NaOH(aq) \longrightarrow NaCl(aq) + H20(l)$$

2. Precipitation Reaction: When two soluble compounds are mixed in a certain solvent and if any new compound is produced that is insoluble or sparsely soluble in that solvent, the compound settles at the bottom of the container as a solid. This new solid compound at the bottom is called the precipitate. The reaction in which the produced compound settles at the bottom of the container as precipitate is called the precipitation reaction. For example, when silver nitrate ($AgNO_{3}$) solution is mixed with sodium chloride (NaCl) solution, they react to produce silver chloride and sodium nitrate. $NaNO_3$ is highly soluble in water, so it remains dissolved in the solution. But since solubility of AgCl is sparse, it settles at the bottom as precipitate:

NaCl(aq) + AgNOiaq) ——— AgCl(s)t + NaNOiaq)

When you add barium chloride (BaCl) solution with sodium sulfate (Na_2SO_4) solution, they produce barium sulfate ($BaSO_4$) and sodium chloride (NaCl). Barium sulfate is precipitated.

$Na_2SO_4(aq)$ + $BaCl_2(aq)$ ——— BaSOis)t + 2NaCl(aq)

However, there are some precipitation reactions in which there occurs an electron exchange. You will know about them in higher classes.

Experiment

Demonstration of a Precipitation Reaction.

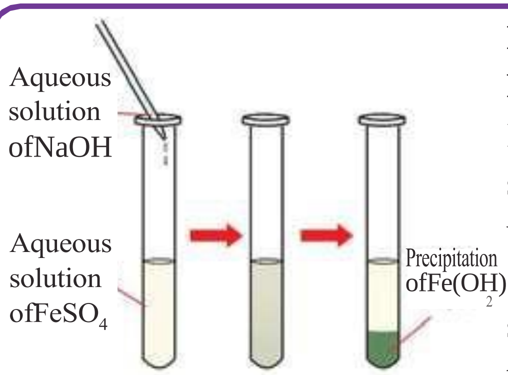


Fig 7.02: Precipitation Reaction.

In a test tube, take 2-3 mL ferrous sulfate solution and add NaOH solution with that in drops. You will see a green prec1p1tate 1s formmg gradually and settling at the bottom of the tube.The two chemical compounds are forming solid $Fe(OH)_2$ precipitate here:

FeS0₄ + NaOH ——— $Fe(OH)_2 \downarrow$ + Na_2SO_4

The precipitate compound is denoted by a bottom-faced arrow mark (t)at its right.

7.3 Special Types of Chemical Reactions

There are some chemical reactions which do not fall in the redox and non-redox classifications. Some of them are discussed below:

Hydrolysis Reactions: The chemical reactions, in which water as a reactant reacts with other compounds and produces some new compounds is called hydrolysis. Example:

$$SiCl_4 + H_2O \longrightarrow Si(OH)_4 + 4HC1$$

Here, $SiC1_4$ and H_20 are participating in a reaction so it is a hydrolysis reaction. This kind of reaction sometimes produces non-transparent soluble compounds. In that case, the reaction may be considered as a precipitation reaction. The following reaction can be classified as both a hydrolysis reaction and a precipitation reaction:

$$AlClis) + 3H_20(1) \longrightarrow Al(OHMs) + 3HC1(aq)$$

Here, $Al(OH)_3$ is non-soluble in water.

Hydration Reaction: One or more molecules of water combine with ionic compounds during formation of a crystal lattice. This kind of reaction is called a hydration reaction. Water molecules that combine with ionic compounds is called lattice water or hydrated water. For example, 5 moles water ($5H_20$) combines with copper sulfate ($CuS0_4$) and produces pentahydrate copper sulfate ($CuS0_4.5H_20$).

$$CuSO_4 + 5H_2O \longrightarrow CuS0_4.5H_20$$

Penta hydrated copper sulfate

There are many such reactions:

$ZnSO_4 + 7H_2O \longrightarrow ZnS0_4.7HzO$
Heptahydrate Zinc Sulfate

$FeSO_4 + 7H_2O \longrightarrow FeS0_4.7H_20$
Heptahydrate Ferrous Sulfate

$CaCl_2 + 6H_2O \longrightarrow CaC1_2.6H_20$
Hexahydrate Calcium Chloride

$MgCl_2 + 7H_2O \longrightarrow MgC1_2.7H_20$
Heptahydrate Magnesium Chloride

A hydration reaction is basically similar to an addition reaction. However, in addition reactions, there is electron exchange while in hydration, there is none.

Isomerization Reaction: Two compounds with similar molecular formula but with different properties are called isomers of each other. A chemical reaction in which atoms in a molecule rearrange themselves to form one isomer from another isomer is called isomerization. For example, H_4N_2CO molecular formula denotes two compounds with varied structural formula: NH_4CNO (ammonium cyanate) and urea (H_2N-CO-NHJ. They are isomers of each other. When heat is applied to ammonium cyanate, it produces urea.

$$NH_4CNO \xrightarrow{\text{Heat}} H_2N\text{-}CO\text{-}NH_2$$

Polymerization Reaction: A large number of molecules of the same compound combine together to form a large molecule of heavy atomic mass, at high temperature and pressure and in the presence of a catalyst. This reaction is called polymerization. In such cases, the large molecule is called a polymer and each of the smaller molecules that combine together are called monomers. Under the effect of 1200 atm. pressure, 200°C temperature and O_2 catalyst, numerous smaller molecules of ethylene combine into a large polymer molecule of polythene. This reaction is polymerization reaction of ethylene. Here, ethylene molecules are the monomers while polythene molecule is the polymer. In the equation, n denotes the number of molecules.

$$n(CH2{=}CH2) \xrightarrow[200°C,\ 1200\ atm]{} (\text{-}CH_2\text{-}CH_2\text{-})_n$$

7.4 Examples of a Few Real Life Chemical Reactions

7.4.1 Chemical Reactions in Reality

We observe many happenings around us everyday which are caused by chemical reactions. Examples:

1. Rust on Iron: We use various instruments made of iron everyday like knife, scissors, machete etc. Ifwe keep them exposed in open air, they undergo rusting. Here, iron undergoes reaction with oxygen and water vapor and produces ferric oxide. Since rust is fragile in nature, oxygen and water vapor from air pass through it and continue to corrode the iron. Thus the whole object made of iron is ruined.

$$2Fe + 1.5O_2 + 3H_2O \longrightarrow 2Fe(OH)_3$$

$$2Fe(OH)_3 \longrightarrow \underset{\text{Rust}}{Fe_2O_3.nH_2O}$$

The number of moles of water in rust is not fixed. That is why, the formula of rust is $Fe_2O_3.nH_2O$ Here, the value of n can be **1**, 2, 3, 4 .... etc. integers.

2. Prevention of Corrosion of Copper and Aluminum: We also use copper-aluminum products in our day to day life. When products made of Cu and Al come in touch with open air, they produce a layer of CuO and Al_2O_3. This layer acts to prevent the air to come in direct contact with Cu and Al and no more reaction takes place. Thus the decay of Cu and Al is prevented.

3. Relief from the bite of ants and Bee: When ants or bees bite us, we feel pain at the spot of the bite. We use lime on that spot to get relief from the pain. The ant in its mouth or the bee in its sting carries an acid which is the cause of our pain. The lime (base) reacts with that acid and neutralizes it. As a result, we are relieved of the pain.

4. Energy Produced through Respiration: Respiration occurs in every cell of our body. In respiration, basically, the glucose ($C_6H_{12}0_6$) molecule is oxidized by 0_2 and in the process CO_2, H_20 and energy is produced.

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6C0_2 + 6H20 + \text{Entergy}$$

The digestion system in the human body forms excess HCl in many of us. To neutralize this acid, many doctors prescribe an antacid type medicine. Antacid is a mixture of $Mg(OH)_2$ and Al(OH\. These two bases neutralize excess HCl and the patient feels relieved. The equation of the reaction is:

$$2HC1 + Mg(OH)_2 \longrightarrow MgC1_2 + 2H20$$

$$3HC1 + Al(OHh \longrightarrow A1Cl_3 + 3H_20$$

5. Natural Gas as Fuel: Natural gas is used as fuel. Maximum percentage of natural gas is composed of methane. When this methane gas is burnt in oxygen, it produces CO_2, H_20 and heat. When we bum CNG, diesel, petrol, kerosene and octane, they produce the same products.

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H20 + \text{Entergy}$$

7.4.2 Ways of Prevention of Some Harmful Reactions

Many products around us are continuously being decayed or eroded due to some chemical reactions. We can make use of our knowledge of chemistry to prevent such decaying and save many of them.

(i) To prevent corrosion of rust on iron, one can paint the outside of the iron products so that it does not come in contact with air. A coating of a comparatively less active metal on iron through electrolysis, which is called electroplating, can also save iron from rusting. The process which lays a coating of zinc on other metals is called galvanizing and the process of tin plating lays a tin coating.The process which lays a coating of a metal on other metals through electrolysis is called electroplating. This way we can save metals from corrosion.

(ii) The roofs and yards of our houses become slippery during the rainy season. We spread sand on those slippery spots. The slippery substance is alkaline. Therefore, it requires some acidic substance to be neutralized. Sand (SiOJ is acidic. This sand neutralizes the alkaline there.

(iii) Sewing needles are kept in coconut oil. The reason is to prevent it from any reaction with oxygen and water vapor of air and get corroded.

7.5 Rate of Reaction

We know, in any reaction, reactants convert to products. Some reactions take less than 1 second while, some take quite a lot of time.

The amount of products produced from reactants per unit time is called the rate of reaction.

Fig 7.03: Reactions with Different Rates, Rust on iron, combustion of candle, Explosion of bomb.

For example, when $AgN0_3$ is added to the NaCl solution, it takes less than 1 second to create the white precipitate of AgCl. On the other hand, it takes years for a bridge to rust. Reactions that take less time have a higher rate of reaction and reactions that take more time have a lower rate of reaction.

Investigation

Experiment on Rate of Reaction

Take four test tubes and mark them 1, 2, 3, 4. Take an approximate amount of0.5 mg sodium carbonate (Na_2CO_3) or washing soda in each of them. Then add normal water to tube 1 and 2 and hot water to 3 and 4. Now add 1 mL lemon juice (citric acid) or vinegar (4-10% acetic acid) to tube number 2 and 4. Observe the following changes:

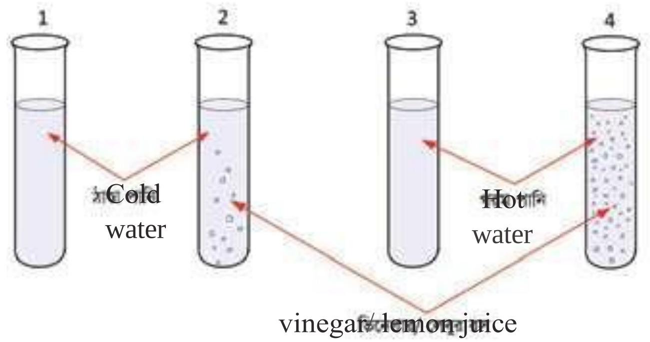


Fig 7.04: Reaction between sodium carbonate and acetic acid or vinegar.

1. Which of the test tubes produces gas bubbles?
2. Which of the test tubes does not produce gas bubbles?
3. Which test tube produces the maximum number of gas bubbles?
4. Which test tube produces the minimum number of gas bubbles?

Think: Why does gas come out in a larger amount from one of the tubes of number 2 and 4?

The above experiment tells you all test tubes do not give the same amount of product at a certain time

7.5.1 Le Chatelier's Principle

In some reactions products react and turn into reactants again. When the reactants react and produced a new substance that is called a forward reaction. When the products again react and revert back to reactants they are called backward reactions. At the start of the reaction, the forward reaction has a higher rate. It decreases gradually with the progress of time. Again, at the start, the rate of the backward reaction remains slow but it increases gradually with the progress of time. At a stage, both the rates become equal. This state is known as equilibrium of the reversible reaction.

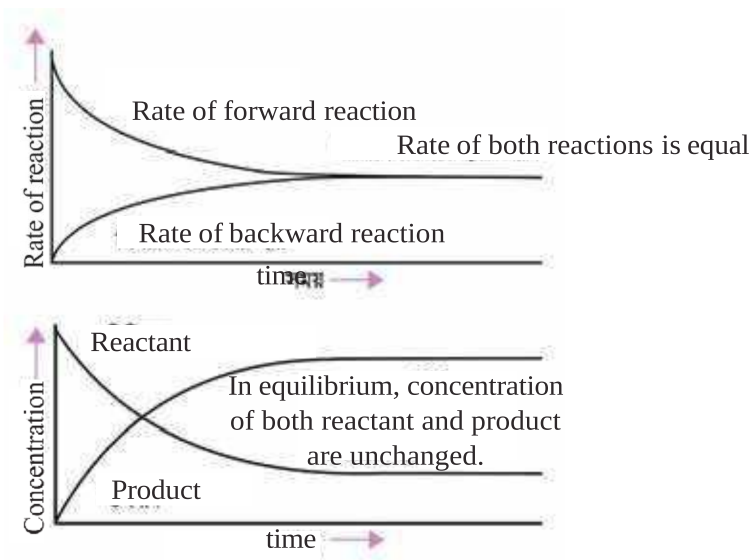


Fig 7.05: Chemical equilibrium.

Both forward and backward reactions continue in equilibrium, the amount of reactants that have already turned into products in the forward reaction, are equal to the reactants that have been produced in the backward reaction at this state. Therefore, it appears that the reaction has stopped but in reality it has not. However, in equilibrium, if we change the parameters of the reaction such as temperature, pressure and concentration etc. the equilibrium also changes. Increase and decrease of products in equilibrium of a reversible reaction is controlled by the Le Chatelier's principle. The principle is:

At the equilibrium of reversible reactions, if any of the factors (temperature, pressure and concentration of reactant) is changed, the equilibrium position will shift in such a way that the effect of factor is neutralized.

Explanation of Le Chatelier's Principle:

The effect of temperature, pressure and concentration of reactants in equilibrium can be explained by the Le Chatelier's principle.

Effect of Heat

Let us consider a reversible reaction:

$$N_2 + 3H_2 \rightleftharpoons 2NH_3 + 92 \text{ kJ}$$

The forward part of this reaction is exothermic; when reactants N_2 and H_2 react to produce NH_3, they also evolve heat. Conversely in the backward part, when NH_3 converts to N_2 and H_2, it absorbs heat. Therefore, heat is required to be applied. Now we shall see according to Le Chatellier's principle, what will happen as we apply heat to this reversible reaction. According to the principle, if heat is applied, the effect due to that heat has to be neutralized. Application of heat will increase the forward reaction, increasing production of heat and that will not neutralize the heat. If the reverse reaction is increased, that will absorb more heat and neutralize the excess heat. Therefore, according to Le Chatelier's principle, we can say that, if heat is increased, the reverse reaction will also increase. In other words, the effect of application of heat in exothermic reactions will drive the equilibrium state to the left side, meaning, NH_3 converts into N_2 and H_2.

In the same way, we can say, decrease of temperature in equilibrium will increase the exothermic forward reaction and neutralize the effect of lesser heat.

The equilibrium will shift from left to right. Reactions that are not affected by temperature will not have any effect on its equilibrium too.

Let us consider another reaction:

$$Nz + 0_2 + 180\ kJ \rightleftharpoons 2NO$$

Application of heat to this reaction will mcrease the forward endothermic reaction or the equilibrium will shift left to right; N_2 and 0_2 will react and produce NO. In equilibrium, if heat is decreased, the reverse exothermic reaction will increase reversing the equilibrium right to left; NO will convert into N_2 and 02.

Effect of Pressure

In equilibrium of gaseous reactions, equilibrium of the reaction will change with the change of pressure. In equilibrium, change of the total number of moles of reactants and of products will create effect of pressure. Example:

$$Nz(g) + 3Hz(g) \rightleftharpoons 2NH_3\ (g)$$

According to Le Chatelier, if pressure is applied, the effect of increased pressure has to be neutralized. In the same volume, the gas with the greater number of moles has the greater pressure and the gas with the smaller number of moles has smaller amount of pressure. In the above reversible reaction, the gaseous product has the greater number of moles (1+3 = 4) whereas the right side has the smaller number (2). So, to neutralize the effect of increased pressure, the gaseous substance has to shift from larger number to smaller number. The forward reaction will increase and N_2 and H_2 will produce NH_3. In other words, the equilibrium will shift from greater moles to smaller moles. So, if pressure is decreased at equilibrium, according to the principle, to neutralize the effect of decreased pressure, the equilibrium state will shift toward greater moles from smaller moles.

We can consider another reversible reaction:

$$N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$$

In this reaction, mole number of reactants is (1+1) = 2 and mole number of product is also 2. Since this reaction has no change in the number of moles, there is no change in pressure too. The reaction does not show any effect of pressure on its equilibrium.

Effect of Concentration

Equilibrium of all reactions are effected by the concentration of reactants. If in the equilibrium state of the reaction, the concentration of any reactant is increased, Le Chatelier says the concentration of the reactantant has to be decreased in order to neutralize the effect of increased concentration. Similarly, if the concentration of any product is increased, the amount of product is neutralized as the reaction reverts and the concentration of reactants is increased. That means, the equilibrium shifts toward left.

Exercise

Multiple Choice Questions

1. Which of the following acids is present in vinegar?
   a. citric acid　　b. acetic acid
   c. tartaric acid　　d. ascorbic acid

2. Which can be used in the wound of bee stinging?
   a. lime　　b. vinegar
   c. table salt　　d. water

3. What type of reactions occur when antacid medicine is taken?
   a. neutralization　　b. combustion
   c. addition　　d. substitution/displacement

4. In the reaction $H_2S0_4 + MgO$ ________

i. heat is produced

ii. electron transition occurs

iii. precipitation occurs

Which is correct?

a. 1 b. ii and iii

c. i and iii d. i, ii and iii

5. The reaction $2FeC1_2 + Cl_2$ $2FeC1_3$

i. Isomerization reaction

ii. redox reaction

iii. addition reaction

Which is correct?

a.i and ii b.i and iii

c. ii and iii d.i, ii and iii

6. What is the oxidation number of Sulfur in H_2SO_4?

a. +2 b. +4

c. +6 d.+8

Creative Questions

I .Both Opu and Setu use natural gas for cooking. Although there are black shades at the bottom of pans in Opu's house, there is none on the pans at Setu's house.

a. What is irreversible reaction?

b. What is meant by chemical equilibrium?

c. What type of reactions occur during cooking in their houses? Explain.

d. In your opinion, in which of the houses of the stem, gas is wasted during cooking? Give reasons for your opinion.

2. $Pb(N0_3)_2$ + 2KI ——————

The table below is filled up in the light of the above reaction [K= 39, I= 127]:

Element	Container 1	Container 2	Container 3	Container 4	Total **Volume** used (mL)	Precipitation
Volume of 0.2 M $Pb(N0_3)_2$ (mL)	1	2	3	4	10	Yellow
Volume of water (mL)	4	3	2	1	10	
olume of 0.5 M KI (mL	1	1	1	1	4	
Total volume of solution of each container	6	6	6	6		

a. What is an exothermic reaction?

b. Why aren't periodic number and valency the same? Discuss

c. What is the total amount of KI used in the period? Determine.

d. Which container will contain more yellow solution? Explain with reasons.

3.

$$Na + \frac{1}{2} Cl_2 \longrightarrow NaCl$$

$$Zn + H_2S0_4 \longrightarrow ZnSO_4 + H_2$$

a. What is an isomerization reaction?

b. What do you understand by a reversible reaction?

c. Determine the oxidation number of sulfur in the product substance of the 2nd reaction.

d. In the first reaction of the stem, redox- occurs simultaneously. Analyze.

Chapter Eight

Chemistry and Energy

In Chapter 7, we saw that most reactions release heat. For example, we cook, drive vehicles by burning wood, coal, natural gas. That is, heat is released in this case. The question is, where does this heat come from? Every chemical substance contains a type of energy that transforms into heat energy during reactions. This inherent energy of matter is called chemical energy. How does this energy prevail in the substances? The battery produces electi1c·1ty which lights up the torch. Burning mineral oil produces heat which is then converted to electricity. Many countries are using the atomic energy to produce electricity. Chemistry or chemical reaction or nuclear reaction is involved in all these. However, these reactions also have some adverse effects on us too.This chapter will discuss all these things.

By the end of the chapter we will be able to-

- explain the relation of producing energy with chemical changes.
- realize the importance of purity of fuel in energy production; limit the consumption of these fuel for saving the environment and show consciousness in selection of appropriate fuels.
- find out chemical reactions related problems and prepare an investigation plan, implementation and test its effectiveness keeping the safety measures in mind.
- take decision responsibly and spontaneously with confidence in performing chemical reactions and in producing energy.
- explain the idea of direct current using the electronic concept of oxidation-reduction reactions.
- describe the process of producing electricity by chemical reactions.
- carry out the reactions using electricity.
- present an opinion on the products of electrolysis of different substances and their commercial use.
- construct the electrodes of galvanic cells.
- differentiate between an electrolytic cell and a galvanic cell.
- explain the application of an electrochemical cell.
- give an opinion on nuclear electricity production after a relative analysis.
- carry out experiments of exothermic and endothermic reactions.
- show consciousness on the worse effects of chemical reactions.
- show interest on using pure fuel.
- show the change of heat on dissolving salts during chemical changes through experiments.

8.1 Chemical Energy

8.1.1 Source of Chemical Energy

Matter has molecules and atoms. An atom remains connected to another atom because of attraction energy (bond). The energy by which atoms are connected to each other is called chemical energy.

Bond Energy

In a chemical bond, the energy by which an atom remains joined with another atom is called bond energy. In sodium chloride, there is an ionic bond between a sodium ion and a chloride ion. There is a covalent bond between carbon and oxygen in carbon dioxide. In iron, one atom is bonded with another due to a metallic bond. The energy that acts here in these cases to maintain the bonds is the bond energy.

Inter Molecular Energy

In a covalent compound, the energy that keeps the molecules combined with each other is called the inter molecular energy. For example, water is a covalent compound. Inter molecular energy combines the molecules of surrounding water with a molecule of water. On the other hand, in the ionic compound sodium chloride, 06 chloride ions surround a sodium ion. There is energy active in between them. Again, each chloride ion is surrounded by 06 sodium ions. They are also combined due to the energy.

The attraction energy in between ions of an ionic compound is stronger than inter molecular energy present between covalent molecules. That is why the melting point and boiling point of ionic compounds is greater than those of covalent bond substances.

Due to the same reason, ionic compounds remain as solids at room temperature whereas covalent compounds usually remain in liquid or gaseous state at room temperature. However, there are some exceptions like naphthalenes. Even though it is a covalent compound, it remains solid in room temperature.

The inter molecular energy in a covalent compound consisting of atoms of two elements (HCl) is greater than inter molecular energy in a covalent compound consisting of atoms of the same element (HJ.

Transformation of Energy in Chemical Reactions

Each substance contains some energy. Usually in chemical reactions, the energy of the reactants is necessary to make the reactions happen or some chemical reactions result in generation of energy. That means, energy is transformed in chemical reactions. The energy required to make a reaction take place or the resultant energy from a reaction may have different forms like heat energy, light energy, electricity, sound etc.

Units of Measurement of Energy

Earlier, calorie or kilocalorie was used as unit to measure energy. The heat applied to raise the temperature of 1 gram water by 1°C is called a calorie (cal in brief). **1** kilocalorie is 1 thousand calories. Kilocalorie is expressed by kcal.

Presently, the international standard unit to measure all kinds of energy is Joule. A joule is the work done by a force of one newton acting through one metre displacement. It is expressed by the abbreviate j. 1 kilojoule (kJ) is equal to 1000 joule.

The relation between calorie and joule is 1 cal = 4.18 J.

8.1.2 Classification of Chemical Reactions According to Change of Heat

Some reactions occur spontaneously while some reactions require the application of energy. Reactions that occur spontaneously heat is produced during the conversion of reactants to products. According to the change of heat, reactions are of two kinds: (i) Exothermic reactions and (ii) Endothermic reactions. In exothermic reactions, the value of tiH is negative and in endothermic reactions, the value is positive.

Any substance has a specific energy at a specific temperature. This energy is called internal energy. If we express the total internal energy of reactants in a reaction with E_1 and the total energy of the products with E_2, then the change of heat energy in that reaction is:

11.H = Total internal energy of the products (EJ
- Total internal energy of the reactants (E,)

In exothermic reactions, the total internal energy of reactants (E) is greater than the total internal energy of products (E). Therefore, the value of H=(E_2-E_1) becomes negative.

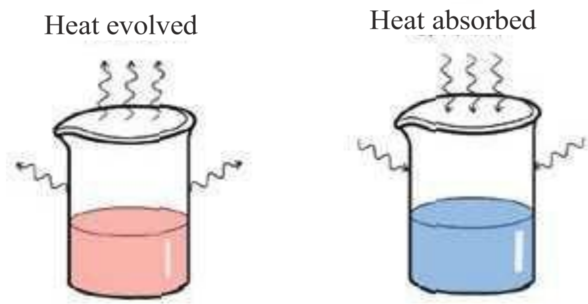


Fig **8.01:** Exothermic and Endothermic process.

For example, when in a reaction, the total internal energy of reactants 50 kJ/mol and the total internal energy of products is 20 kJ/mol, H = (20-50) = -30 kJ/mol.

Again, in endothermic reactions, the total internal energy of reactants is lesser than the total internal energy of products. Therefore, the value of H= E_2-E_1 in this case is positive. For example, when in a reaction, the total internal energy of reactants 70 kJ/mol and the total internal energy of products is 80 kJ/mol, H = (80-70) = +10 kJ/mol.

Exothermic Reactions

The chemical reactions in which heat is evolved are called exothermic reactions. An equation of an exothermic reaction can be written with the word Heat at the right side. If it is written with the expression H, the value will be negative (-). You have seen the natural gas burnt while cooking, produces heat. If water is poured on dry lime, that substance becomes hotter. Methane is the basic ingredient of cooking gas. When we bum this gas, each mole of it reacts with oxygen of air and produces carbon dioxide, water and 890 kJ heat.

CHig) t 20z(g)	coz(g)	+	$2H_20(g)$	+ 890 kJ/rnol
Methane Oxygen	Carbon dioxide		Water	Heat

Or,

CHig) + 20z(g)	coz(g)	+	$2H_20(g)$	H = -890 kJ/rnol
Methane Oxygen	Carbon dioxide		Water	Heat

Again, dry lime is calcium oxide (CaO). When water is poured in it, calcium hydroxide Ca $(OH)_2$ is produced. Alongside, 63.95 kJ/mol heat is produced. That's the reason of it being heated.

CaO(s)	+	$2H_2O(l)$	———	Ca(OH)z(aq)	+	63.95 kJ/mol
Calcium Oxide		Water		Calcium hydroxide		heat

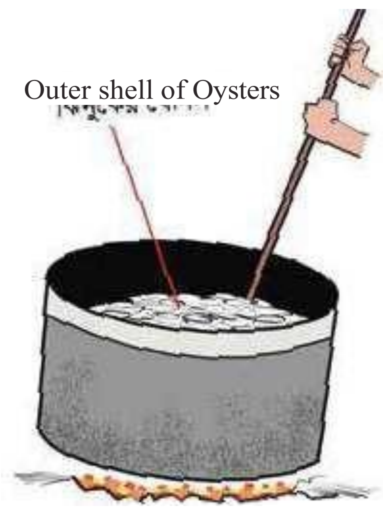
Or,

CaO(s)	+	$2H_2O(l)$	———	Ca(OH)z(aq)	;	L'lH = -63.95 kJ/mol
Calcium Oxide		Water		Calcium hydroxide		heat

In both the above reactions, the total internal energy of reactants (E,) is greater than the total internal energy of products (E_{2}). That extra energy has evolved as heat in the reaction.

Endothermic Reactions

Chemical reactions in which heat is absorbed are called endothermic reactions. They are also called heat absorbing reactions. In the equation of endothermic reactions, on the left side, the head may be recorded. If it is written with the expression H, the value will be positive (+). In villages, the outer shells of snails or oysters are gathered and burnt to produce edible lime. Actually, these casts contain about 98% calcium carbonate. The heat from the fire transforms this calcium carbonate into calcium oxide and carbon dioxide. The calcium oxide is lime which remains as left over and the carbon dioxide mixes in the air.



8.02: Preparation of lime from Oysters.

CaCOis)	+ 176.8 kJ/mole	———	CaO(s)	+ CO_2(g)
Calcium carbonate	heat		calcium oxide	carbon dioxide

Or,

CaCOis) ——— CaO(s) + CO_2(g) H = 176.8 kJ/mole

8.1.3 Calculation of Heat Change in Chemical Reactions Using the Bond Energy

The value of H in a chemical reaction is determined in two ways. We have just seen one in the above discussion. In the other, it is determined using the bond energy- deduce the total bond energy of products from the total bond energy of the reactants. The result in both the ways is the same.

The energy required to break the bonds of the atoms of a compound and separate them is called the bond energy. Again, the energy required to form the bonds of atoms of a compound and combine them is called the bond energy.

During chemical reaction, breaking the bonds of reactants and formation of new bonds of products take place. Energy is needed to break the bonds and energy is released in bond formation.

In any reaction, if the total bond energy of reactants is B_1, and the total bond energy of products is B_2, then the heat change in that reaction is:

tiH = The total bond energy of reactants (B_1)
-The total bond energy of products(B_2)

= Total energy required for breaking the old bonds (B_1)
- Total energy released in the formation of new bonds(B)

In exothermic reactions, the value of B_1 is lesser than B_2, so the value of H is negative while in endothermic reactions, the value of B_1 is greater than B_2, so the value of H is positive.

Table 8.01: Bond and Bond Energy

Bond	Bond Energy (kJ/mol)	Bond	Bond Energy (kJ/mol)
C-H	414	N-H	391
c-cl	326	0-H	464
C-C	344	0=0	498
C=C	615	C=C	812
N=N	946	cl-cl	244
Br-Br	193	I-I	151
0-0	143	H-H	436
H-Cl	431	H-Br	366
H-I	299	H-F	563
C=0	724	C-0	350

When the table says, the bond energy of O=O is 498 kJ/mol, we understand, 498 kilojoule heat is required to break an O=O bond. On the other hand, the formation of an O=O bond evolves 498 kilojoule heat.

Example

Problem: Determine the heat change in the reaction CH_4 + Cl_2 CH_3Cl + HCl. Given, bond energy of C-H = 414 kJ/mol, bond energy of C-Cl = 244 kJ/mol and bond energy ofH-Cl = 431 kJ/mol.

Solution: In the reaction CH_4 + Cl_2 CH_3Cl + HCl 1 mole C-H bond and 1 mole Cl-Cl bond has been broken among the reactants while 1 mole H-Cl bond and 1 mole C-Cl bond has been formed. Therefore,

Total bond energy applied on reactants to break bonds= (414 + 244) kJ = 658 kJ

Total bond energy evolved from products to form bonds = (326 + 431) kJ = 757 kJ

The heat change in the reaction *11H* = (658 - *757)k]* = -99 *k]*

Since the value of */iH* is negative here, so the reaction is exothermic. This reaction evolves 99 kJ/mol heat.

8.2 Uses of Chemical Energy

8.2 Uses of Chemical Energy

We can transform the chemical energy into different energies and put that to our use.

8.2.1 Transformation of chemical energy into different types of energy

Chemical energy can transform into any type of energy like heat, light, electricity, sound or mechanical energy. Some examples are discussed below.

Burning of Fuel

We get heat and light energy when we bum coal, natural gas, wood etc. This energy is obtained basically from the chemical energy present in these substances. Burning is actually to let a substance react with the oxygen of air. Methane (CH_4) is the main ingredient of natural gas. When methane is burnt, it produces carbon dioxide, water vapor, heat and light.

Fireworks

The fireworks that you see on the sky during large festivals render light, sound and mechanical energy. The chemical elements inside the fireworks react with each other and the chemical energy in them produces light, sound and mechanical energy.

Dry Cell

You are familiar with battery. The batteries used in torches and remotes are dry cells. The chemical ingredients inside a dry cell react with each other and the chemical energy is transformed into electricity.

Daniel Cell

The batteries you see on buses, trucks etc. are Daniel cells. Zinc metallic sticks in zinc sulfate salt solution and copper metallic sticks in copper sulfate salt solution are used to make Daniel cells. The following reaction takes place in this cell:

$$Zn(s) + CuSOiaq) \longrightarrow ZnS0_4 (aq) + Cu(s)$$

This reaction turns the chemical energy into electricity.

8.2.2 Chemical Energy and Use of Various Energies Obtained from Chemical Energy

Chemical energy remains stored in molecules and atoms of elements. When a substance reacts with another, then we get chemical energy. We turn that energy into various energies and put them to use. Chemical energy is the most used of all kinds of energies on earth.

When wood or natural gas is burnt for cooking, their chemical energy turns into heat energy. The heat obtained from burning wood is used for making bricks or making earthen pots. Iron, steel and ceramic industries require huge amount of heat. Coal, petroleum, natural gas etc. mineral fuels are used in heat engines. These fuels are burnt in the burning chamber to produce heat and the heat is then turned into mechanical energy to run automobiles, ships, planes, trains etc.

The first thing that strikes our mind when we talk about chemical energy is photo-synthesis. Plants have chlorophyll in their green parts. Chlorophyll helps them to utilize sunlight and conduct the reaction between water absorbed from the earth through their roots and carbon dioxide from air. Thus, they produce glucose $(C_6H_{12}O_6)$ and oxygen (0_2). This oxygen is released by the plants. This reaction is called photo-synthesis. However, the sunlight that participates in the reaction remains in the plant in the form of chemical energy.

$$6CO_2 + 12H_2O \xrightarrow[\text{Sunlight}]{\text{Chlorophyll}} C_6H_{12}O_6 + \qquad + 6H_2O$$

Fig 8.03: Photosynthesis.

Besides, the body of both plants and animals produce fat and protein. They also contain chemical energy. Again, humans and other animals consume them as food. The body of humans and plants can be called chemical engines. Plants get chemical energy from this carbohydrate, protein and fat. This energy turns into heat or other energy. Plants and animals use these transformed energies to conduct different activities. Therefore, it is understood that without chemical energy, life is impossible.

8.2.3 Appropriate Use of Chemical Energy

Petroleum, coal natural gas etc. are called fossil fuel. These fuels have chemical energy stored in them. Burning these fuels or letting them to react with oxygen, heat energy can be obtained. This heat energy is used for cooking, running automobiles and electricity generation.

Besides providing heat energy, burning these fossil fuels have harmful effects on nature. They produce carbon dioxide. The amount of that every year is 21.3 billion tons of carbon dioxide. This gas is a greenhouse gas, meaning it contains heat. As a result, the world is getting warmer day by day. Again, carbon dioxide reacts with rain water and produces carbonic acid (H_2COJ When it comes down to earth with rain, we call that acid rain, which is very harmful for nature. These bad effects of fossil fuels are imposing a threat to life on earth. Therefore, we need to be meticulous in using fossil fuels. We should not use excess fossil fuel. Excessive use of fossil fuels will end up their reserve. Meticulous use will ensure that the reserve remains for our future and they won't impose any bad effect on our lives.

8.2.4 Importance of Purity of Fuel

We are constantly making use of various kinds of fuels to get chemical energy. Their purity is an important factor. If we bum them in insufficient air, carbon monoxide is produced alongside carbon dioxide, which is a harmful gas. It is dangerous for our health. Natural fuels are of crude form. They have mixture of compounds of nitrogen, sulfur, phosphorus etc. That is why, these fuels need refinement before being sent to the market. If we bum them without refinement, the oxides of these elements also go in the air. These oxides mix with rainwater and form acids which again come down to earth with rain. The acid rain is:

CO_2 + H_20 —— H_2C0_3

Carbon dioxide + Water —— Carbonic Acid

$2S0_2$ + 0_2 —— $2S0_3$

Sulfur dioxide + Oxygen ---• Sulfur trioxide

$2SO_3$ + —— $2H_2S0_4$

Sulfur trioxide + Water —— Sulfur acid

+ $2H_2O$ + O_2 —— $4HNO_3$

Sulfur trioxide + Water + Oxygen ---• Nitric acid

This acid rain causes huge damage to our environment. Plants die due to this rain. Water in water bodies tum acidic which makes survival of the fishes and other living bodies tough. Then, the smoke of automobiles consists of carbon monoxide, nitrous oxide and unused methane. In the presence of sunlight, these react to create various piosonous gases. They are known as photochemical smog. Elements of this smog harm the ozone (0_3) layer of our atmosphere. Ozone protects the earth from the ultraviolet rays of sun. If this ozone layer is harmed, lives of humans will be in danger.

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8.2.5 Negative Effects of the Use of Chemical Energy

We bum fuels in order to get energy. Mainly, we make use of chemical energy through the use of fuels. Although, presently we are using solar energy, nuclear energy, wind energy, hydro energy etc. yet, the major part of our required energy is provided by fossil fuels. We have already learned that every year, we are producing 21.3 billion tons of carbon dioxide gas by burning fossil fuels. Trees take in carbon dioxide in its photo-synthesis process. Besides, some other natural processes use up half of it. The other half remains on earth. As carbon dioxide is a heavy gas, it remains below the atmosphere. It does not undergo reactions with other elements of the atmosphere too. However, it has high heat absorbing capacity. Due to this, the temperature of the earth is increasing day by day. This is called global warming. This global warming is melting the ice of the polar region and thus increasing the sea level. Many countries including Bangladesh are at risk of being submerged. Besides carbon dioxide, some other gases are also contributing to the global warming. It is denoted by the term "Greenhouse effect." The gases responsible are known as greenhouse gases. You have already learned about acid rain and photochemical smog. These facts put carbon dioxide as a major portion of the greenhouse gases for harming the atmosphere. The greenhouse gases undergo reactions with the ozone layer and harm its quality. The ozone layer acts as the filter of sunlight in the atmosphere. The ultra violet ray of the sun is very harmful for our skin and it may even cause cancer. The ozone layer prevents this ultra violet ray.

8.2.6 Uses of Ethanol as Fuel

The other name of ethanol is ethyl alcohol the formula of which is CH_3-CH_2-OH. Burning of this alcohol also produces heat like the fuels already discussed. Therefore, it can also be used in engines of all kinds of vehicles and carriers as a fuel. Many countries including North America are using it as a mix with fossil fuels. All automobiles in USA use fuel with 10% ethanol mixed in it. Thus ethanol may be a suitable substitute for fossil fuels relieving the pressure on our reserves.

8.3 Chemical Process by Electricity

8.3.1 Electrochemical Cells

Burning fuels, chemical energy can be turned into heat energy which can again be transformed into electrical energy. Now we will learn how to convert chemical energy directly into electrical energy and how to put that electrical energy to use in order to conduct reactions. The mechanism that helps chemical reactions to convert chemical energy into electrical energy directly or uses electrical energy to conduct chemical reactions is called an electrochemical cell. In an electrochemical cell, two metal sticks or graphite sticks are submerged in one or two electrolytic solutions. The sticks are connected directly or through a battery with a metallic wire. The graphite sticks are called electrodes. Electrochemical cells are of two kinds:

(i) Electrolytic Cells: The cell where electricity is driven from an outer source to carry out a chemical reaction inside the cell is called an electrolytic cell.

(ii) Galvanic Cells: The cell where chemical elements undergo reactions and produce electrical energy is called a Galvanic cell.

Conductor

The materials, through which electricity can pass, are called electrical conductors. For example, metals, graphite, molten salt, salt solution, acid and base solutions etc are electrical conductors.

Depending on the mechanism of passing of electricity, conductors are of two kinds: Electronic Conductors and Electrolytes.

Electronic Conductors

The substances through which electricity is passed by means of electrons are called electronic conductors. You have seen, metals contain metallic bonds. As a result, they contain lots of free electrons. Graphite also contains free electrons. These substances let electricity pass through and for that, they are electronic conductors. For example, iron (Fe), copper (Cu), nickel (Ni) etc. are electron conductors.

Electrolyte

The substances that let electricity pass in their melted and solution state but do not allow in their solid state and simultaneously brings about a chemical change in that substance are called electrolytes. The electrolytes remain ionized during their melted or solution state. The ions are used by electrolytes to conduct electricity. Ionic compounds and some polar covalent compounds become electrolytes in their molten or solution state. For example, sodium chloride (NaCl), copper sulfate ($CuS0_4$), sulfuric acid (H_2S0_4), water (H_20), ethanoic acid (CH_3COOH) etc. are of this type.

Electrolytes are again of two types:

(i) Strong Electrolyte: The electrolytes that remain completely ionized in molten or solution state are called strong electrolytes. Sodium chloride (NaCl), copper sulfate ($CuSO_4$) and sulfuric acid (H_2SO_4) are strong electrolytes.

(ii) Weak Electrolytes: The electrolytes that remain ionized at a very little amount in molten or solution state are called weak electrolytes. Water (H_20), ethanoic acid (CH_3COOH) etc. are of this type.

Electrode

Electrode is a metallic or non-metallic electric conductor. They are electronic conductors sunk in the solution of electrolytes. In the electrochemical cell, an element or ion donates an electron to an electrode in an oxidation reaction. The positive ion accepts electrons from the other electrode in the reduction reaction. This way, oxidation-reduction occurs in the whole cell. The electrode where oxidation occurs is called the anode electrode and the electrode where reduction occurs is the cathode.

8.3.2 Electrolytic Cell, Electrolysis and the Mechanism of Electrolysis

Electrolytic cell uses electricity to conduct chemical reactions. There occurs a chemical reaction at the time of electricity passing through molten or solution of electrolytes, which is known as electrolysis. When electricity passes through molten sodium chloride, it produces chlorine gas at the anode and sodium metal at the cathode. This is electrolysis of sodium chloride:

$$2NaC1(1) \longrightarrow 2Na(s) + Clz(g)$$

Mechanism of Electrolysis of Molten Sodium Chloride

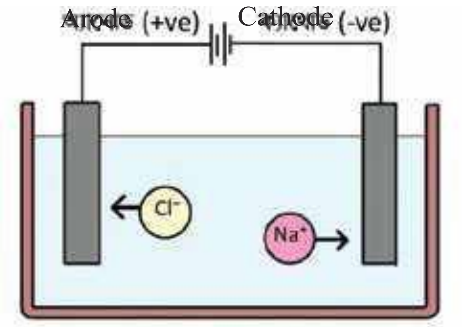


Fig 8.04: Electrolysis of Sodium Chloride in Electrolytic Cell.

Take molten sodium chloride in a glassware or ceramic ware. The molten sodium chloride contains sodium ion (Na+) and chloride ion (Cl-) ion. Both of them are able to migrate. Two metallic bars or graphite sticks are submerged into the molten sodium chloride. If we connect one of them to the positive part of a battery and another to the negative part, the anode connected to the positive part of the battery will attract negatively charged Cl- ions while cathodes connected with the negative part of the battery will attract positively charged Na+ ions. Cl- ions will donate electrons at the anode and become chlorine gas. The oxidation at the anode:

$$\longrightarrow \frac{1}{2}Cl_2 + e^-$$

On the other side, Na+accepts electron from the cathode and becomes metallic sodium. The reduction at the cathode:

$$Na^+ + e^- \longrightarrow Na$$

The ion that is attracted by the cathode is called a cation and the ion attracted by the anode is an anion.

Identification of Chlorine Gas at Anode with Litmus Paper

If we collect the gas produced during the electrolysis of molten NaCl in a test tube and hold a wet blue litmus on the test tube, the paper will tum red. That will prove the presence of chlorine gas.

$$Cl_2 + H_2O \longrightarrow HCl + HOCl$$

Chlorine + Water Hydrochloric acid + Hypochlorous acid

Since Chlorine gas and water undergo a reaction and produce two acids, the blue litmus turns red.

Electrolysis of Concentrate Sodium Chloride Solution

In concentrated sodium chloride solution, NaCl becomes ionized and produces Na+and Cl- ions.

$$NaCl \longrightarrow \quad + \; Cl^-$$

The difference from molten sodium chloride is that the solution contains H+and OH- ions too as water is partially ionized here.

$$\longrightarrow \quad +$$

During the electrolysis in this electrolytic cell, Na+ and H+ will go towards the cathode together. We know, H+ion is more prone to accept electrons than the Na+ion. So, H+ion accepts one electron at the cathode and becomes a H atom. Two H atoms again join together and become a H_2 molecule. The reaction at the cathode:

$H+ + e- \quad H$ (Reduction reaction)

$H + H \quad H_2$

Cl- and OH- go simultaneously towards the anode. We know, OH- ion is more prone to donate an electron than Cl-. However, since the molarity of Cl- in the solution is higher than OH- ion, so it donates electrons at the anode earlier than OH-. One Cl- ion donates an electron at the anode and becomes a Cl atom. Two Cl atoms join together producing a Cl_2 molecule. The reaction at the anode:

cl- cl + e- (Oxidation)

cl + cl Cl2

Na+ and OH- remain as left over in the container. They undergo a reaction and produce NaOH.

This way, if any solution consists of multiple cations and anions, which cation of will discharge first at the cathode or which anion will receive the charge at the anode is determined by three factors:

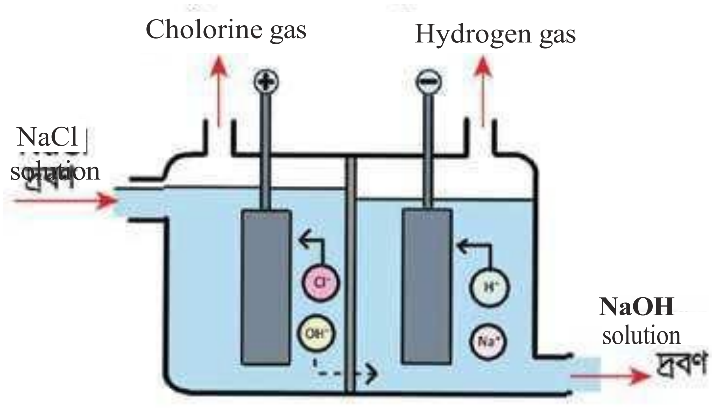


Fig 8.05: Electrolysis of Sodium Chloride Concentrate Solution.

(i) **The Tendency of Cations and Anions to Discharge:**

If there are more than one kind of cations m an electrolysis, there is a priority list for the cations which specifies which of them will discharge first. The series is called Reactivity Series of Metals or Electro Chemical Series. Between any two elements of this series, the element above is more reactive and it take parts the reaction earlier than the other. Again, the one ion of element at the lower order between any two elements will accept the electron earlier and discharge or become reduced. For example, among Na+and H+, H+ is at lower order than Na+ and so, it will discharge accepting electrons earlier and be reduced. Again, $Fe^{2+}$is at a comparative lower order between $Fe^{2+}$and Zn^{2+}. So, Fe^{2+}will discharge earlier.

Table 8.02: Electrochemical senes

Cation	Anion
u+	$N0_{3}^{-}$
K+	$S0_{4}^{2-}$
Na+	c1-
Mgz+	Br-
AP+	r
Zn^{2+}	Off
Fe^{2+}	
Sn^{2+}	
Pb^{2+}	
H+	
Cu^{2+}	
Ag'	
Au^{3+}	

There is another series specifying the priority of anions to donate electrons and discharge in electrolysis. This series is called Electrochemical Series of Anions.

The one that is at the comparative lower order between any two ions in the series will donate an electron earlier and discharge or be oxidized. Between SO/ and Cl-, Cl- is situated lower than the other. So, Cl- will donate an electron earlier and be discharge or be oxidized. OH- is at the lower order between Cl- and OH-. So OH- will discharge, donating an electron first and be oxidized.

(ii) Effect of Concentration of Cations and Anions: When there are more than one cations and anions in the solution, the effect of molarity is a more important factor than the tendency to discharge. The molarity of Cl- ion in 0.1 molar NaCl solution at room temperature will be 0.1 molar. On the other hand, ionizing water, the molarity of OH- ion will be 10-^{7} molar. That means the molarity of Cl- ion is 10^{6} times larger than that of OH- ion. According to the electrochemical series, OH- is situated lower than Cl- and it is supposed to be the first to discharge. But due to molarity or concentration, Cl- ion in this case will be the first to discharge.

(iii) Nature of Electrode: Sometimes, the kind of electrode causes an exception in the above two factors of discharge in an electrolytic cell. NaCl aqua solution has two kinds of cations- Na+and H+. When a platinum electrode is used, then according to the factor (i), H+discharges and produces H_2 gas. But this changes when mercury is used as a cathode and then Na+ion discharges earlier.

Electrolysis of Pure Water

In the electrolysis of pure water, anodes and cathodes of some inert metals are used in electrolytic cells. Usually it is platinum. Water exists a little bit ionized:

$$\rightleftharpoons 4H^+ + 4OH^-$$

A few drops of sulfuric acid is added to water to increase decomposition of water. Now, when electricity is passed through, anode attracts hydroxyl (OH-) ion and cathode attracts hydrogen (H+) ion. The following reactions take place at the electrodes:

$$\textit{Cathode:}\ 4H^+ + 4e^- \qquad 2H_2 \ \text{(Reduction)}$$

$$\textit{Anode:}\ 40H^- \qquad 0_2 + 2H_20 + 4e^- \ \text{(Oxidation)}$$

Hydrogen is produced at the cathode and Oxygen is produced at the anode.

You may be thinking why some drops of sulfuric acid or some lattice of NaCl is required here. You know, electricity does not pass until it is a complete circuit. Electron is the medium of the flow of electricity in anode, cathode or battery. Water hardly gets ionized. So, pure water acts like non-conductor.

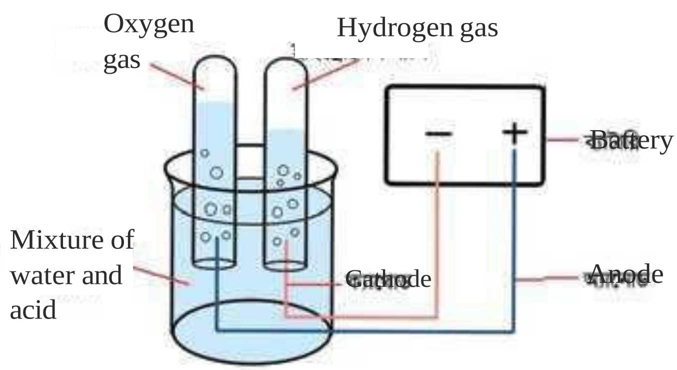


Fig 8.06: Electrolysis of Water.

To increase the conductivity of water, some drops of sulfuric acid is necessary.

8.3.3 Use of electrolysis

Presently, mills and industries have sprung up all over the world. The contributions of electrolysis m the industrial sector 1s enormous. Production of important compounds, extraction of metals from ores, purification of metals, protection from decay, prevention of rust etc. processes require electrolysis and electrolysis requires electrolytic cells. Some of the usages are described below:

Extraction of Metals: Alkali metals, alkaline earth metals, aluminum etc. active metals are extracted through electrolysis. Usually, the cathodes produce these metals when electricity is passed through the electrodes in the liquids of such metallic compounds or solutions. For example, in the electrolysis of sodium chloride, we find sodium metal at the cathode and chlorine gas at the anode.

In the electrolysis of molten pure aluminum oxide or alumina (Al_2O_3), aluminum metal is produced at the cathode and oxygen gas at the anode.

$$Al_2O_3 \rightleftharpoons \text{ZAP+} + 30^{2-}$$

Reaction at the anode: 30^{2-} $_2$ $0_2 + 6e^-$

Reaction at the cathode: ZAP+ + 6e- ZAl

Purification of Metals: After extraction, the metals contains vanous other elements mixed in them. Electrolysis is highly effective to purify these metals. Purification of copper, zinc, lead, aluminum etc. involves the electrolysis process. The same adulterated metal electrode of the adulterated metal is connected to the positive edge of the battery. A pure electrode of the same metal is connected to the negative edge of the battery. When electricity is passed through, the metallic ion from the impure electrode goes into the solution and from the solution the ion is transferred to the pure electrode. As a result, the pure electrode thickens while the impure electrode decays.

Electroplating: Adding a coating of a metal on another metal is called electroplating. The process is used for increasing brightness of a metal or to prevent degradation of a metal. Less reactive metals do not react with oxygen of the air. To prevent degradation of a metal, a coating of a comparatively less reactive metal is given on the outer layer of that metal. Usually, nickel, chromium etc. metals are used in electroplating. Iron rusts and decays when it comes in contact with water vapor and air. Nickel, chromium or silver coating is used on iron. They prevent air and water vapors to come in direct contact with iron. The process is discussed below:

To electroplate iron products such as a spoon, a solution of $AgNO_3$ is taken in a glass container. The product that will receive the coating is connected to the negative edge of a battery and thus is dealt as a cathode. A silver foil is used as an anode. When electricity is passed in the solution, the metallic Ag atom from the anode donates an electron and goes into the solution as Ag+ ions. This Ag+ ion from the solution accepts an electron from the cathode and sticks itself to the cathode as metallic silver. Thus the coating of silver is done.

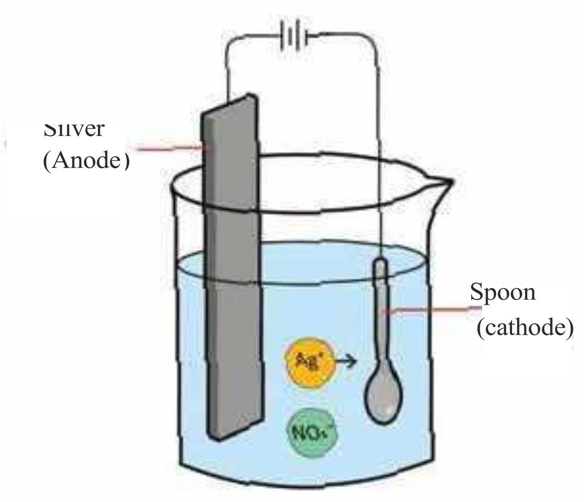


Fig 8.07: Silver Electroplating on Spoon.

Decomposition of $AgNO_3$ in solution: AgN03 Ag++ N03-
Oxidation at anode: Ag Ag++ e-
Reduction at cathode: Ag+ + e+ Ag

Commercial Use of Products with Electrolysis

We can do many things with electrolysis. Various metals such as sodium, aluminum, zinc, calcium, magnesium etc. are extracted from ores by electrolysis. Besides, purification of copper, gold, silver etc. involves electrolysis. The present world has a great demand for these metals.

We know, silver and copper has the least amount of resistance. Since silver is a precious metal, copper is generally used in producing an electric wire. Can you imagine a place on earth without an electric wire? Aluminum is another important metal as it is necessary to make utensils. Since the metal is light, it is extensively used in making airplanes. Zinc and magnesium are required to add coatings on iron products. Chromium, nickel, gold, silver etc. are electroplating metals on less precious metals to add brightness. This makes the ornaments more lucrative.

Chlorine gas produced from electrolysis of sea water is used as an anti-parasite agent. Sodium hydroxide is used as a raw material in different industries.

8.4 Production of Electricity by Chemical Reactions

Galvanic Cell or Voltaic Cell

Galvanic or Voltaic cells are those electrochemical cells where the elements within undergo reactions to produce electricity. In a Galvanic cell, usually two electrodes of different elements are submerged in two different electrolytic solutions in two different containers. The more reactive metal electrode is used as the anode and the less reactive metal electrode is the cathode. In a galvanic or voltaic cell, an electrode made of a particular metal must be placed in a solution of a salt of the same metal (electrolyte) so that ions of that metal are present in the electrolyte For example, if an electrode is made of copper, it has to be kept in $CuSO_4$ solution. Similarly, a zinc electrode is kept in $ZnSO_4$ solution. When the two electrodes are externally connected with a metal wire, electrons can flow from one to other, meaning flow of electricity is ensured. A U shaped salt bridge is created between the two electrolytic solutions. The U shaped glass tube contains KCl salt solution. To make it more clear to you, the structure of a Daniell cell is described below.

Daniell Cell

The cell was invented by John Frederick Daniell in 1836. It is named after him.

Two glass or ceramic containers are taken, one partially filled with copper sulphate ($CuSO_4$) solution and another with zinc sulphate ($ZnSO_4$) solution. A copper stick is dipped in $CuSO_4$ and a zinc stick is dipped in $ZnSO_4$. AU-shaped salt bridge is dipped in the two solutions, as shown in the picture, to connect them. A metal wire is used to connect the two electrodes. A bulb connected at the middle of the wire lights up when electricity starts to flow. Here, a zinc atom donates two electrons to the zinc electrode and turns into zinc ion (Zn^{2+}). It leaves the electrode and goes into the solution. The zinc electrode accepts the two electrons and becomes negatively charged. Then the electrons flow through the connecting wire. Since the metallic zinc turns into Zn^{2-} in the electrode, so it is an oxidation reaction at the anode:

Oxidation at anode: $Zn \qquad Zn^{2+} + 2\ e^-$

Now, the two electrons from the zinc anode enters the copper electrode. Through this electrode, the Cu^{2+} ion from $CuSO_4$ solution accepts the electrons and turns into metallic copper (Cu). Since the process is reduction here, so the copper electrode is regarded as the cathode electrode.

Reduction at cathode: $Cu^{2+} + 2\ e^- \qquad Cu$

The total reaction in the cell: $Zn + Cu^{2+} \qquad Zn^{2+} + Cu$

Since zinc has donated electrons at the anode, so that constitutes oxidation. But donating electron only does not complete a reaction. The copper ion at the cathode electrode has accepted those electrons and completed the reduction reaction. That means half the reaction has occurred at the anode and the other half at the cathode. So, the reaction at the anode is oxidation half reaction and the reaction at the cathode is reduction half reaction. And the total reaction is a redox reaction.

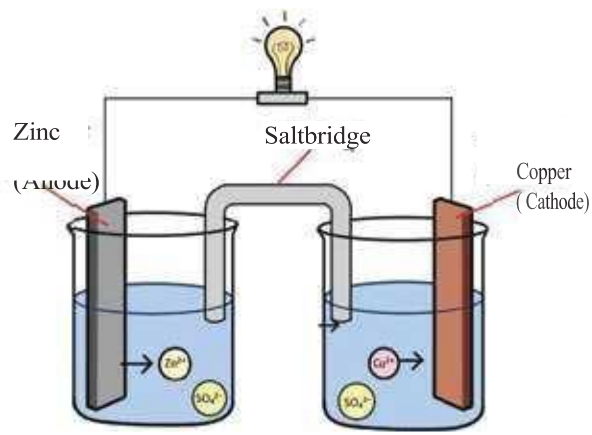


Fig 8.08: Galvanic (Deniell) cell.

Electrons from anode enter the cathode through the connecting wire. That means the flow of electricity occurred here or electricity was produced. That proves, a Galvanic cell transforms chemical energy into electrical energy.

Table 8.03: Difference between Electrolytic Cell and Galvanic Cell.

Electrolytic Cell	Galvanic Cell
The cell where electric energy is used to facilitate a chemical reaction IS called an electrolytic cell.	The cell where a chemical reaction produces electric energy is called a Galvanic cell.
In an electrolytic cell the anode IS positively charged and cathode 1s negatively charged.	In a Galvanic cell, the anode is negatively charged and the cathode is positively charged.
Producing substances, electroplating, metal purification etc. involve electrolytic cells.	Electricity production mechanism like a battery uses this technology.

Electrodes in Galvanic Cells

There are various kinds of electrodes of Galvanic cell. The easiest to make is a metal-metal ion electrode. This kind of electrode can be made by dipping half or more than half of a stick or foil of a metal in a solution containing ion of the same metal. The written expression of such an electrode can be composed of the metal name followed by its ion with a vertical line in between. For example, if a Zn stick is dipped in a $ZnSO_4$ solution, which makes a zinc metal electrode, it can be expressed ZnlZn^{2}+. The reaction that occurs here is:

$$Zn \rightleftharpoons Zn^{2+} + 2\,e^{-}$$

Electrodes of more reactive metals such as sodium, potassium, calcium etc. cannot be produced in this manner. In such cases, amalgam is commonly used. An amalgam is a mixture of mercury and active metals.

Identification of Anodes and Cathodes in Galvanic Cells

Determination of anode and cathode in a Galvanic cell constituted with two electrodes depends on the element they are made of. Electrodes made of less reactive elements situated at the lower ranks of the electrochemical series constitute a cathode while the more reactive elements of the upper ranks constitute the anode. Of the electrochemical series, any two elements constituting a Galvanic cell, the lower ranked electrode is cathode and the higher ranked electrode is anode. For example, if a Galvanic cell is constituted with a copper electrode and a silver electrode, the copper metal electrode is anode and the silver metal electrode is cathode. Table 8.05 shows copper is comparatively higher ranked than silver.

Table 8.04: Electrode and Reaction.

Electrode	Reaction
	Zn(s) ⇌ zn^{2}+(aq) + 2e-
$Culcu^{2}_{+}$	Cu(s) ⇌ Cu^{2}+(aq) + 2e-
$FelFe^{2}$+	Fe(s) ⇌ Fe^{2}+(aq) + 2e-
AglAg+	Ag(s) ⇌ Ag+(aq) + e-

Table 8.05: Electrode.

Electrode
u1u+
KIK+
NalNa+
MglMg2+
AllAP+
$Znlzn^{2}_{+}$
$FelFe^{2}_{+}$
$NilNi^{2}_{+}$
$Snlsn^{2}_{+}$
$PblPb^{2}_{+}$
H2lW
$Culcu^{2}_{+}$
AglAg+
$Au1Au^{3}_{+}$

In this cell, copper atom donates electron and turns into copper 10n.

Oxidation half reaction at anode:

Cu Cu^{2}+ + 2 e-

Again, silver ion accepts electron and turns into silver atom.

Reduction half reaction at cathode:

2Ag+ + 2e- 2Ag

Adding the two half reactions, we get the total reaction of the cell:

Cu + 2Ag+ Cu^{2}+ + 2Ag

Salt Bridge and Its Use

You have seen in the Daniell cell, in anode, metallic zinc donates two electrons to become zinc ion. This electron is conducted through the connecting wire towards the cathode. As a result, the ion in the anode solution increases.

Oxidation half reaction in anode:

$$Zn \rightarrow Zn^{2+} + 2\ e^{-}$$

On the other hand, the Cu^{2+}ion in the CuSO4 solution at the cathode accepts the two electrons and turns into charge neutral Cu atom without changing the composition of SO/ ion. As a result, the solution becomes negatively charged and the flow of electricity stops within a while. The salt bridge comes into effect at this stage. A chemical substance named agar-agar mixed with KCl is put inside a U-shaped tube. It creates a gel like substance which is called the salt bridge.

Both K+ and Cl- ions in this substance have the same velocity. Two cotton buds at the two faces of the bridge (like in the fig) help connect the two solutions externally.

Now, the surplus charges in the anode are joined by the same number of Cl- ion from the bridge in the anode solution. Similarly, the reduced number of positive charges in cathode solution is joined by K+ ions from the bridge. Thus, the charge neutrality of both the solutions is maintained and the flow of electricity is continued.

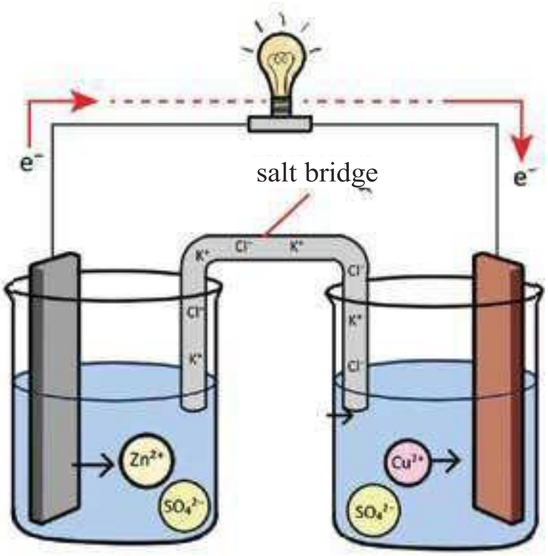


Fig 8.09: Salt bridge in Cell.

Dry cell

Dry cell is a kind of Galvanic cell. Dry cell transforms chemical energy into electrical energy. We use dry cells in torch lights, TV remotes, toy remotes etc. Dry cell is also composed of an anode and a cathode.

A small container made of zinc is used as an anode in a dry cell. The container is filled with a paste of manganese dioxide (MnOz), ammonium chloride (NH_4Cl), zinc chloride (ZnClz) and distilled water. A carbon (graphite) stick is inserted at the center of the container to act as a cathode. When two wires connect the two edges (positive and negative) of a bulb or electronic item with the zinc container and the carbon stick, the following reaction occurs:

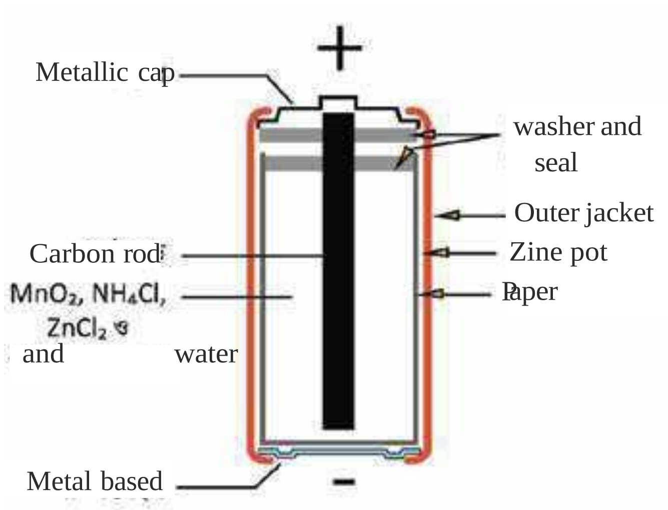


Fig 8.10: Dry cell.

Zinc at the anode donates two electrons and becomes Zn^{2}+:

Anode reaction,

$$Zn \longrightarrow Zn^{2+} + 2e^-$$

These two electrons come to the carbon rod through the connector and combine with ammonium ion (NH/) and manganese dioxide (MnOz) to produce ammonia gas (NH_3), dimanganese tri-oxide. The reaction:

Cathode reaction,

$$2NH_4^+ + 2MnO_2 + 2e^- \longrightarrow 2NH_3 + Mn_2O_3 + H_2O$$

The total cell reaction stands:

$$Zn + 2NH_4^{+} + 2MnO_2 \longrightarrow Zn^{2+} + 2NH_3 + Mn_2O_3 + H_2O$$

When the anode and cathode edges are connected to a bulb or any electronic item, the flow of electricity begins or electricity is generated. Therefore, wherever electricity is required, if we connect the dry cell there, the above reaction will occur and we'll get electricity.

Application of Electrochemical Cells

Fig 8.11: Machine to test Blood Sugar.

Coating a metal on another metal has been there in practice from the ancient age. Now that has increased hugely. Electrolysis is used for extraction of metals, production of valuable chemicals, electricity generation, purification of substance etc. Hydrogen fuel cell is used for electricity generation. Hydrogen molecule is oxidized at its anode and oxygen molecule is reduced at the cathode to produce water. As a result, in the cell electron is conducted from anode to cathode. This electricity can be used to run cars even. All mobile phones, computers, calculators etc. all over the world use batteries.

Blood sugar in the diabetic patients is tested and determined by a machine that uses electrolysis mechanism. The figure above demonstrates that. The part on the left hand has small thin anode and cathode in it. There is a small channel in between them. When blood is inserted in the channel that forms a complete cell. Indeed, the source in the machine would supply electricity that oxidizes glucose of blood at the anode. On the other hand, the calculating system of the machine determines the number of glucose cells in blood and shows it on the screen converting that into digits. Interesting is that all these processes take less than a minute.

Effect of Battery on Health and Environment

We use batteries for various purposes. In torch lights, we use dry cells, buses and trucks uses lead-storage batteries etc. These batteries use various metals and metallic ions. These are extremely harmful for our body. Dry cell contains zinc and manganese dioxide and lead-storage battery contains lead (Pb), lead oxide (PbO), etc. According to chemical properties, these are toxic and carcinogenic. We trash them anywhere we feel like after use. That gives the extreme hazard of mixing with soil and water leading to contamination.

Fig 8.12: Battery in a Mobile phone.

8.5 Nuclear Reactions and Generation of Electricity

Nuclear Reaction

The reaction where the nucleus of an element undergoes a transformation is called a nuclear reaction. The electron exchange in any chemical reaction occurs from the outermost energy layer of an atom or ion. This leaves the nucleus intact. But in the case of nuclear reactions, an electron does not have any role; the nucleus undergoes change and nucleus of a new element's atom is formed.

The reaction that results in the amalgamation of smaller nucleus into a larger nucleus of an atom or the larger nucleus breaking into a smaller nucleus is a nuclear reaction. There are various kinds of nuclear reactions, Fission and Fusion are the two most significant of them.

Nuclear Fission Reaction

The nuclear process in which the nucleus of a larger and heavy element is broken into the nucleus of smaller elements is called a fission reaction. When we strike a^{2} Unucleus with a neutron at low velocity, the nucleus becomes almost equally divided into two parts and produces ^{1}*t Ba* and Kr nuclei 03 neutrons (5n) and a huge amount of energy. It is a nuclear fission reaction.

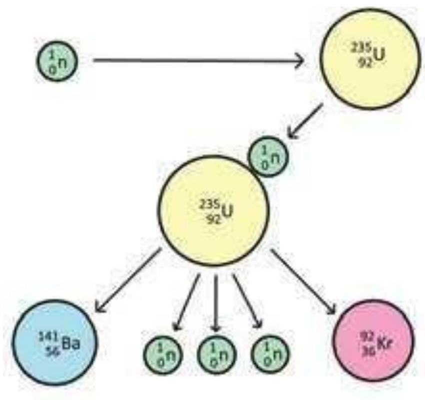


Fig 8.13: Nuclear Fission Reaction.

$^{235}_{92}U$ + $^{1}_{0}n$ ——— ^{1}tgBa + Kr + 3 5n + *Huge amount of energy*

Nuclear Fusion Reaction

The nuclear process in which a number of nucleus of smaller and light elements combine into a nucleus of a larger element is called a fusion reaction. Below is an example of a fusion reaction:

$^{2}_{1}H$ + $^{3}_{1}H$ ——— 1He + 5n + *Huge amount of energy*

Fusion reaction is the basis of a hydrogen bomb.

Nuclear Chain Reaction

Basically, the nuclear fission reactions are nuclear chain reactions. The reactions that do not require application of extra energy to continue once they start are called chain reactions. You have seen, when we strike a ^{2}§ U nucleus with a neutron it breaks into one ^{1}*t Ba* and one *j Kr* nucleus, 03 neutrons (5n) and huge amount of energy. If we can control the pace of these three neutrons, they will strike other ^{2}§ U isotopes. That way, more neutrons will be produced. These newer neutrons will again do the same thing if they are brought under control, resulting in more neutrons. This kind of reaction is a chain reaction. The control of nuclear chain reaction is quite a complex thing and chain reaction is the basis of electricity generation in nuclear reactors.

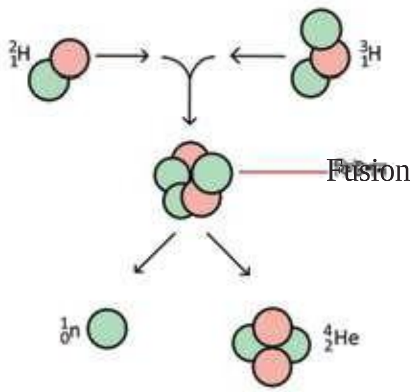


Fig 8.14: Nuclear Fusion Reaction.

Generation of Electricity

Nuclear reactors are used for power generation. The reactor which helps control the chain reactions that occur during a nuclear fission reaction is called a nuclear reactor. These reactors can produce huge amount of electricity. The smaller elements that are produced during a fission reaction are highly accelerated. These smaller elements bombard each other as well as the reactor walls and produce a huge amount of heat energy. This heat is channeled through to an elevator chamber where it is used for producing vapors. The vapors are then channeled to run turbines so that electricity can be produced. In some versions, the elevator chamber is situated within the reactor. Nuclear reactors are used for


Fig 8.15: Nuclear reactor.

power generation m many countries of the world. The government of Bangladesh has taken the necessary preparation for setting up a nuclear power generation facility at Ruppoor of Pabna district. Bangladesh will become self-sufficient in electricity once the project is complete. In the near future, all off Bangladesh will have electricity coverage.

Experiment

Make a Galvanic cell to produce electricity.

Principle:The electrochemical cell where electricity 1s generated through a chemical reaction is called a Galvanic cell. Two rods, one zinc rod partially dipped m zmc sulphate ($ZnSO_4$) solution and one copper rod in copper sulphate ($CuSO_4$) solution, are connected by a copper wire to make the Galvanic cell. Here

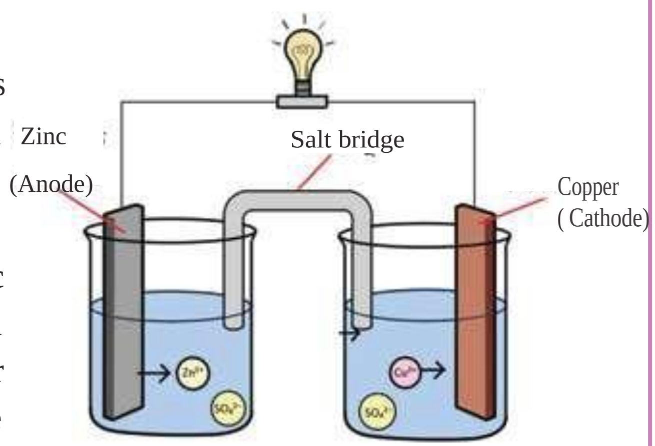


Fig 8.16: Electricity production in a Galvanic cell.

in the cell, the zinc atom donates two electrons and turns into zinc ion ($Zn^{2}+$). The electrons reach the copper rod through the connecting wire. Copper ion ($Cu^{2}+$) from copper sulphate solution accepts these two electrons and turns into metallic copper. The flow of electrons through the copper wire generates electricity. The zinc rod acts as an anode and the copper rod as a cathode in the cell.

$$Zn \longrightarrow zn^{2}_{+} + ze- \quad \textit{(Reaction in anode)}$$

$$Cu^{2+} + 2e^{-} \longrightarrow Cu \quad \textit{(Reaction in cathode)}$$

$$Zn + cu^{2}_{+} \dashrightarrow Zn^{2}_{+} + Cu \quad \textit{(Reaction in Cell)}$$

Necessary Apparatus and Chemicals: Two beakers, zmc sulphate ($ZnSO_4$) solution, copper sulphate ($CuSO_4$) solution, zinc rod, copper rods, an LED bulb, a salt bridge or a long piece of wet paper, copper wire etc.

Procedure: Follow the figure and dip the zinc rod in $ZnSO_4$ and the copper rod in $CuSO_4$ solution in the two beakers. Now place the piece of wet paper following the picture so that the two edges are dipped in the two solutions. Now connect the copper wire to the zinc and copper rods. Connect the copper connector part of the wire to the positive edge of the LED and the zinc connector part to the negative edge of the LED. The LED will light up as soon as the connection is settled. At this stage, the zinc rod will continue to decay as zinc ion continues to go into the solution and the copper ion from the solution transfers to the copper rod.

In reality, the above reaction occurs inside the cell. The chemical energy in the chemical reaction is transformed into electrical energy here.

Caution:

1. The two solutions have to be of equal volume.
2. The bridge has to be maintained properly.

Experiment

Observing the change of temperature after dissolving ammonium chloride (NH_4Cl) in water

Principle: Ammonium chloride, when dissolved in water, gets ionized in the following way:

$$NH_4Cl \text{ ———— } NH_4^{+} + cl^{-}$$

To break the crystal of ammonium chloride and to get its molecules ionized, some energy is required. This energy comes from the water which results in the fall of temperature of the water. Thus the dissolving of ammonium chloride in water is an endothermic reaction.

Apparatus and Chemicals: Beaker, ammonmm chloride (NH_4Cl), distilled water, glass rod and thermometer.

Procedure:

Take 50 gram distilled water in the beaker. Record the temperature of water with a thermometer. Add 10 grams of ammonium chloride in the water.

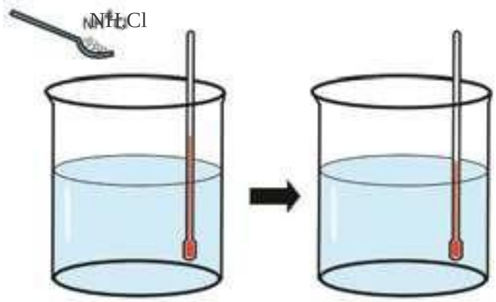


Fig 8.17: NH_4Cl solution in beaker.

Stir the ammonium chloride with the glass rod so that the substance is fully dissolved. Record the temperature as soon as it is dissolved.

Result: The data collected will show that the temperature of water decreased when ammonium chloride was dissolved in it. That proves the reaction as endothermic.

Experiment

The observation of change of temperature adding lime in water

Principle: Lime or calcium oxide added to water undergoes the following reaction:

$$\underset{\text{Calcium oxide}}{\text{Cao}} + \underset{\text{Water}}{H_2O} \longrightarrow \underset{\text{Calcium hydroxide}}{Ca(OH)_2} + \textit{Heat}$$

This reaction is an exothermic reaction. Therefore, the temperature of water along with calcium hydroxide is increased.

Apparatus and Chemicals: beaker, calcium oxide (lime), distilled water, glass rod and thermometer.

Procedure:

1. Fill half of the beaker with distilled water.

2. Record the temperature of water using the thermometer.

3. Add lime or calcium oxide to the water in the beaker.

4. Stir the solution in the beaker as the reaction starts.

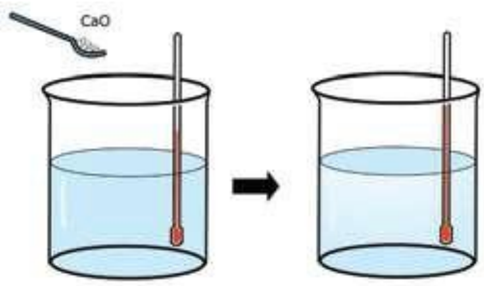


Fig 8.18: Solution oflime in beaker.

5. Record the temperature of water as soon as possible with the thermometer. You will see, the temperature is higher than the previous one.

Result: Adding lime to water raises the temperature of water. It is an exothermic reaction.

Exercise

Multiple Choice Questions

1. How many kinds of conductors are there on the basis of electrical conductivity mechanism?

a. One b. Two

c. Three d. Four

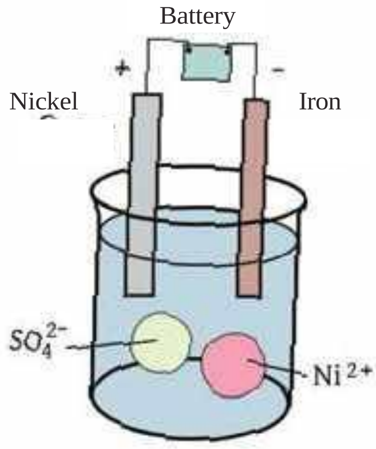
Answer questions 2 and 3 depending on the picture above.

2. The process of the stem does to iron-

a. is increased in amount b. prevents corrosion

c. increases strength d. increases purity

3. In the above picture:



i. Ni is corroded

ii. Fe acts as an anode

iii. Exchange of electron occurs

Which is correct?

a.i and ii b. ii and iii

c. i and iii iv. i, ii and iii

4. Which of the followings acts as an oxidant in the dry cell?

a. Zn rod b. MnO_2

c. Carbon rodd. d. NH_4^+

5. What is the name of the process of giving metallic coating on a different metal through electrolysis?

a. Volcanizing b. Metal purification

c. Galvanizing d. Electroplating

6. Which of the followings is used for striking a nucleus during a nuclear reaction?

a. Proton b. Electron

c. Positron d. Neutron

7. Electrolysis of an aqueous solution of NaCl with platinum electrode produces-

i. Hydrogen gas

ii. Chlorine gas

iii. Sodium hydroxide solution

Which is correct?

a. i & ii b. ii & iii

c. i & iii d. i, ii & iii

Creative Questions

1. (i) Petroleum + 02 ——— CO2 + H20 + Energy

(ii) $^{238}U + {}_0n^1$ ——— $_{56}Ba + {}_{36}Kr + 3{}_0n^1$ + Energy

(iii) Zn + $CuC1_2$ ——— $ZnC1_2$ + Cu + Energy

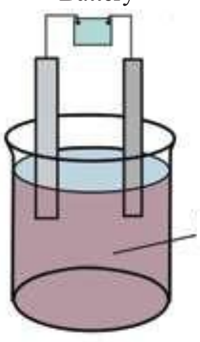
a. What is electroplating?

b. Why a salt bridge is used in an electrochemical cell?

c. In the stem, the second reaction is not a chemical reaction. - Explain.

d. Compare the reactions (i) and (iii) in terms of production of energy.

2.



a. What is a metallic conductor?

b. Why is acidic water called an electrolytic conductor? Explain

c. Explain the reaction that occurs in an anode of the above cell of the picture.

d. Explain the necessity of electricity supply to the illustrated reaction.

3. 1. Electrolytic cell 11. Galvanic cell

a. What is an exothermic reaction?

b. Why are some drops of sulfuric acid required in the electrolysis of water?

c. Describe the formation of number (i) cell.

d. Analyze the possibility of electricity production through cell number (ii).

Chapter Nine

Acid-Base Balance

Most of fruits slightly acidic.

We use various kinds of compounds in a chemical laboratory. Acids, bases and salts are most frequently used. As chemistry learners, you also need to learn about acid, base and salt. We mostly use diluted acids and bases instead of concentrated acids or bases in our laboratories. We take in acids, bases and salts with our food which is important for our bodies. Salt is formed by neutralizing acid with base or vice versa. We can determine the acidity from various experiments in the laboratory. Litmus test and pH value test are the most commonly used. These necessary acids, bases and salts are also harmful to some extent to our environment. We will discuss about all these in this chapter.

By the end of the chapter, we will be able to-

- explain the characteristics of acids, bases and salts
- identify acids, bases and salts from your everyday surroundings
- differentiate between basic and alkaline substances
- describe the effect of acid and base on common materials
- evaluate the financial effect of acid and alkaline materials on our household materials
- explain the concept of pH
- explain the importance of measuring pH
- realize the importance of equilibrium of acid-base in the maintenance of environmental balance
- explain the cause of acid rain, its hazards and the ways of protection from it
- explain the water cycle
- explain the hardness of water
- identify the advantages of using hard water
- explain the financial losses due to use of hard water
- describe the causes of water pollution and the means of water purification
- mention the harms of drinking arsenic contaminated water
- determine the nature of household/lab/saline water measuring the pH
- comparing the nature of compounds (acid, base) by determining the pH value or Litmus test or universal indicator
- show interest in using pollution free water
- show awareness about the terrible side of acid violence and make others aware of them
- exhibit effects of acid and base on useful materials with experiments
- take appropriate precautions in using acidic and basic materials

9.1 Acid

Acid is highly important among chemicals. Acid is a kind of chemical which, when dissolved in water decomposes into hydrogen ion or proton (H+). Hydrochloric acid (HCl), sulfuric acid (H_2SO_4) etc. are concentrated acids, so they get decomposed in aqueous solution:

$$HCl(aq) \longrightarrow H^+(aq) + Cl^-(aq)$$

$$H_2SO_4(aq) \longrightarrow 2H^+(aq) + SO_4^{2-}(aq)$$

Again, carbolic acid (H_2CO_3), acetic acid (CH_3COOH) etc. are diluted acids. They decompose in aqueous solution in the following manner:

$$H_2CO_3(aq) \rightleftharpoons 2H+(aq) \quad + \quad co/-(aq)$$

$$CH_3COOH(aq) \rightleftharpoons H+(aq) \quad + \quad CH_3Coo\text{-}(aq)$$

In the case with HCl and H_2SO_4, the decomposition is shown by moonfaced arrow mark. That means, these acids get 100% decomposed in water. That is why they are called strong acids. The decomposition of the later two acids are shown with dual faced arrows, meaning they are partially decomposed in water. That is why they are called weak acids. For instance, at 25°C temperature, out of 1000 CH_3COOH molecules, only 4 will be decomposed in water. The rest 996 molecules remain intact in water. When the amount of acid in the solution of acid and water is higher than water, the solution is called a concentrated acid. When the amount of water in such solutions is higher, it is known as a dilute acid. Acid tastes sour. You have certainly tasted tamarind which is too sour. Tamarind contains tartaric acid which makes it sour. Blue litmus turns red when it is put in an acidic solution.

Acid undergoes a reaction with metallic oxide and produces salt and water:

Cao	+	2HC1	$\longrightarrow$		+	H_2O
Calcium oxide (Metallice oxide)		Hydrochloric acid (Acid)		Calcium chloride (Salt)		Water

Acid undergoes a reaction with more reactive metals to produce salt and hydrogen gas.

$$2Na + 2HC1 \longrightarrow 2NaCl +$$

Sodium (Metal) Hydrochloric acid (Acid) Sodium chloride (Salt) Hydrogen

The food items that we take everyday contains various acids. For example, milk contains lactic acid, soft drinks contain carbonic acid, lemon or orange has citric acid, tamarind has tartaric acid, vinegar has ethanoic acid, tea contains tannic acid etc. When we eat or take these foods, the acids go inside our body. They help in digesting our food and prevent diseases. Besides, there are pickles containing different acids which act as appetizers. Since these acids are weak they cannot harm our health. Inside the body, the stomach wall generates hydrochloric acid which is a very strong acid. It is used for decomposing food inside. However, sometimes there is excess secretion of HCl from the stomach which starts to decompose the cells of the stomach wall. Again, if we remain hungry or keep our stomach empty, the HCl decomposes the cells of the stomach hurting the stomach living for which we feel pain. This situation is called peptic ulcer. Therefore, we need to avoid the foods that inspire excess secretion of acid and to stay without food for a long time as well. The chapter will let you know many other properties and uses of acid.

9.1.1 Demonstrating Properties of Dilute Acids through Experiments

(i) Taste: All dilute acids are sour in taste. We have already seen that the acidic foods are sour. However, remain careful not to taste any acid in the laboratory. If your tongue comes in contact with any of these acids, they will instantly corrode your tongue. You may try the taste of tamarind instead which will tell you tartaric acid tastes sour.

(ii) Corrosive: Acids are corrosive. If you put a piece of metal in acid, the outer edge of the metal will be corroded.

(iii) Litmus Test: Acid turns blue litmus into red. Take 2-3 mL hydrochloric acid in a test tube and add a blue litmus to it. You will see, the blue colour will

tum red. You may try the same test with H_2SO_4, HNO_3 or any other acid. Even tamarind or pickles will give you the same result.

(iv) Reaction with Reactive Metals: An Acid undergoes a reaction with reactive metals (K, Na, Mg etc.) and produces salts of that metal and hydrogen as well. For example, Mg undergoes a reaction with sulfuric acid and produces $MgSO_4$ and H_2 gas.

$$Mg + H_2SO_4 \longrightarrow MgSO_4 + H_2\uparrow$$

(v) Reaction between Dilute Acid and Metallic Carbonate: Dilute acids undergo reactions with metallic carbonate to produce salt, water and carbon dioxide. For example, calcium carbonate and dilute HCl undergo a reaction and produce calcium chloride salt, water and carbon dioxide gas. The gas comes out in bubbles.

$$CaCO_3 + 2HCl \longrightarrow CaCl_2 + H_2O + CO_2\uparrow$$

Channel this produced carbon dioxide in lime water, the lime water will tum turbid. The reaction is:

$$Ca(OH)_2 + CO_2 \longrightarrow CaCO_3 + H_2O$$

The lime water looks turbid as insoluble $CaCO_3$ is produced at this stage. This turbid lime water again turns opaque when extra CO_2 is channeled in. At this stage CO_2 and H_2O undergo a reaction with $CaCO_3$ and produce soluble calcium bicarbonate [$Ca(HCO_3)_2$] which makes the water look opaque.

$$CaCO_3 + CO_2 + H_2O \longrightarrow Ca(HCO_3)_2$$

The metallic carbonates undergo the similar kind of reactions with dilute sulfuric acid or dilute nitric acid and produce sulfate or nitrate salts.

$$Na_2CO_3 + H_2SO_4 \longrightarrow Na_2SO_4 + H_2O + CO_2$$

$$CaCO_3 + 2HNO_3 \longrightarrow Ca(NO_3)_2 + H_2O + CO_2$$

(vi) Reaction between Dilute Acids and Metallic Bicarbonates: Metallic hydrogen carbonates or metallic bicarbonates also undergo reactions with dilute acids and produce salts, water and carbon dioxide. For Example:

$$Ca(HCO_3)_2 + 2HC1 \text{ ————— } CaC1_2 + 2H_2O + 2CO_2$$

$$2NaHCO_3 + H2SO_4 \text{ ——— } Na2SO_4 + 2H2O + 2CO2$$

$$NaHCO_3 + HNO3 \text{ ——— } NaNO_3 + H_2O + CO2$$

(vii) Reaction between Dilute Acids and Metal's Hydroxides (Alkali): Dilute acids undergo reactions with metal's hydroxides and produce salt and water. It is a neutralizing reaction. For example, if dilute HCl solution is slowly added to dilute NaOH solution, it produces NaCl (salt) and water.

$$NaOH + HCl \text{ ———— } NaCl + H_2O$$

(viii) Reaction between Dilute Acids and Metal's Oxides: Acids undergo reactions with metal's oxides and produce salt and water. The oxides are usually of alkaline nature. That is why the reactions here are also neutralizing reactions.

$$Cao + 2HC1 \text{ ——— } CaCl_2 + H_2O$$

In the same way, copper oxide undergoes a reaction with dilute sulfuric acid and forms copper sulfate and water.

$$H_2SO_4 + CuO \longrightarrow CuSO_4 + H_2O$$

Or, calcium oxide and nitric acid undergo a reaction to produce calcium nitrate and water.

$$2HNO3 + Cao \text{ ——— } Ca(NO_3)_2 + H_2O$$

9.1.2 The Role of Water in Chemical Properties of Acids

In all the discussions above, we have used the phrase 'Dilute acid'. Dilute acid solution means acid has been added to water to make an acidic solution. The question is whether an acid can maintain its properties when added to water or they undergo changes. Suppose, you have taken some oxalic acid lattice and put a dry blue litmus paper on them. You will observe no change in the colour of litmus. The reason here is that dehydrated oxalic acid lattice does not contain any hydrogen ion. When you dissolve this dehydrated oxalic acid in water, it will decompose and donate an H^+ion, which will tum the blue litmus into red. That means, the hydrogen ion present in an aqueous solution shows acidic property.

Citric acid partially decomposes in aqueous solution. The same thing happens in the case with ethanoic acid and carbonic acid too.

Partial decomposition means instead of all molecules added in the solution, some of them decompose and the rest remains intact.

Citric acid lattice + water Citric acid (aq)

Citric acid (aq) H^+ (aq) + citrate ion

Hydrogen chloride is completely ionized in aqueous solution and produces hydrogen ion:

Hydrogen chloride+ water HCl (aq)

HCl (aq) H^+(aq) + Cl^- (aq)

Pure sulfuric acid and nitric acid are colourless liquids. Both the compounds remain in the molecular state. Since they are not ionized or hydrogen ion is not present in them, pure sulfuric acid and pure nitric acid neither show acidic properties nor do they conduct electricity. They produce hydrogen ion only when they are dissolved in water, showing an acidic property and conducting electricity. So, we can write,

H_2SOil) + water ---- H_2SOiaq)

H_2SOiaq) ——— 2ff (aq) + so/-(aq)

Similarly,

$HN0_3$ (1) + water ---- HNOiaq)

HNOiaq) ——— H^+ (aq) + $N0_3^-$(aq)

The acids that get partially ionized in aqueous solution are weak acids. Strong acids ionize completely in aqueous solution. That shows the weak acids have lesser amount of hydrogen ions. Strong acids have comparatively greater number of hydrogen ions.

9.1.3 Concentrated Acids

The acid that contains comparatively lesser amount of water is concentrated acid. Different concentrated acids like concentrated hydrochloric acid (HCl), concentrated sulfuric acid (H_2SO_4), concentrated nitric acid (HNO_3) etc. are used in laboratories, at different times. If these acids come in contact with our body parts, they create injury on those spots. That is why, when using these acids, we need to put on hand gloves, goggles, mask, apron etc. for safety.

Concentrated Hydrochloric Acid: The solution that is produced when hydrogen chloride gas is dissolved in water is called hydrochloric acid. In the solution the amount of water is comparatively lesser than the amount of hydrogen chloride gas. The moment the cork of the container bottle of concentrated HCl is opened, there is a fog created and a highly pungent smell spreads all over. That is why, before opening the bottle of concentrated HCl, nose and mouth should be covered with a mask and eyes should be protected with goggles.

$$HCl(g) + H_2O(l) \longrightarrow HCl(aq)$$

Concentrated Nitric Acid: The solution that is produced when nitrogen dioxide gas is dissolved in water is called nitric acid. Comparatively higher amounts of NO_2 gas is dissolved in a small amount of water to prepare nitric acid (HNO_3).

$$3NO_2 + H_2O \longrightarrow 2HN0_3 + NO$$

The moment the cork of the container bottle of concentrated HNO_3 is opened, there is a fog created and a highly pungent smell spreads all over. The colour of the container bottle of nitric acid is brown. It is for preventing light for if light enters the bottle, the HNO_3 decomposes. The brown colour of the bottle prevents light to enter the bottle.

Concentrated Sulfuric Acid: The solution that is produced when sulfur dioxide gas is dissolved in water is called sulfuric acid. Comparatively higher amounts of SO_3 gas is dissolved in a small amount of water to prepare sulfuric acid (H_2SO_4).

$$SO_3 + H_2O \longrightarrow$$

9.2 Base and Alkali

Base: Generally, metals or metal like reactive radical oxides and hydroxides that undergo reactions with acids and produce salt and water are called bases. Examples:

$$Cao + 2HC1 \longrightarrow CaC1_2 + H_20$$
$$2KOH + H_2S0_4 \longrightarrow K_2S0_4 + 2H_20$$
$$NH_40H + HCl \longrightarrow NH_4Cl + H_20$$

Apart from CaO and KOH, examples of bases are sodium oxide (Na_2O), copper oxide (CuO), ferrous oxide (FeO), sodium hydroxide (NaOH), calcium hydroxide [$Ca(OH)_2$], ferrous hydroxide [$Fe(OH)_2$], ammonium hydroxide (NH_4OH) etc.

Ammonium ion (NH_4+), phosphonium ion (PH_4+), etc. radicals are reactive like metals. Metallic ions like Na+, K+etc. combined with non-metallic ions like Cl-, SO/ etc. produce ionic compounds like NaCl, KCl, Na_2SO_4, K_2SO_4 etc. Similarly, NH/, PH/ ions combined with Cl-, SO/ ions produce ionic compounds NH_4Cl, PH_4Cl, (NH_4\SO_4, (PH $_4)_2SO_4$ etc. The reaction between acids and bases that produces salt and water are called acid-base neutralizing reactions. Therefore it is said that acid neutralizes a base and a base neutralizes an acid.

Alkali: Hydroxide compounds of metals or metal like reactive radicals that are soluble in water are called alkali. A compound can be an alkali if (i) it contains a hydroxide (OH-) radical and (ii) it dissolves in water.

NaOH is an alkali for it has an OH- radical and it dissolves in water. $Fe(OH)_2$ cannot be called an alkali for although it has an OH- radical, it does not dissolve in water. It is base only. CaO is base but not an alkali for it does not contain an OH- radical. So, you realize, the bases containing OH- radicals and soluble in water are alkali. Thus it can be said, all bases are not alkali but all alkalis are bases.

There are many basic compounds in our household. The toilet cleaners in our houses are base containing sodium hydroxide (NaOH), the glass cleaners containing ammonium hydroxide (NH_4OH) are bases.

9.2.1 Properties of Dilute Bases

The solution prepared by adding comparative smaller amounts of base in larger amount of water is called a dilute base.

Litmus Test: Take a small amount of dilute sodium hydroxide solution in a test tube. Put a piece of red litmus paper in it. You will see the red litmus will tum blue. Again, take some NaOH solution in a test tube. Put a blue litmus paper in the tube. The blue litmus will remain as it is, blue. This proves, the basic solution only turns red litmus into blue.

Feelings: If you touch NaOH solution with your hand, it will feel slippery. Basic compounds are slippery. Some properties of base are discussed here. However, contact with base harms our skin.

9.2.2 Dilute Base in Reaction with Metallic Salts

Undergoing reaction with aluminum nitrate [$Al(NO_3)_3$], ferrous nitrate [$Fe(NO_3)$J, ferric nitrate [$Fe(NO_3)_3$], zinc nitrate [$Zn(NO_3)_2$] etc. metallic salts, dilute base produces the related metallic hydroxide. Mentionable, here we have used only nitrate salts. Apart from it, metallic chloride, metallic sulfate, metallic sulfate salts will produce the same result. Look at the following example:

Reaction between dilute NaOH and $Al(NO_3)_3$

If we take some $Al(NO_3)_3$ solution in a test tube and add some drops of dilute NaOH solution in it, they produce aluminum hydroxide [$Al(OH)_3$] and sodium nitrate (NaNOJ $Al(OH)_3$ gathers as white precipitate at the bottom of the test tube while sodium nitrate remains dissolved in the water and it does not add any colour to the water. The reaction:

$$Al(NO_3)_3 + 3NaOH \longrightarrow Al(OH)d + 3NaN0_3$$

Reaction between dilute NaOH and $Fe(NO_3)_2$

If we take some ferrous nitrate $Fe(NO_3)_2$ solution in a test tube and add some drops of dilute NaOH solution to it, ferrous hydroxide [$Fe(OH)_2$] and sodium nitrate ($NaNO_3$) are produced. $Fe(OH)_2$ gathers as green precipitate at the bottom of the test tube while sodium nitrate remains dissolved in the water and it does not add any colour to the water. The reaction:

$$Fe(NO_3)_2 + 2NaOH \longrightarrow Fe(OH)_2\downarrow + 2NaNO_3$$

Reaction between dilute NaOH and $Fe(NO_3)_3$

If we take some ferric nitrate $Fe(NO_3)_3$ solution in a test tube and add some drops of dilute NaOH solution in it, they produce ferric hydroxide [$Fe(OH)_3$] and sodium nitrate (NaNOJ $Fe(OH)_3$ gathers as a reddish brown precipitate at the bottom of the test tube while sodium nitrate remains dissolved in the water and it does not add any colour to the water. The reaction:

$$Fe(NO_3)_3 + 3NaOH \longrightarrow Fe(OH)_3\downarrow + 3NaNO_3$$

Reaction between dilute NaOH and $Cu(NO_3)_2$

If we take some copper nitrate [$Cu(NO_3)_2$] solution in a test tube and add some drops of dilute NaOH solution to it, copper hydroxide [$Cu(OH)_2$] and sodium nitrate ($NaNO_3$) are produced. $Cu(OH)_2$ gathers as light blue precipitate at the bottom of the test tube while sodium nitrate remains dissolved in the water and it does not add any colour to the water. The reaction:

$$Cu(NO_3)_2 + 2NaOH \longrightarrow Cu(OH)_2\downarrow + 2NaNO_3$$

Reaction between dilute NaOH and $Zn(NO_3)_2$

If we take some zinc nitrate [$Zn(NO_3)_2$] solution in a test tube and add some drops of dilute NaOH solution to it, zinc hydroxide [$Zn(OH)_2$] and sodium nitrate (NaNOJ are produced. $Fe(OH)_2$ gathers as white precipitate at the bottom of the test tube while sodium nitrate remains dissolved in the water and it does not add any colour to the water. The reaction:

$$Zn(NO_3)_2 + 2NaOH \longrightarrow Zn(OH)_2\downarrow + 2NaNO_3$$

Reaction between Alkali (dilute NaOH) and Ammonium Salt

Ifwe take some ammonium chloride (NH_4Cl) in a container and add some alkali (NaOH) solution to it, we get ammonia gas (NH_3), sodium chloride (NaCl) and water (H_2O). The reaction:

$$NH_4Cl + NaOH \longrightarrow NH_3 + NaCl + H_2O$$

It is a characteristic reaction between ammomum salt and alkali. Alkali undergoes a reaction with any ammonium salt and produces NH_3 gas. Examples:

$$NH4Cl + KOH \longrightarrow NH_3 + KCl + H_2O$$
$$2NH4Cl + Ca(OH)_2 \longrightarrow 2NH_3 + CaC1_2 + 2H_2O$$
$$2NH4Cl + Cao \longrightarrow 2NH_3 + CaC1_2 + H_2O$$

9.2.3 Role of Water in the Chemical Properties of Alkali

Both the compounds potassium hydroxide and sodium hydroxide have ions, but when they are in solid state, the ions are not free. The moment they are dissolved, they become fully ionized and produce free hydroxide ions. Only hydroxide ions in the solution carry a negative charge.

$$KOH(s) + Water \longrightarrow K+(aq) + oH-(aq)$$
$$NaOH(s) + Water--- Na+(aq) + oH-(aq)$$

Ammonia gas is the summation of ammonia molecules. When ammonia gas is dissolved in water, their reaction produces ammonium ion and hydroxide ion. However, ammonia dissolves only partially in water and a very small number of hydroxide ion is produced.

Therefore, ammonia solution contains ammonia molecules, water molecules and a small number of ammonium and hydroxide ions. The characteristic of an alkali solution depends on the presence of mobile hydroxide ions. The alkalis that dissolve partially in aqueous solution are weak alkali. Strong alkali becomes fully ionized in aqueous solution. That means, the weak alkali solution consists of lesser number of hydroxide ions than that of the strong alkali.

Individual Task

Complete the following tasks. Describe a change that is observable. Write down the ionic equation.

Addition of iron ----- to dilute sulfuric acid solution.

Addition of solid sodium carbonate to dilute hydrochloric acid solution.

Addition of ammonia solution to copper sulfate solution.

9.3 Corrosive Properties of Concentrated Acids and Alkali

Concentrated acids and concentrated alkali are highly corrosive. They can corrode clothes and skin. They can damage the eyes if they go into the eyes. Concentrated acids and concentrated alkali are added slowly to water and turned into dilute solutions as they dissolve completely.

If by any chance, concentrated acids and concentrated alkali come into contact with your body, the spot must be cleaned time and again. Then you should inform your teacher.

Individual task

Experiment of Strong and Weak Acids or Strong and Weak Alkali

An experiment will tell you which acid is strong and which is weak. Take 50 mL dilute hydrochloric acid in a beaker. Now set two graphite rods in the beaker in a way so that they do not touch each other. Connect one graphite rod with an edge of a battery by a wire and the second graphite with the other edge of the battery taking the wire through a bulb. The bulb will light up. Observe the brightness of the light.

Now take some ethanoic acid in another beaker. It is a weak acid. Set two graphite rods in this beaker also. Connect one graphite rod with the edge of a battery by a wire and the second graphite with the other edge of the battery taking the wire through a bulb. The bulb will light up. Observe the brightness of the bulb. You will see the brightness of the bulb in the beaker containing HCl solution is better than the one in ethanoic acid.

Strong acids provide more H^+in the aqueous solution than the weak acids. This excess amount of H^+conducts more electricity in the solution. That is why the bulb in the strong acid gives more light. On the other hand, the weak acid supplies lesser number of H^+in the aqueous solution resulting in lesser amount of electricity conduction in the solution. So, the bulb gives less light.

Weak acid Lesser amount of H^+(proton) produced

Strong acid Greater amount of H^+(proton) produced

Similarly, an experiment with strong alkali (NaOH) and weak alkali (NH_4OH) will prove that the bulb in the solution ofNaOH will give a brighter light and the bulb in the solution of NH_4OH will give a dim light. So, it will be proved that NaOH is a strong alkali and NH_4OH is a weak alkali.

9.4 The Conception of pH

pH is used as a unit to determine the nature of a aqueous solution, a measure of the acidity, alkalinity or neutrality of the solution. The pH of a solution is the negative logarithm of concentration of hydrogen ions present in the solution. That means-

$$\boxed{pH = -\log[H^+]}$$

Where pis written in small hand letter and His capitalized.

$[H^+]$ expresses the molar concentration of **H+**ions; how many moles of **H+**ions are there in one liter solution.

The presence ofH^+in **1** liter distilled water is 10^{-7} moles

The pH of distilled water = $-\log[H^+] = -\log(10^{-7})$

So, the pH of distilled water = 7

When there is any ion within the third bracket in molarity unit, the concentration of the ion is expressed. If acid is added to distilled water and for this reason, the number of H^+ increases 10 times to make it 10^{-6} moles per liter, the pH of the solution will drop down.

$$pH = -\log[10^{-6}] = 6$$

The more the molarity ofH^+ ion, the lesser the value of pH will be.

If alkali is added to distilled water, the OH^- of alkali will undergo a reaction with $H^+$and lessen the number of H^+. For example, due to adding alkali in water, if the number ofH^+ drops down to 10^{-10} moles per liter, then the pH will be:

$$pH = -\log[10^{-10}] = 10$$

That means, the pH value will rise from 7; the pH value of the alkaline solution is more than 7. The significance of pH value 7 is that the solution is neither alkali nor acidic; it is a neutral solution. When the value of pH is less than 7, the solution is acidic. When the value of pH is more than 7, the solution is alkaline.

9.4.1 Measuring pH

Measurement of pH is done using a pH scale.

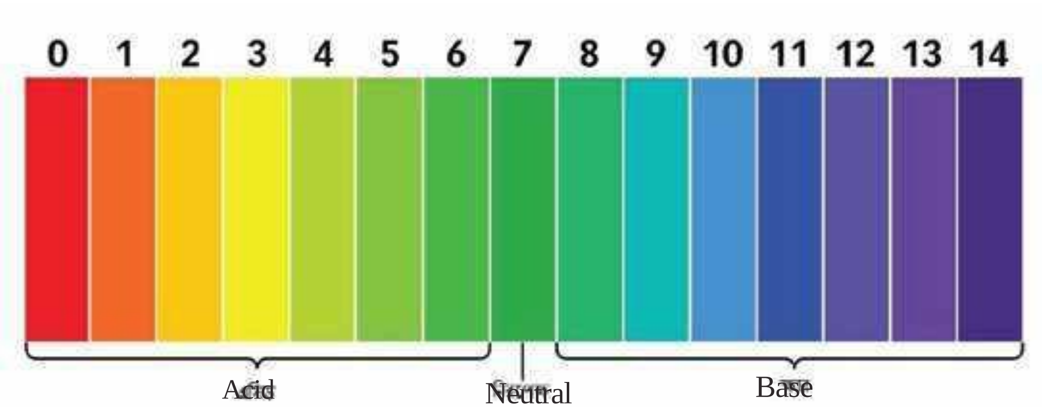


Fig 9.01: pH Scale.

pH Scale: Although in mathematical terms, the value of pH may be any number from negative to positive, in reality, the value is measured on a scale of Oto 14.

The pH of a neutral solution is 7. You have already seen that the value of acidic solution is less than 7 and the value of alkaline solution is more than 7. According to the scale, the strongest acid will have a value of O and the strongest alkali will have the value of 14.

Measuring System: You have already learned how to measure pH of a solution from the molarity of its hydrogen ion. Now you will learn how to measure it in experiments. The process involves the universal indicator, pH paper, pH meter etc.

Universal Indicator: Universal indicator is the mixture of various acid and base indicators. Universal indicator turns to different colours for different values of pH. There is a chart of colours for different values in the Universal indicator.

This is known as the Universal Indicator Colour Chart. To know the value of pH of an unknown solution, add a few drops of the universal indicator to the solution and then compare the colour of solution with the standard colour chart and determine the value of pH.

pH Paper: pH Paper is used for knowing the value of an unknown solution. Add a small piece of pH paper to the solution, it will change its colour. There is a standard colour chart for various pH values. Compare the colour of the pH paper with that standard colour chart and determine the value of the pH.

pH Meter: pH Meter is used for knowing the value of the pH of an unknown solution. Inserting the electrode of the pH meter in the unknown solution the value of pH can be known directly from the digital display on the pH meter.

Litmus Paper: Litmus paper is the easily available cheaper alternative to know the approximate value of pH. The litmus paper is red when the value of pH is less than 7 and the colour is blue when the value is more than 7.

Fig 9.02: pH paper and standard Colour Chart.

Fig 9.03: pH Meter.

Fig 9.04: Red and Blue Litmus Paper.

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9.4.2 Importance of pH

pH has got limitless significance in terms of bio-chemical reactions in animal bodies and use of cosmetics. They are stated below:

Table 9.01: pH of different parts of human body.

Parts of Human body	pH
Stomach	1
Human skin	4.8-5.5
Urine	6
Blood	7.43-7.45
l ncreatic juice!	8.1

Agriculture: pH has a great importance in agriculture. Plants absorb various ions, water etc. from the soil for its own nutrition. The best value of pH of soil in this regard is 6.0-8.0. Again, if the value is less than 3.0 or more than 10.0, the beneficial microbes in the soil die. When the value drops down, measured amounts of CaO is added to the soil. On the other hand, if the value of pH of the soil rises up, measured amounts of ammonium sulfate $[(NH_{42}SO_4$ or ammonium phosphate $[[NH_4\backslash PO_4$ fertilizers are used to settle the pH of the soil.

pH in Different Bio-chemical Reactions of a Body: Various bio-chemical reactions occur in different parts of the animal body. They require different values of pH in various parts of the body.

Cosmetics: Human beings use different chemicals to to clean their skin, beautification of skin, clean the hair and other actions. When the pH of skin is 4.8-5.5, the skin is acidic and that prevents attacks of microbes on the skin. Therefore, the pH of cosmetics is maintained at 4.8-5.5.

9.5 Neutralization Reaction

We know an acid donates H+to an aqueous solution while a base donates OH-. Therefore, a mixture of acid and base facilitates H+and OH- to produce water. For example, in water, HCl donates H+and NaOH donates OH-. Ifwe mix both, the H+and OH- will undergo a reaction to produce water. The negative Cl- ion of the acid and the positive Na+ion of the base will undergo a reaction to produce the salt NaCl. The reaction where an acid and a base undergo a reaction to produce salt and water is called a neutralization reaction. In this reaction both acid and base lose their respective acidity and basicity to produce the neutral substance salt and water.

$$\underset{\text{Acid}}{HCl(aq)} + \underset{\text{Base}}{NaOH(aq)} \longrightarrow \underset{\text{Salt}}{NaCl(aq)} + \underset{\text{Water}}{H_20(l)}$$

Look at the above reaction. One mole hydrochloric acid neutralizes one mole sodium hydroxide completely. Therefore, two moles of hydrochloric acid will completely neutralize two moles of sodium hydroxide. Again, the reaction between sulfuric acid and sodium hydroxide produces sodium sulfate salt and water.

$$\underset{\text{Acid}}{H_2SOiaq)} + \underset{\text{Base}}{2NaOH(aq)} \longrightarrow \underset{\text{Salt}}{Na_2SO_4(aq)} + \underset{\text{Water}}{2H_2O(l)}$$

The above reaction shows that one mole sulfuric acid neutralizes two moles sodium hydroxide completely. It proves, a specific amount of a specific acid will completely neutralize a specific amount of a specific base.

9.5.1 Importance of Neutralization Reaction in Daily Life

In Digestion: Acid is secreted in the stomach for digestion. If for some reason, the amount of acid in the stomach increases, we feel uneasy. Generally, it is called acidity. If this acidity continues for a long time, it creates an infection in the stomach. We take antacid to neutralize this acidity. Antacid contains $Al(OH)_3$ and $Mg(OH)_2$, which are alkaline in nature. They neutralize the excess acids inside our stomach.

$$Al(OH)_3 + 3HC1 \longrightarrow AlC1_3 + 3H_20$$
$$Mg(OH)_2 + 2HC1 \longrightarrow MgC1_2 + 2H_20$$

In Dental Care: If you do not clean your mouth after taking some sweets, after sometime, you will feel a sour taste inside your mouth. Actually, there are innumerable bacteria in our mouth which forms various organic acids from our foods. That is why we feel the sour taste. These acids cause decay of the enamel (calcium compound) of our teeth. Alkali present in toothpastes neutralizes these acids and saves our denture.

In Agriculture: When plants absorb different metallic ions like Fe^{2+}, Mg^{2+}, Ca^{2+}, K^+etc. from the soil, the soil becomes acidic. It loses fertility. Lime is used to increase the fertility of soil which is chemically calcium oxide (CaO). This lime neutralizes the acid in the soil and brings back the fertility.

9.5.2 Salt

You have already learned acid and base undergo reactions to produce salt and water. The positive ion of the salt comes from the base. That is why the positive ion is known as the basic radical. The negative ion comes from the acid. That is why the negative ion of the salt is called an acid radical. An aqueous solution of salt produced from the reaction between a strong acid and a strong base is neutral in nature. For example, aqueous solutions of NaCl, Na_2SO_4 etc. are neutral. An aqueous solution of salt produced in the reaction between a strong acid and a weak base is acidic in nature. $FeCl_3$, $Zn(NO_3\backslash$ etc. are examples of this kind. An aqueous solution of salt produced in the reaction between a strong base and a weak acid is basic in nature. Na_2CO_3, CH_3COONa (Sodium ethanoate) etc. are examples of this kind.

9.6 Acid Rain

Oxides of non-metals undergo a reaction with water to produce various acids. Pure air has a mixture of a small amount of carbon dioxide and different oxides of oxygen. Animals breathe out carbon dioxide in their respiration. The temperature of the spot where thunder strikes reaches 3000°C. At that temperature, N_2 and 0_2 present in air undergo reaction and produce NO. This NO gets oxidized by oxygen and becomes NO_2. These oxides get dissolved in the rain water and produce some acids which come down to earth with rain water. Rain with these acids is called acid rain.

$$coz(g) + H20(l) \longrightarrow H2COiaq)$$

$$2NOz(g) + H_20(l) \longrightarrow HNOz(aq) + HNOiaq)$$

That is why the pH value of rain water is 5-6. However, some man-made reasons like carbon dioxide emitted from vehicles, power plants and industries mix with air which undergoes a reaction with rain water and produces carbonic acid

(H_2COJ Besides, the power plants, brick kilns etc. use coal and petroleum rich with nitrogen and sulfur which again produce oxides of these elements. These also produce acids which come down with rain water.

That is why, in some places, the amount of acid in rain sometimes goes higher than expected. As a result the pH of rain water in these spots may drop down to 4 or below 4, which is acid rain. This rain results in a drop down of pH of soil. This has severe harmful effect on crops and plants. The pH value of water in the water bodies also goes down and makes the situation uninhabitable for the lives there. Fish production is hampered. Acid rain also harms the buildings, metallic structures, marble architectures and sculptures.

9.7 Water

The other name of pure water is life. Water is polluted everyday due to bathing, washing etc. Water becomes hard for various reasons. We can transform hard water into mild water following various ways.

9.7.1 Hardness of Water

The source of water is rivers, canals, bils, ponds, sea and tubewell etc. Various mineral salts are dissolved in this water. It is not easy to get foam of soap if calcium or magnesium chloride, sulfate, carbonate or bicarbonate etc. salts are dissolved in the water. This kind of water is called hard water. However, water can be hard also if it has iron or manganese salts dissolved in it. Why does not this kind of water produce foam of soap? Soap is a sodium or potassium salt of higher organic acid. For example, sodium stearate ($C_{17}H_{35}COONa$) is the sodium salt of stearic acid. It is used in soap. When we use this soap in hard water, so long calcium or magnesium salt remains in the water, it does not produce any foam, only the soap is decayed.

$$2C_{17}H_{35}COONa + CaCl_2 \longrightarrow (C_{17}H_{35}COO)_2Ca + 2NaCl$$

Salts of magnesium and other salts also undergo the same kind of reaction. If hard water is used in water pipes or boilers of industries, the mineral salts present in the water gathers on the pipe as a thick layer and the water flow is obstructed.

In the boiler, there is wastage of heat and the boiler may even burst. The property of water that causes the soap not to clean the dirts properly is called hardness of water.

Hardness of water is of two kinds: temporary hardness and permanent hardness.

(i) Temporary hardness: Hardness of water caused by bicarbonate (HCO_3^-) salts of calcium, magnesium, iron etc. in water is called temporary hardness. And this kind of water is known as temporary hard water. When heat is applied to this kind of water, it produces insoluble carbonate salt. It gathers at the bottom of the container as precipitate. The water can easily be separated by using a filter. Thus the temporary hardness of water is removed and the water turns into mild water.

$$Ca(HCO_3)_2 \longrightarrow CaCO_3(s)\downarrow + CO_2(g)\uparrow + H_2O(l)$$

(ii) Permanent hardness: Hardness of water caused by chloride or sulfate salts of calcium, magnesium, iron etc. in water is called permanent hardness. And this kind of water is known as permanent hard water. Mere heating does not remove this kind of hardness. Various measures or reactions are used to remove this hardness from water. Usually, the water of closed water body is mild water. Rain water is also mild. It does not contain significant amounts of salts of magnesium, calcium etc.

How to remove permanent hardness of water: Addition of sodium carbonate to permanent hard water reacts with the calcium ion and magnesium ion and produces precipitates of calcium carbonate and magnesium carbonate. Thus the calcium ion and magnesium ion is removed from water and it becomes mild.

$$CaCl_2 + Na_2CO_3 \longrightarrow CaCOd + 2NaCl$$

9.7.2 Water Pollution and Pollution Control

Water Pollution

A major part of the body of animals and plants is water. That is why, all living beings need a lot of pure water. However, water is polluted in various ways. For example, all domestic disposals and sewage wash away to the water bodies.

Trashes disposed from hospitals and other places are also washed away to the water. Fertilizers and pesticides used in agriculture also get washed into the water bodies. Industries dump their chemical trashes, vehicles dump their fuels which ultimately reach the water. Thus, water becomes odorous and poisonous. Lead, cadmium, mercury, chromium etc, heavy metals mix with water from all these trashes. These heavy metals may cause diseases, even like cancer.

Again, the human actions are not only contaminating the surface water, but also sub-surface water. The tendency to extract excess sub surface water by shallow pumps and too much excavation results in arsenic contamination in sub-surface water. Arsenic is a poisonous substance. If a human being drinks too much water contaminated with arsenic, he/she may even die.

Pollution Control

Waste treatment facilities are available in the big cities of our country, although the number is not sufficient. Bio gas, electricity alongside organic fertilizers can be gotten from sewage and rotten domestic disposals. The proper initiative in this regard can reduce the environment and water pollution. Small sized bio gas plants will utilize all this disposal and sewage and will also be of benefit to us.

It must be mandatory to establish effluent treatment plants (ETP) in every industry. In no way, the industrial wastes should be disposed directly into the open water reservoir. Everyone should be conscious about it. We should keep the directorate of environment informed with information about this kind of offence. We should keep n mind that organized public consciousness and public opinion is the most effective way to prevent water pollution in our country.

9.7.3 Testing the Purity of Water

Colour and Odour Observation: Pure water is colourless, odourless and a transparent liquid. Little amounts of mineral salt is dissolved in it. If any mineral salt is dissolved in it in a large amount, it can be called polluted water. In general observation, if any odour or any suspended materials in the water or any residue is found after filtration then the water is polluted.

Temperature of Water: In summer, the temperature of water is usually 30-35°C with an occasional rise up to 40°C. If somehow the temperature of water rises by a few degrees then it should be considered heat polluted. If the water used in power plants to cool the machineries or hot water from boiler is released directly into an open reservoir of water, the heat pollution occurs. We can detect the heat pollution with just a thermometer.

pH Value of Water:Ifthe pH value of water is less than 4,5 and greater than 9.5, it will be a threat to living beings. pH can be determined by using pH paper or a pH meter.

BOD: The elaboration of BOD is Biological Oxygen Demand. It means the demands of bio chemical oxygen. The amount of oxygen needed to decompose the organic matters in water in the presence of air is known as BOD of that water. Water that has much BOD value is a polluted one.

COD: The elaboration of COD is Chemical Oxygen Demand. COD is used to express the total chemical matter in water. The quality of the water analyzed by measuring the extent of organic pollutants in water (specially in rivers, canals etc.). A greater value of COD means that the extent of pollution in that water is also greater.

BOD and COD, both are used to denote the pollution level of water. The COD value of any water is greater than the BOD value. It happens because the necessary amount of oxygen to decompose only the organic matters in water is BOD while COD is the amount of oxygen needed to decompose all organic and inorganic matters in water.

Purification of Water

Chlorination: The easiest way of sterilization of water is chlorination. If a certain amount of bleaching powder is added to water, the produced chlorine oxidizes the germs and kills them. This process is called chlorination of water. Filtering the water after adding bleaching powder makes it drinkable.

Boiling: Water can be sterilized by boiling for 15 to 20 minutes. Noteworthy that boiling arsenic contaminated water makes it more harmful.

Sedimentation: Adding one spoonful of alum dust $[K_2SO_4.Al/SO_{4})_3.24H_2O]$ to a bucket of water and allowing it to settle for half an hour creates sedimentation of all impurities of water to settle at the bottom of the bucket. Then by pouring the upper level water into another container, we get pure water. This is the way to get rid of all insoluble pollutants from water.

Filtration: Presently filters are available in the market that helps get rid of germs, arsenic and other pollutants from water. We get pure drinking water using these filters.

Experiment

Determining the acidic or alkaline nature of apple with litmus paper.

Principle: Food can be acidic, alkaline or neutral. Aqueous solution of food that are acidic turns the blue litmus paper into red. Aqueous solution of food that are alkaline turns the red litmus paper into blue. The litmus paper does not change its colour when the solution is neutral.

Apparatus and Chemicals: mortar, test tube, glass rod, filter paper, funnel, blue litmus paper, red litmus paper, distilled water, peeled apple.

Procedure:

1. Make a paste of the peeled apple in the mortar adding some water to it.
2. Take the paste in the beaker.
3. Add 10 mL distilled water in the beaker and mix the paste well, using the glass rod.
4. Now use the filter paper and the funnel to filter the solution to get the watery portion of it from the beaker into the test tube.
5. Observe the change of colour of the litmus papers one by one by dipping them in the test tube.

Observation and decision

Food Name	Probable Change of Colour in the Litmus Paper	Decision
Apple	Blue litmus paper turned red but the red litmus paper didn't change	Apple is acidic
Apple	Red litmus paper turned blue but the blue litmus paper didn't change	Apple is basic

Result: If you did the experiment correctly, you would find apple is acidic.

Individual Task

Following the procedure stated above, if you carry out experiments with rice and cucumber, you will see rice is a neutral food; it does not change the colour of red litmus paper into blue or the blue into red. Cucumber is a basic food for it turns red litmus into blue.

Individual Task

Preparation of pH paper

Take one of the coloured vegetables (red spinach, red cabbage, beet etc.) or coloured flower (china rose, red rose etc.). Cut it in small pieces. Boil in steam at low temperature. Insert a piece of filter paper in the coloured extract you obtained. Dry the paper in air and then cut it into several small pieces. That is the pH paper you have made. To know the value of pH, sink it in a solution of a known pH and make a colour chart of the pH range. Make pH paper with all vegetables or flowers are available to you. Select the best one to use.

Exercise

Multiple Choice Questions

1. Which of the following compounds will be produced when sulfuric acid is added to lime stone?

a. CO_2 b. H_2

c. O_2 d. SO_2

2. Which of the followings is a base?

a. soft drinks b. lemonjuice

c. vmegar d. washing soda

3. In the presence of which of the following aqueous solutions does ammoma gas becomes alkaline?

a. NH_4^+ 10n b. OH^- ion

c. **NH3** d. H_2O

4. The reaction between nitric acid and an unknown metal produces a colourless solution. When we add sodium hydroxide to the solution, it produces a white precipitate. However, excess amount of sodium hydroxide dissolves that also. The metal is:

a. copper b. iron

c. lead d. zmc

5. pH of ethanoic acid is 4. To increase the pH we need to add-

1. ammonia solution

11. concentrated hydrochloric acid

111. solid magnesium carbonate

Which one is correct?

a. i and ii b. ii and iii

c. i and iii d. i, ii and iii

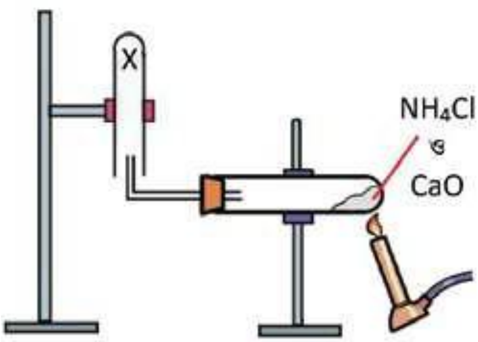
6. Which of the followings makes the lime water turbid?

a. NO_2 b. CO

c. SO_2 d.

Creative Questions

1.



a. What is the colour of NO_2 gas?

b. Explain whether the pH of lime water will be greater or less than 7.

c. Explain a chemical property of the aqueous solution of gas X.

d. What will happen if gas X is passed through HCl gas? Write the answer with an equation.

2. The effluents produced from textile and dying industries containing paint and sulfuric acid are dumped in nearby water reservoirs. As a result, those reservoirs become unfit for aquatic life.

a. Which acid is found in tamarind?

b. Write down your opinion about the pH of the water reservoirs of the stem.

c. Give a logical advice to control acid pollution by effluent treatment plants in textile and dying industries.

d. Analyze the probability of acid rain in the nearby places of textile and dying industries along with reaction.

Chapter Ten

Mineral Resources: Metal-Nonmetal

Mineral stone of various colour.

We are using different kinds of materials and products everyday that are made by tin, iron, copper, gold, porcelain. These may be elements, compounds or a mixture of both. Many of them are obtained from mines. What is a mineral resource? How do we get metals and nonmetals from the mines? Besides, how we make various necessary products from these is the focus of this chapter.

By the end of the chapter we will be able to -

- explain mineral resources
- compare among rocks, minerals and ores
- find out the appropriate ways of metal extraction
- explain the cause of making alloys
- describe source of sulfur and reactions of formation of some of its important compounds, their chemical properties and analyze their uses in houses, industries and agriculture
- analyze the importance of limitation, appropriate use and recycling of minerals
- show sincerity in use of minerals and keenness in preserving

10.1 Mineral Resources

We obtain all our necessary metals, nonmetals, metalloids and their compounds from earth, air or water. The part of air, water or earth from where we get these is called a mine. Those found in these mines are called minerals. Minerals may be solid like iron or copper mineral. They may be liquid like petroleum or mineral oil's mineral. They may also be gaseous like natural gas. Our country abounds in natural gas which is used for cooking, fuel of vehicles, power generation or raw materials in various industries. Middle eastern countries have petroleum minerals which they are exporting throughout the world and which meets up the demand of petroleum products. South Africa has mines of gold and diamond. Besides, different countries have different minerals which contribute to the development of that country as well as the whole world. These solid, liquid and gaseous minerals are called mineral resources.

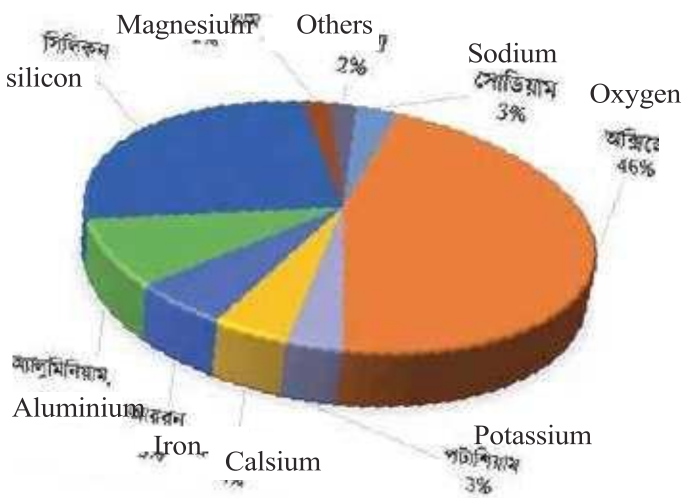


Fig 10.1: Ingredients of the Earth Crust.

10.1.2 Rocks

Different mineral substances mix up to make some hard particles which again combine together into a substance which is called rock. Basing on the way of their formation, rocks are of three kinds: (i) Igneous rocks, (ii) Sedimentary rocks and (iii) Metamorphic rocks.

Igneous Rock

The molten mix of different substances that pour out from the volcanoes is called magma. When magma cools down and solidifies it is called igneous rock. Granite is an example of this rock. Igneous rock is the source of many minerals.

Fig 10.2: Igneous rock, Sedimentary rock and Metamorphic rocks.

Sedimentary Rock

As an effect of weather and climate, rainfall, wind, fog storms etc. clay and sand from the earth's crust is washed or blown away which again gathers in some places as sediment. Then different particles in that sediment organize themselves in layers and transform into a rock which is known as sedimentary rock. An example of this is sandy stone.

Metamorphic Rock

At various pressures and temperatures, the igneous and sedimentary rocks transform into a new kind of rock which is called a metamorphic rock. Coal is this kind of a rock.

Formation of Different Layers of Sub-surface Rocks

Rocks are organized in different layers underground. Gravitational force, temperature, pressure and natural force etc. help form different layers of rocks underground.

Fig 10.03: Layers of Rocks.

10.1.3 Minerals and Ores

Minerals: The substances available above and underneath the soil from which we get necessary metals and nonmetals, to make various products, are known as minerals. The places where these minerals are found are called mines.

Ores: The minerals from which metals and nonmetals can be extracted profitably are called ores. For example, galena (PbS) is the ore oflead as from it, the metal lead is profitably extracted. Aluminium cannot be profitably extracted from bauxite and so bauxite is called the mineral of aluminium but not the ore of aluminium. Therefore, we can say, all ores are minerals but not all minerals are ores.

Sulfide of iron is called iron pyrites (FeS). Iron can be extracted from pyrites.

Position of Minerals

Earlier, it was idealized that minerals are available only beneath the surface. Now, this concept is no more correct. Some minerals are obtained from beneath the surface but some are also available on the surface. Sulfur minerals are available beneath the earth's surface. White clay or keulin mineral is available on the surface at Bijoypur of Netrokona. The sand of Cox's bazaar sea beach contains zircon, the mineral of zirconium and hematite, the iron mineral, bauxite, the aluminium mineral etc. are available on the surface of various places. Halogen minerals are available in the sea water.

10.2 Metal Extraction

The process through which metals are obtained from the ores is called metal extraction. Different metals have different properties. That is why there is no one process of extracting all metals from their ores; there is difference in the process of extracting different metals. Some non-reactive metals like gold, platinum etc. are sometimes found in their pure state. However, less and more reactive metals are usually found in their compound states like oxides, sulfides, nitrates, carbonates etc. That is why, the compounds of reactive metals are extracted by reduction or by electrolysis process. There are a number of steps of metal extraction from their ores, which are: 1. Crushing the ores. 2. Condensation of ores. 3. Conversion of condensed ore to oxides. 4. Conversion of metallic oxides to free metals. 5. Purification of metals. However, the steps of metal extraction is decided by the properties of the ores. All steps are not necessary for all ores.

1. Crushing the Ores:

If the stones of ore that are excavated from the mines are big, they need to be crushed first. Firstly they are crushed in the Joe crusher to smaller pieces and then they are turned into powder or small lattices in the Ball crusher.

2. Condensation of Ores:

Fig 10.04: Joe Crusher.

Usually the ores contain some substances apart from the metal that is to be extracted from it. This mixture of substances in the ore is called impurities. The crushed powder of ores still contains the impurities mixed with them. For example, bauxite ore contains sand as impurity when it is excavated from the mine. The process that is employed to separate these impurities from the intended metals is called condensation of ores. Condensation is of various kinds like Hydrolytic method, Magnetic separation, Froth Floatation, Chemical method etc.

Hydrolytic Method: This method is usually applied for oxide ores. The particles of oxide are comparatively heavy while the impurities are light. In the process the ore is poured on a slanted, chambered table and water is poured on the ore. At this, the heavy ore becomes condensed and goes inside the chamber while the impurities are washed away with water. This way, the ores are condensed.

Froth Floatation Method: The sulfide ores are condensed in this method. The ore is first taken inside a large tank and water is added. Later, oil is slowly added to the mixture. When air is blown on the ore, the sulfide ore dissolves in the oil and floats up as froth. The froth is collected while the impurities remain at the bottom of the tank.

Experiment of Froth Floatation Method

Ingredients: sand, kerosene, spatula, liquid/powder soap, watch glass, a large test tube with cork, celcopyrite, galena or hematite powder

Process:

1. Mix equal amounts of sand with one spatula of washed ore. Take the mixture in a large test tube and fill half of it with water.
2. Shake the test tube closing it with a cork. Have the sand and ore separated?
3. Add some powder/liquid soap and a few drops of kerosene oil.

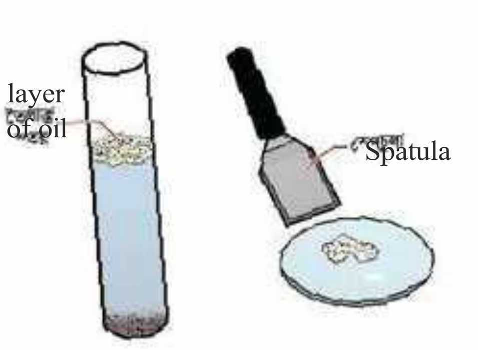


Fig 10.05: Froth Floatation Process.

4. Again shake the corked test tube well.
5. Taking some foam into the watch glass with a spatula examine whether there 1s any ore.
6. Sand sinks to the bottom of the test tube and ores float to the surface of the test tube.

Magnetic Separation Method

The process is used if either of the ores or gangue has magnetic property. Crushed ores are passed through a plastic conveyor belt. The outer wheel of the conveyor belt has the magnetic property. It attracts the magnetic ores or gangue and they are gathered below and near the wheel. The nonmagnetic portion of the mix gathers separately a little afar. As a result, the ore 1s separated from the gangue.

The process is applied to separate the magnetic ores like chromites $FeO.Cr_2O_3$, rutile TiO_2 etc.

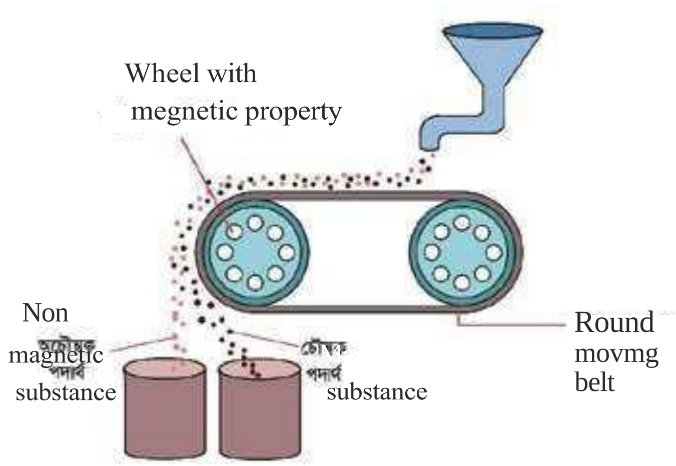


Fig 10.06: Megnetic Seperation.

Chemical Method:

This method is applied if a particular substance undergoes a reaction with either of the ores or gangue. For example, to obtain aluminium oxide ores from bauxite, chemical method is applied. Bauxite contains a mix of iron oxide, titanium oxide, sand, impurities etc. Add sodium hydroxide solution.

(NaOH) with bauxite ($Al_2O_3.2H_2O$) and heating that up to 1500-2000°C will produce sodium aluminate (NaAlO):

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

When hot sodium aluminate is let to react with water, it produces aluminium hydroxide and sodium hydroxide. Sodium hydroxide is dissolved while Aluminium Oxide is collected in the container as residue.

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

Heating the separated aluminium hydroxide at 1100°C will produce pure aluminium oxide and water.

$$2Al(OH)_3 \xrightarrow{1100°c} Al_2O_3 + 3H_2O$$

Aluminium Hydroxide Aluminium Oxide

This pure aluminium oxide is the output of condensation.

Conversion of Condensed Ore to Oxides: Condensed ore converts into metal oxide by calcinations or roasting.

Calcinations of Ores: If condensed ore is heated at temperature below the melting point in the absence of air, organic substances and moisture will be removed from the ore. This process is called calcinations. The calcinations enforce water, carbonate, bi-carbonate, hydroxide like impurities to be removed in the form of carbon dioxide or water. If these impurities are not removed at this stage, it will be tough to remove later.

$$Fe_2O_3.\ 3H_2O \longrightarrow Fe_2O_3 + 3H_2O \qquad =\text{heat}$$

$$ZnCO_3 \longrightarrow ZnO + CO_2$$

$$\longrightarrow CaO + CO2$$

Roasting: Generally, roasting is applied for sulfide ores. If sulfide ore is heated at temperature below the melting point in presence of air, organic substances and moisture will be removed from the ore as oxides.

$$2PbS + 3O_2 \longrightarrow 2PbO + 2SO_2$$

$$2ZnS + 3O_2 \longrightarrow 2ZnO + 2SO_2$$

iv. Conversion of Metallic Oxides to Free Metals

The metallic oxides obtained from the calcinations and roasting needs to undergo a reduction reaction to extract the metal. The reduction can be done in various ways like reduction through electrolysis, carbon reduction method and self-reduction etc. The position of the metal in the series of metal's reactivity determines the method. Below is given a table for your convenience to understand the methods easily:

Table 10.01: Reactivity Series of Metal

Metal's Position in the Reactivity Series	Metal	Reduction Method
Highly reactive metals at the top rankings	K	Reduction is done through Electrolysis
	Na	
	Ca	
	Mg	
	Al	
Medium standard reactive metals at the mid level rankings	Zn	Reduction is done through Carbon Reduction
	Fe	
	Pb	
Less reactive metals at the bottom rankings	Cu	Reduction is done through Self Reduction
	Hg	
	Ag	
Non-reactive metals at the fag end of rankings	Pt	Found in pure form
	Au	

Reduction by Electrolysis: The top ranking metals in the reactivity series like K, Na, Ca, Mg and Al undergo reduction by electrolysis. The Aluminium extraction from Aluminium oxide by electrolysis is described below.

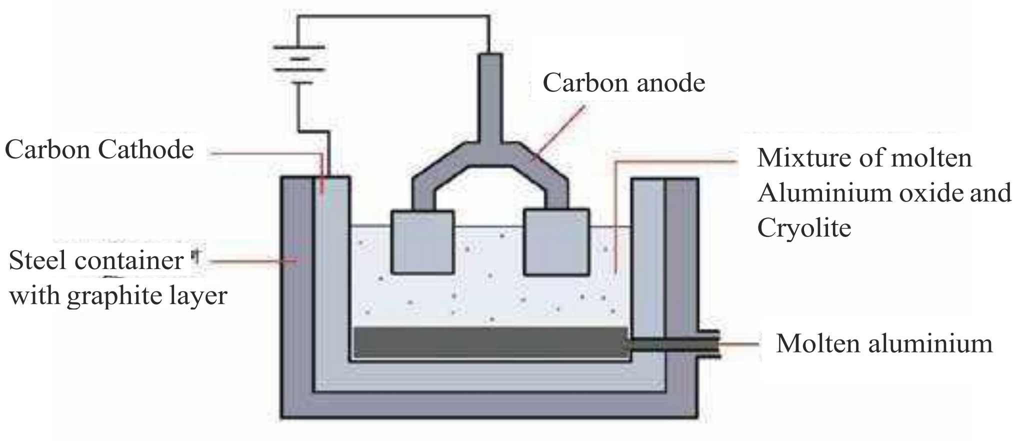
Solid aluminium oxide needs to be melted into liquid first. Aluminium oxide melts at 2050°C. To raise the temperature so high is very tough. If aluminium oxide is added with cryolite (Na_3AlF_6), it melts at 800°C-1000°C. The melted $Al_2 0_3$ consists of AP+and 0^{2-} ion.

$$\longrightarrow 2Al3+ + 30^{2-}$$

A steel container with graphite carbon layer is necessary in the method. The mixture of aluminium oxide and cryolite is taken in the container and some carbon rods are dipped in the mixture in a way so that they do not touch the steel container. The steel container is connected to the negative charge of the battery and the carbon rods are connected to the positive charge. Once the electric conduction starts, the electrolysis starts too. In the electrolysis, 0^{2-} donates electrons at the anode and produces 0_2 gas. AP+present in the solution accepts the electron at the cathode and turns into Al metal.

$6O^{2-}$ ——— 302 + 12e- (Anode reaction)

$2Al^{3+} + 6e^-$ ——— 2Al (Cathode reaction)



Figl0.07: Aluminium Extraction.

Carbon Reduction Method

Metal is extracted by heating carbon along with metallic oxide. For example, Zn from ZnO, Fe from FeO, Pb from PbO, or Cu from CuO are extracted this way.

ZnO + C ——— Zn+ CO

FeO + C ——— Fe+ CO

PbO + C ——— Pb+ CO

CuO + C ——— Cu+ CO

This method is called carbon reduction. The mid level position holder metals in the reactivity series are extracted in this method.

Individual Task

Assignment for Learners: Extraction of lead from lead oxide.

Ingredients: yellow color lead oxide, a piece of white paper, Bunsen burner, match stick

Caution: the vapors of lead or lead oxide is poisonous. Do not touch it directly with your hands, Do not breath in this vapor.

Procedure:

i. Lower down the flame of the burner.

ii. Bum a match stick in a way as to leave no residue of Gunpowder.

iii. Wet the burnt out part of the match stick and then add a bit of led oxide to it.

iv. Hold the led oxide part of the stick on the burner and observe whether a small point of bright gray coloured molten lead is formed or not.

v. Cool the stick. Put it on the white paper and find out the lead particle. If necessary, use a lens. If you do not get the lead particle, follow the procedure ii-iv again.

Comment

i. State the reason for dipping the match stick in water.

ii. Was there any chemical reaction in that action? Show reasons for your answer.

iii. Where did the carbon come from to free the lead?

iv. Write down the equation of the reaction using formula and words.

v. Will you get the same result if you use copper, iron or zinc oxide instead of lead? Show reasons.

Auto-reduction

In the case with the oxides of metals positioned at the lower part of the reactivity series like Cu, Hg and Ag, only heating instead of any reductant can conduct the reduction reaction. For example, the ore of mercury can be reduced in the following way:

$$HgS + 0_2 \longrightarrow Hg(l) + S02$$

$$2HgS + 30_2 \longrightarrow 2Hg0(s) + 2S0z(g)$$

$$2Hg0(s) + HgS(s) \longrightarrow 3Hg(l) + S0z(g)$$

(v) Purification of Metals

The metals obtained from the above reduction methods are not fully pure. They also contain impurities. Some methods are used to purify them.

The Method of Adding a Smelting Agent

Some impurity still remains with the metal extracted after reduction. The substance that is added to purify it from the impurity is called a smelting agent. If the impurity is alkaline, acidic smelting agent (SiO) will be added and if they are acidic, alkaline smelting agent will be added. Smelting agent and impurity combine together into slag. Since slag is insoluble, it is separated from the upper layer of the solution of molten metal. Even the smelting process does not give a pure metal. The metal is purified by electrolysis.

Purification by Electrolysis

In purification by electrolysis, the impure metal is used as an anode a rod of the same metal in pure form is used as a cathode. The salt solution of the metal that is to be purified is used as an electrolytic solution. When electricity is passed in the cell, the atom of the metal from the anode donates an electron which enters the solution as an ion. On the other hand, metallic ion accepts the electron and adds to the pure metal at the cathode. The method is used for copper and other metals. The application of the method in purification of copper is described below.

Purification of Copper by Electrolysis

<r,

Copper obtained from reduction method is 98% pure. Electrolysis can yield

99.9% pure copper. For this, the aqueous solution of $CuSO_4$ is taken in a container. The metallic rod that needs to be purified connected to the positive charge of a battery is put in the container. It acts as an anode. A rod of pure copper is connected to the negative charge of the battery and put in the cell as a cathode. Usually, the impure copper rod is thick and the pure rod is thin.

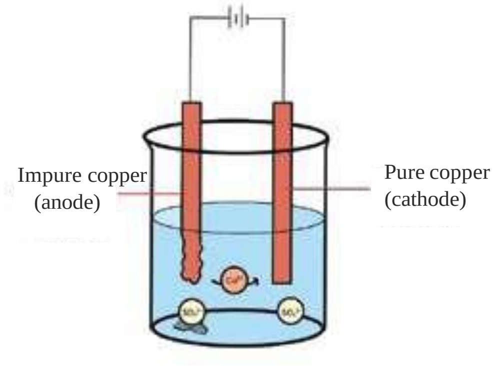


Fig 10.08: Purification of impure copper through electrolysis.

Now, as electricity is passed in the cell from the battery, the Cu^{2+} ion from the impure rod goes into the solution. From the solution, the Cu^{2+} goes to the cathode and gathers with the pure rod as Cu. Oxidation reaction occurs at the anode and reduction reaction occurs at the cathode.

Cu(s) ———— Cu^{2+} + ze- (Cu^{2+} goes to the solution from the impure copper at the anode)

cu^{2+} + ze- ———— Cu(s) (Cu^{2+} joins the pure copper cathode from the solution)

Extraction of Iron:

Iron is an important metal. Hematite (Fe203) is an important ore of iron. Iron is primarily extracted in three stages:

(1) Concentration

(2) Calcination/ Thermal oxidation, and

(3) Iron is extracted in the furnace by smelting. Figure 10.09

Several chemical reactions occur m this process:

Fe2O3 + 3C ———— Fe + 3CO

3Fe2O3 + CO2 ———— ZFe2O3 + CO2

Fe2O4 + CO2 Fe+ CO2

CaCO3 ———— CaO + CO2

CaO + SiO2 CaSiO3(Molten slag)

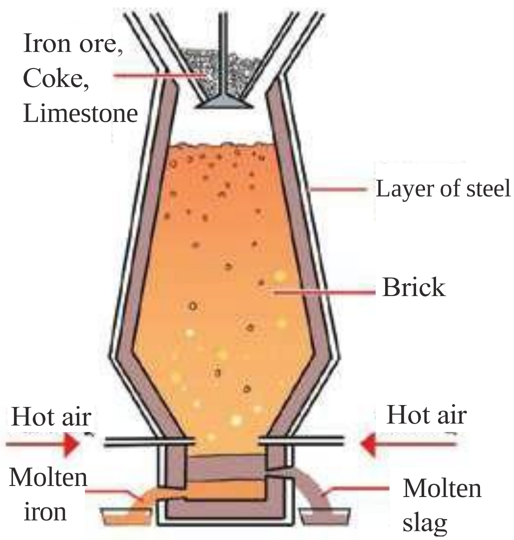


Fig 10.09: Iron extraction in blast furnace.

Group Assignment

1. The melting point of sodium is 801°C. The melting point of the mixture of sodium chloride 40-42% and calcium chloride 58-60% is about 600°C.Consider the above information and describe a method of sodium extraction. You will consider the following issues:

- Expenses of smelting
- If the mixture is used, will sodium and calcium be free simultaneously?
- Environmental pollution by the products of the reaction.

2. The melting point of aluminium oxide is 2050°C. The melting point of aluminium oxide and cryolite (Na_3AlF_6) is 800-1000°C. Consider the above information and describe method of aluminium extraction.

Additionally, you will consider:

- Expenses of smelting
- If the mixture is used, will sodium and calcium be free simultaneously?
- Environmental pollution by the products of the reaction.

3. What kind of environmental pollution is caused by the byproduct gas of copper extraction? How do you prevent this kind of harm (acid rain)? How do you think this gas may be used profitably without causing harm to the environment?

Metal	Ore	Extraction Method	Remarks
Mercury	Cinnabar (HgS)		
Zinc	Zinc blend (ZnS)		
	Calamine (ZnC03)		
Lead	Galena (PbS)		
Iron	Magnetite (Fe304)		
	Hematite (Fe203)		
	Limonite(Fe_2O_3.3H20)		
Copper	Copper pyrites ($CuFeS_2$)		
	Celcoisite (Cu_2S)		
Aluminium	Bauxite (Ab03. $2H_2O$)		
Sodium	Brine (NaCl)		
Calcium	Lime stone (CaC03)		

4. Look at the picture and answer the questions:

Write the equations of the probable reactions that will occur in the furnace in language and in formulas. You should consider: Silicon dioxide is present in the ore as gangue. The product of the reaction may undergo reactions with the reactants and other products.

5. Write the equation of the probable reaction of metal extraction from the ores presented in the table. Give opinion in favour of your answer in the remarks column.

10.3 Selected Alloys

Metal alloy is a mixture of metals made by mixing some molten metals and cooling them. The time between 5000 BC to 3000 BC is called the Copper age in history. The humans at this time used to make ornaments, weapons and machineries with copper. However, since copper is a soft metal, things made of copper did not last long. That is why, people in that period used to mix molten copper with molten tin. Then they used to cool the mixture and get bronze. Basically, bronze is an alloy. The solid substance obtained from mixing any molten metal or nonmetal with another molten metal and cooling the mixture is called an alloy. The invention of alloy by those ancient people was an epoch- making invention. The 3000 BC to 1000 BC is called the Bronze age. In this period, people used to make weapons and machineries with bronze. Alloys are more effective than metals in making different machineries. Iron and carbon are mixed to make steel which is another alloy. Again, mixing molten carbon, nickel and chromium, in hot, molten iron, we get stainless steel. The knives and scissors that doctors use in the hospitals are made of stainless steel. Molten copper and molten zinc together produce another alloy named brass. Brass is used in electric switches, utensils etc. Crockery are made of bronze which is an alloy of copper and tin. A mix of aluminium, magnesium, manganese and iron produces the alloy named duralmin which is used in making the body of planes.

Table 8.02: Different alloys and their uses.

Alloy	Ingredients and Composition	Use
Steel	Iron 99% Carbon 1%	Rail and wheels, engines, ships, vehicles, crane, weapons, knives, scissors, watch springs, magnets, agricultureal tools
Rust free steel (Stainless Steel)	Iron 74% Chromium 18% Nickel 8%	Knives, forks, kitchen sinks, containers of chemical industries, operation tools
Brass	Copper 65% Zinc 35%	Ornaments, ball-bearings, electric switches, door knobs, utensils
Bronze	Copper 90% Tin 10%	Melting machineries, plates, glasses
Duralumin	Aluminium 95% Copper4% Magnesium, Manganese and iron 1%	Body of airplanes, bicycle parts
24 carat gold	Gold 100%	Dentistry, coins, electronic connectors
22 carat gold	Gold 91.67% Copper and other metals 8.33%	Ornaments
21 carat gold	Gold 87.5% Copper and other metals 12.5%	Ornaments

You have learned that alloys are compositions of vanous metals. These compositions do not contain equal amounts of the metals to mix. In alloys, one metal is the representative metal while the other metals are non-representative metals. For example, in bronze, the representative metal copper is 65% while there is 35% zinc. The alloy is named after the representative metal. Steel has 99% iron and 1% carbon. Therefore, steel is called the alloy of iron. In the same way, brass is 90% copper and 10% tin which makes it an alloy of copper. Again, in brass, there is 65% copper and 35% zinc. Therefore, brass is also copper's alloy.

10.4 Symptoms, Causes and Prevention of Corrosion of Certain Metals and Alloys

If things made of iron or iron alloy are left in the open for a long time, their surfaces produce a reddish brown substance. This substance is called rust. Iron decays by producing rust. Similarly, if things made of pure copper, brass or bronze are exposed to the air for a long time, a black/brown/green layer is created. This layer is called copper slag. Copper decays producing copper slag.

Generally, exposure of pure metals and their alloys to open air for a long time creates a different coloured substance which is known as corrosion of metals.

The substance created due to corrosion of iron is hydrated ferric oxide ($Fe_20_3.nH_20$). Differently coloured copper slag has different elements in them like cuprous oxide (Cu_20), cuprous sulfide or celcoisite (Cu_2S) etc. That is why; the copper slag does not have a specific formula. Some metals usuallydonate electrons to tum into positive ions when they are exposed to open air. Here, an oxidation reaction occurs. Some ingredient of the atmosphere accepts that electron and turns into a negative ion in a reduction reaction. Then, the positive and negative ion combines into a new compound. The new compound undergoes a reaction with the metal and corrodes the metal.

The rusting reaction on iron occurs very slowly and in steps. In one step, oxidation occurs and in another reduction occurs. It requires oxygen (OJ and water (H_20) from the atmosphere. Water of the atmosphere converts into H+and OH-.

$$\longrightarrow H^+ + OH^-$$

When iron comes in contact with H+of open air, it donates electrons and turns into Fe^{2+}. It is oxidation.

$$2Fe \longrightarrow 2Fe^{2+} + 4e^-$$

The electrons donated by Fe is accepted by 0_2 and H+to produce H_20 by reduction.

$$O_2 + 4H^+ + 4e^- \longrightarrow$$

At this stage, Fe^{2+}, H+and 0_2 undergo a reaction and produce $Fe^{3+}$and water.

$$4Fe^{2+} + 4H^+ + O_2 \longrightarrow 4Fe^{3+} + 2H_2O$$

Then, Fe^{3+}undergoes a reaction with OH- and produces $Fe(OH)_3$

$$Fe^{3+} + 3OH^- \longrightarrow Fe(OH)_3$$

This ferric hydroxide turns into hydrated ferric oxide or rust $Fe_20_3.3H_20$.

$$2Fe(OH)_3 \longrightarrow Fe_2O_3.3H_2O$$

Investigation

Experiment of the Formation of Rust

- Take four test tubes and mark them 1 to 4.
- Take the necessary measures to make them similar to the figure.
- Boil the water of test tube 3 for a minute and add 1 mL cooking oil or olive oil to the water. The oil will restrict the air from entering the water.
- Preserve the test tubes in this situation for a week and observe.

Keep testtubes for a week and observe

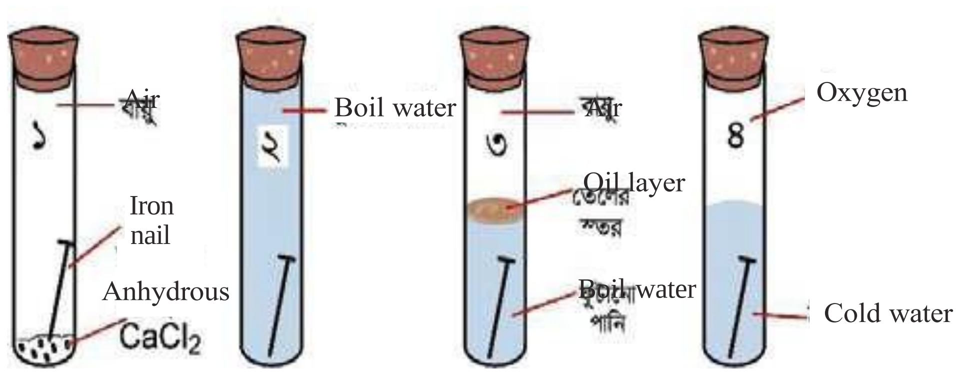


Fig 10.10: Experiment of rust on iron (Boil the water to remove dissolved oxygen from water).

Prevention of Metal Corrosion

Metals and their alloys do not corrode if they are not in direct contact with air. This can be done in various ways like painting, electroplating, galvanizing etc. The iron made doors and windows of our homes are painted so that they do not come in direct contact with air. We know that the less reactive metals usually do not undergo reactions with oxygen but the more reactive metals rapidly undergo reactions with oxygen of air and water. Therefore, a coating of a less reactive metal is laid on more reactive metals. Thus the more reactive metals are saved from corrosion. The coating can also be given by electroplating and galvanizing.

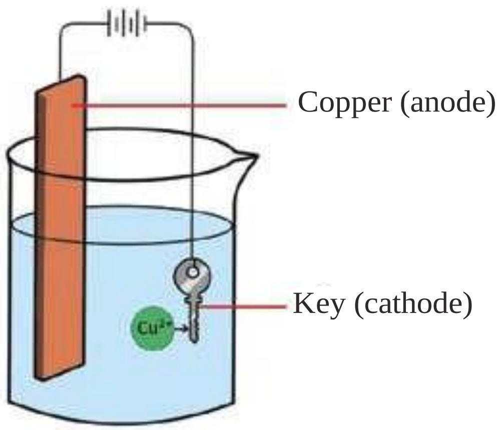


Fig 10.11: Copper electroplating on key.

Electroplating

Generally speaking, the method of laying a coating of less reactive metal on more reactive metals by electrolysis is called electroplating. In this method, the metal that will be the coating is connected to the positive charge of the battery and the metal that will get the coating is connected to the negative charge. Then the electroplating is done through electrolysis. For example, to add a coating of copper on iron, a solution of $CuSO_4$ is taken. The copper rod is connected to the positive charge while the iron rod is connected to the negative charge. As electricity is passed in the cell, Cu donates two electrons which go into the solution as Cu^{2-}.

$$Cu \longrightarrow cu^{2+} + 2e^- \quad \text{[Oxidation reaction]}$$

Now, this Cu^{2+} accepts two electrons from the Fe rod to become Cu and attaches to the Fe rod.

$$Cu^{2+} + 2e^- \longrightarrow Cu \quad \text{[Reduction reaction]}$$

Galvanizing : The method of laying zinc coating on any metal is called galvanizing. It does not require electrolysis. Zinc is coated anyway on any metal.

Recycling of Metals

The amount of every element is definite in the world. After using metallic products, instead of discarding them, they are sent to the factories for making that metal. Usable metal is made from that trashed metal. This method is called Recycling of metal. For example, trashed aluminium utensils are sent to aluminium factories to recycle new aluminium. Trashed iron is sent to steel mills for recycling. 21% of the total copper used in America is recycled copper. 60% of aluminium used in Europe is recycled aluminium.

10.5 Nonmetal Minerals

The nonmetal that are extracted from mines are called nonmetal minerals. Sulfur is a nonmetal mineral extracted from mines.

Sulfur

Sulfur is a yellow coloured substance. Sulfur mines are situated deep inside the earth. The substance is extracted from mines by the Frasch method. Three tubes with a single center is inserted into the depth of the sulfur layer which is known as a Frasch pipe. Sulfur melts at **l** I 5°C temperature. That is why super heated water is sent through the pipe to the layer so that the element melts. We know, at I atm pressure, the boiling point of water is I 00°C but if pressure is increased the boiling point rises up. Water at any temperature between 100-374°C temperature at extra pressure is called super heated water. Hot air is passed at 20-22 atm pressure through the centre tube. Molten sulfur comes out through the middle tube due to the effect of the pressure. It is collected **in** containers.

Use of Sulfur

Sulfur is used in large amounts in different industries.

1. It is used in the preparation of sulfuric acid.

ii. It is added to rubber to make rubber more sustainable. The method is called vulcanizing of rubber.

iii. Sulfanide is used in the preparation of various medicines. It kills bacteria. It is produced from sulfur.

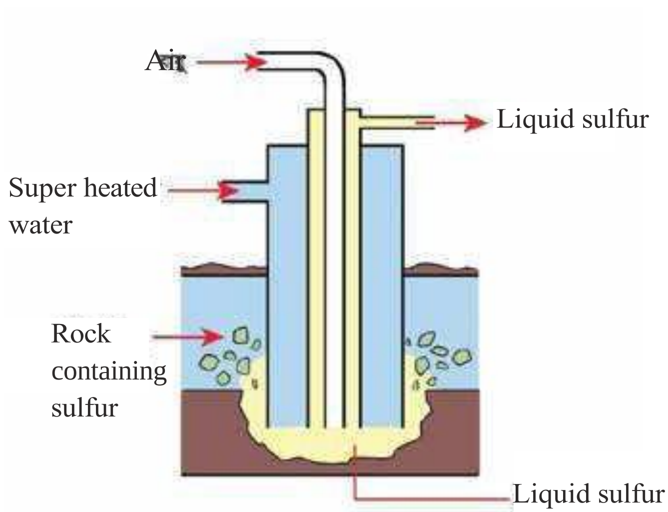


Fig 10.12: Frasch Method of Sulfur Extraction.

Sulfur Compounds

Some important sulfur compounds are discussed below.

Sulfur Dioxide

Sulfur undergoes a reaction with oxygen from air to produce sulfur dioxide.

$$S + O_2 \text{ ----------- } S0_2$$

Sulfur dioxide is a highly toxic gas with an acute odour which harms our body if it enters inside through our mouth and nose. It creates burning sensation in the eyes. If coal and petroleum contains sulfur, burning them produces $S0_2$ gas. This goes into the air. During rain, it undergoes reaction with water and produces sulfurous acid (H_2S0_3) which comes back on earth with rain water. This is acid ram.

$$SO_2 + H_2O \quad \text{———}$$

Sulfuric Acid

Of all the chemical, sulfuric acid is the highest used and so it is called the king of chemicals. Sulfuric acid is prepared from solid sulfur in the industries. The method of its preparation is called the Contact method.

The Contact Method: The method is described in the steps below:

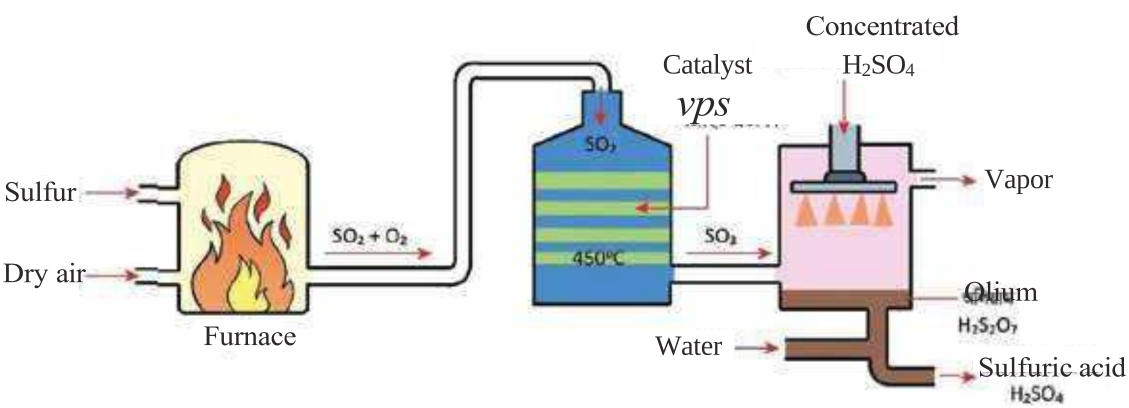


Fig 10.12: Preparation of Sulfuric Acid by Contact Method.

Step 1: Firstly, sulfur and dehydrated air are supplied in a furnace. Sulfur and oxygen undergo reaction here to produce sulfur dioxide.

$$S + O_2 \longrightarrow$$

Step 2: The SO_2 gas is channeled with some more oxygen to another furnace. This furnace has the temperature of 450-500°C and the catalyst vanadium penta-oxide. SO_2 gas and 0_2 gas undergo reaction here at that temperature to produce sulfur tri-oxide.

$$2SO_2 + O_2 \longrightarrow 2SO_3$$

Step 3: When SO_3 comes in contact with H_2O, H_2SO_4 is produced. However, direct reaction between them will produce gaseous H_2SO_4 which will create a state of dense fog. That is a hazard for the industries. Besides, getting liquid H_2SO_4 from this gaseous H_2SO_4 by condensation is a tough task. So, first, sulfur tri-oxide is absorbed in concentrated H_2SO_4 and that forms fuming sulfuric acid. (Fuming sulfuric acid is called oilium. The formula is H_2S_2Or)

$$H_2SO_4 + SO_3 \longrightarrow H_2S_2O_7$$

The fuming sulfuric acid is then driven into a reaction with H_2O which produces liquid sulfuric acid.

$$H_2S_2O_7 + H_2O \longrightarrow 2H_2SO_4$$

The Properties of Sulfuric Acid

Acid Property: Dilute or concentrated H_2SO_4 undergoes a reaction with any alkali to produce salt and water. This is called the acid property of sulfuric acid. For example, sulfuric acid reacts with calcium hydroxide and produces calcium sulfate salt and water.

H2S04	+	$Ca(OH)_2$	$\longrightarrow$	$CaS0_4$	+	$2H_20$
Sulfuric acid		Calcium hydroxide		Calcium sulfate		Water

Oxidation Property: If a lot of water is added to H_2SO_4, the solution is called dilute sulfuric acid. It does not have the oxidation property. But the concentrated sulfuric acid has the oxidation property. It oxidizes copper and produces copper sulfate and reduces itself into sulfur dioxide and water.

$$2H_2SO_4 \text{ (Concentrated)} + Cu \longrightarrow CuSO_4 + SO_2 + 2H_2O$$

Dehydrating Property: The substance that absorbs water from any compound is called a dehydrating agent. This property in a chemical is its dehydrating property. Dilute H_2SO_4 does not show any dehydrating property but this is not true in the concentrated case. The concentrated H_2SO_4 absorbs water from sugar ($C_{12}H_{22}O_{11}$). So, concentrated sulfuric acid is a dehydrating agent.

$$C_{12}H_{22}O_{11} + H_2SO_4 \longrightarrow 12C + H_2SO_4.11H_2O$$

Individual Task

- Take 2-3 mL lime water in a test tube and add a few drops of dilute sulfuric acid to it. Observe the change minutely and write the reasons. Write the probable equation.
- Take a pinch of potassium iodide KI in a test tube and add a few drops of concentrated sulfuric acid to it. Observe the change minutely and explain the reasons. Write the probable equation.

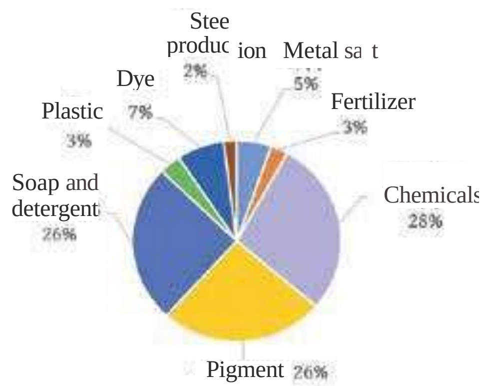


Fig 10.13: Usage of Sulfuric Acid.

- Take a spoonful of sugar $C_{12}H_{12}O_{11}$ in a test tube and add a few drops of concentrated sulfuric acid to it. Observe the change minutely and write the reasons. Write the probable equation. You need to be cautious when doing the experiment.
- What property of sulfuric acid (acid, oxidation and dehydrating properties) is exhibited in which of the above three experiments? Explain each of them.
- Follow the pie chart of figure 10.13 containing usage of sulfuric acid and based on your reading, analyze the economic significance of sulfuric acid in Bangladesh.

Exercise

Multiple Choice Questions

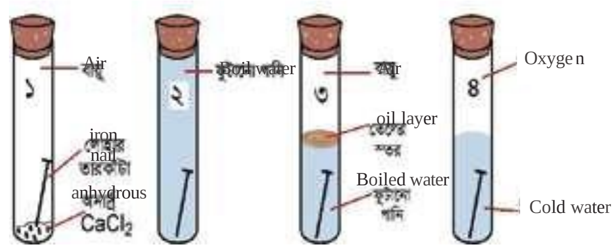
1. Which of the records in the table exhibits the characteristics of a metal?

	Melting Point	Boiling Point	Density
a.	1539	2887	7.86
c.	-113	45	0.79

	Melting Point	Boiling Point	Density
b.	-219	183	0.002
d.	117	888	1.96

Answer the questions 2 and 3 from the following stem:

A group of students were investigating rust. They kept nails in four test tubes according to the figure below:



2. Which of the test tubes nail will exhibit the highest amount of rust?
   a. 1st b. 2nd C. 3rd d. 4th

3. The decisions that can be reached from the experiment are:
   i. Rusting needs oxygen
   ii. Salt is acting as a catalyst
   iii. The presence of oxygen only does not confirm rust.

Which is correct?
   a. i and ii b. ii and iii
   c. i and iii d. i, ii and iii

4. Which of the following specimens of gold is hardest?
   a. 18 karat b. 21 karat
   c. 22 karat d. 24 karat

5. Sulfuric acid is added to water in drops during the dilution method because sulfuric acid-
   i. has a high hydration enthalpy
   ii. is a di-alkaline acid
   iii. is a corrosive substance

Which is correct?

a. 1 b. i and ii

c. ii and iii d. i, ii and iii

6. By absorbing SO_3 in 98% sulfuric acid, the required amount of water is added for dilution because sulfuric acid-

i. forms a deep mist with water vapors

ii. emits a huge amount of temperature on addition of water.

iii. is a dehydrating agent.

Which one is correct?

a. 1 b. i and ii

c. ii and iii d. i, ii and iii

7. Which of the followings is a gangue?

a. Al_2O_3 b. ZnS c. SiO_2 d. PbS

8. Cinnabar is an alloy to the metal

a. Mercury b. Copper c. Zinc d. Lead

9. What is the melting point of aluminium?

a. 2050°C b. 2000°C

c. 1000°C d. 950°C

10. Which of the following metals is more reactive?

a. Cu b. Zn

c. Fe d. Pb

11. Copper slag consists of

1. $CuCO_3$

11. $CuSO_4$

iii. $Cu(OH)_2$

Which one is correct?

a. i and ii b. i and iii

c. ii and iii d. i, ii and iii

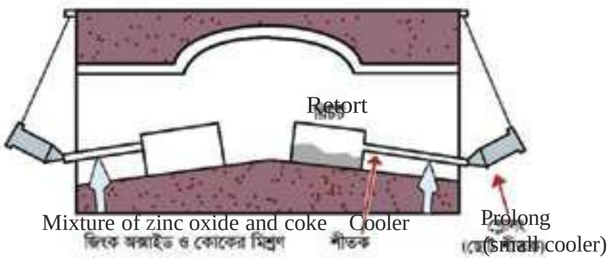
12. What is the composition of tin in bronze?

a. 90% b. 65%

c. 35% d. 10%

Creative Questions

1. Zn metal is extracted by taking the ZnO produced in heat reduction of calamine in a retort shown in the figure below. Produced metal is purified by electrolysis.



a. Write the chemical formula of calamine.
b. Explain heat reduction.
c. Explain the principal reaction occurring in the retort.
a. Write the chemical formula of calamine.
b. Explain heat reduction.
c. Explain the principal reaction occurring in the retort.
d. Evaluate why metal is extracted in three steps, not by electrolysis only.

2. Some minerals mixed with bauxite and calamine were found in a mine. A group of scientists under the leadership of Dr. Thomas extracted two metals in two different ways.

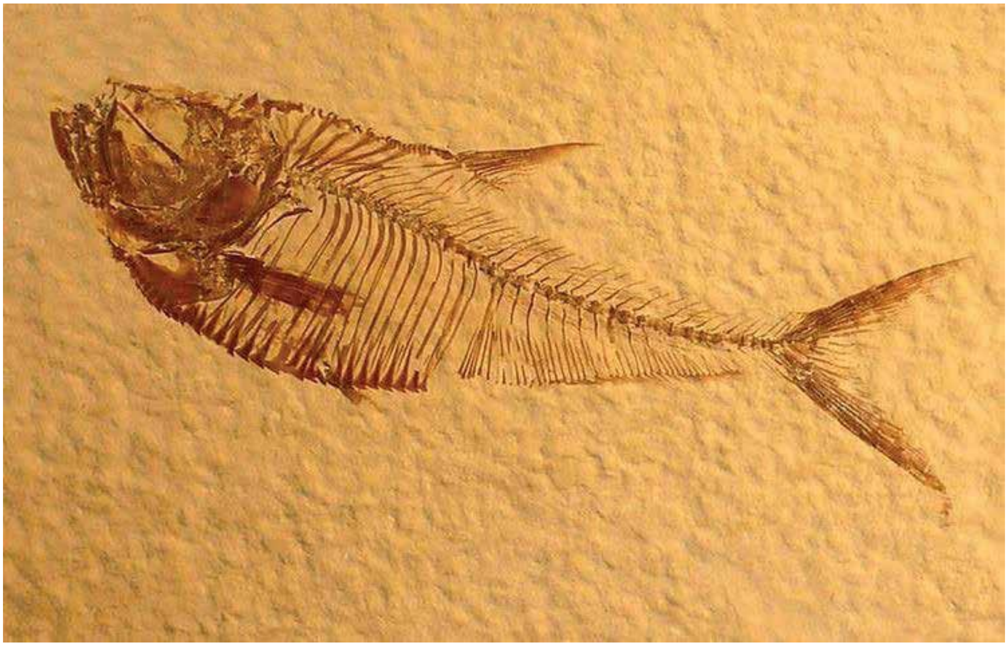
a. What is the mineral?
b. Explain, "Not every metal is an ore".
c. Explain the nature of oxides found in the dissociation of the second ore.
d. Write with logic the cause of extraction of two metals in two different ways.

3. If we bum an element belonging to Group 16 of the periodic table in open air, we get an oxide A. The oxide is a highly toxic gas with an acute odor. A can produce an acid B in the industrial sector if we apply Le Chatelier's principle.

a. What is an ore?
b. An oxide is acidic- explain.
c. Describe the method of preparation of an acid B.
d. The oxidation property of B acid depends on its density- explain with logic.

Chapter Eleven

Mineral Resources: Fossils



This Earth is about 4.54 billion years old. Many years ago, the appearance of this earth was not the same as it looks now. 500 or 600 million years ago, this earth was full of dense forests, low marshy lands and seas and oceans. Deceased animals, plants, lichens and fungus destroyed by natural disasters were amassed in the low-lying areas, which were later covered with silts. In this way, the remnants of these plants and animals got covered with thousands of feet of soil and layers of different kinds of rocks for millions of years. Extreme pressure, high temperature and different kinds of physical changes for millions of years resulted in the creation of coals, petroleum or natural gases which are called fossil fuels. Carbon is the major component of coal while the main element of petroleum is hydrocarbon, a compound made of carbon and hydrogen. Hydrocarbon is an organic compound. The organic compounds like Alcohol, Aldihyde, Kitone and Carboxylic Acid are mainly created from hydrocarbons. This chapter will focus on these elements.

By the end of this chapter we will be able to -

- explain the concept of fossil fuels
- explain petroleum as a mixture of organic compounds
- explain the uses of petroleum
- explain the variety and classification of hydrocarbons
- explain the characteristics and reactions for preparing saturated and unsaturated hydrocarbons and to differentiate between them
- describe the chemical reaction of preparing plastic products and synthetics and their uses
- mention the bad impacts of misusing plastic products on environment
- explain the merits, demerits and usage method of natural gas, petroleum and coal
- explain the method of preparing alcohol, aldihyde and organic acid from hydrocarbons
- use alcohol, aldihyde and organic acid
- carry out investigative work about the impacts of plastic products on environment
- distinguish between organic and inorganic compounds through experiments
- show awareness about the proper use of fossil fuels

11.1 Fossil Fuel

The ruins of plants and animals of ancient periods which are found underground are called fossil fuels. The remains of animals and plant-bodies corresponding to hundreds of millions of years have been discovered as fossils. Coals, natural gases and petroleum that we use as fuels are found as fossils under the ground. That is why, coals, natural gases and petroleum are called fossil fuels.

Hundreds of millions of years ago, there was a time when this world was full of forests, low marshy lands and seas where aquatic plants, phytoplankton (a kind of fungi living in water) and zooplankton (a kind of small creature living in water) were available. These types of plants and animals went under the soil because of massive natural disasters from time to time. They went more underneath the ground with the passage of time and they started going deeper into the soil gradually. As a result, pressure and temperature on them started to increase. In the absence of air, they underwent decay and chemical changes. Fossil fuels have been created from all types of tiny and gigantic plants and animals because of heat, pressure and chemical changes for hundreds of millions of years. Coals have been created from gigantic plants while petroleum has been created from phytoplankton, zooplankton and bodies of deceased animals. As this change goes on, petroleum turns into natural gas. So in some places both petroleum and natural gases are found together. For instance, petroleum has been traced along with natural gas in Haripur Gas Field of Bangladesh. As the main source of this fossil fuel is animal body, the main elements of these fuels are carbon and carbon compounds.

11.1.1 Natural Gas

The proportion of various components in natural gas generally varies based on its natural source. The major component of natural gas is Methane (80%). Moreover, Ethane (7%), Propane (6%), Butane and Isobutene (4%) and Pentane (3%) are also available in natural gas. But the natural gas so far discovered in Bangladesh contains 95-99% Methane.

11.1.2 Constituents of Petroleum and their Separation

Petroleum is generally available 5000 feet or even deeper into the layers of rocks. Sometimes, petroleum is accompanied by natural gas which puts a pressure on the upper surface of petroleum. When a well is dug, this natural gas helps the petroleum to come out into the upper surface of the earth. The Petroleum which is obtained directly from the well is called Crude Oil or Petroleum. This Crude Oil is opaque and sometimes has a bad smell because of the presence of some compounds of Sulphur. This Petroleum is mainly a mixture of different kinds of hydrocarbons and it is not directly useable. This Crude Oil is separated through the Fractional Distillation process based on boiling points.

Fractional Distillation is also a kind of distillation which contains some long columns for condensation of vapour. Again these columns are divided into different parts and the lowest part has the highest temperature. The higher the part is, the lower the temperature is. As a result, if the combination of more than one liquid is inserted into the lower portion of the Fractional Distillation columns after vaporisation through heating, the combination will go to the upper part of the columns. As the upper parts have a lower temperature, each component of the combination of the liquid is separated into different parts of the Fractional Distillation columns according to the boiling points. Petroleum is a combination of different hydrocarbons and

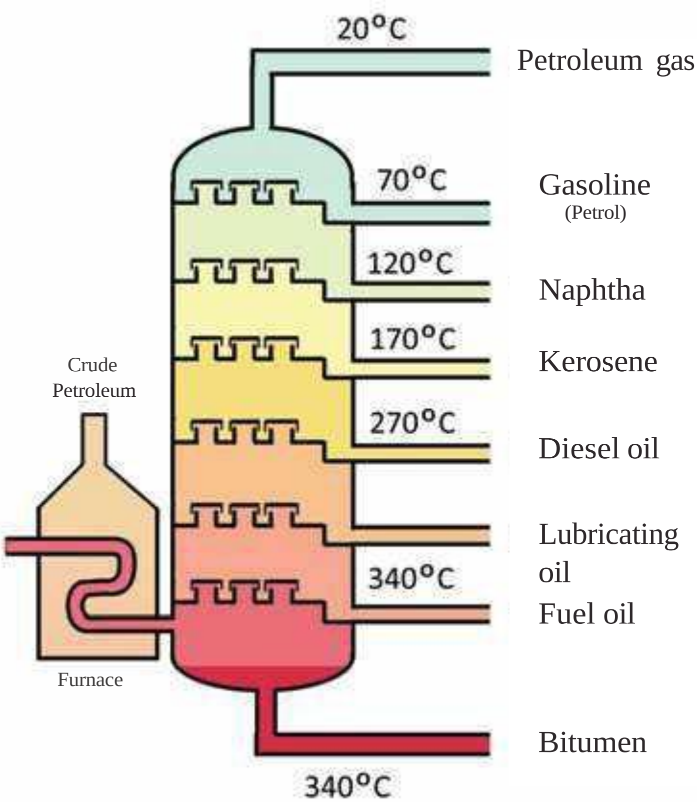


Fig 11.01: Fractional Distillation of petroleum.

they have different boiling points. As stated earlier, crude oil is opaque but if it is separated through fractional distillation, this crude oil will be split into different parts like petrol, gas, petroleum, naphtha, kerosene, diesel, paraffin wax and pitch etc which can be used for different purposes. Names of different parts obtained from the fractional distillation columns, boiling points of different parts, number of carbons available in the hydrocarbons of different parts and their uses are described below:

(i) **Petroleum Gas:** The boiling point of this part is 0°C to 20°C. 1 to 4 carbons are available in the molecule of the hydrocarbons of this part. Petroleum contains 2% of petroleum gas which is liquefied after putting pressure on it and then it is filled in cylinders. This gas named Liquefied Petroleum Gas (LPG) is used in producing heat for cooking and other purposes.

(ii) **Petrol (Gasoline):** The boiling point of this part is 21°C to 70°C. 5 to 10 carbons are available in the molecule of the hydrocarbons of this part. Petroleum contains 5% of petrol which is also called gasoline. Gasoline is used as fuel in vehicle engines.

(iii) **Naphtha:** The boiling point of this part is 71°C to 120°C. 7 to 14 carbons are available in the molecule of the hydrocarbons of this part. Petroleum contains 10% of naphtha. It is used as fuel and in producing different chemical substances and other necessary products in petrochemical industries.

(iv) Kerosene: The boiling point of this part is 121°C to l 70°C. 11 to 16 carbons are available in the molecule of the hydrocarbons of this part. Petroleum contains 13% of Kerosene which is used as fuel of jet engines.

(v) Diesel: The boiling point of this part is 171°c to 270°C. 17 to 20 carbons are available in the molecule of the hydrocarbons of this part. It is used as vehicle fuel, lubricant and dissolvent.

(vi) Paraffin Wax: The boiling point of this part is 271°C to 340°C. 20 to 30 carbons are available in the molecule of the hydrocarbons of this part. It is used in producing toiletries and Vaseline.

(vii) Pitch: The boiling point of this part is above 340°C. More than 30 carbons are available in the molecule of the hydrocarbons of this part. It is used in road construction.

11.2 Hydrocarbons

Hydrocarbon is a compound containing only carbon and hydrogen. Example: Methane (CH$_4$ Ethene (CH$_2$ $_4$ Cyclohexane (CHz)$_6$ $_1$, Benzene (CH$_6$ $_6$ etc. You can see that the compounds have no molecule other than carbon and hydrogen.

Hydrocarbons are of mainly two types: (i) Aliphatic Hydrocarbon and (ii) Aromatic Hydrocarbon

11.2.1 Aliphatic Hydrocarbons

The word 'Aliphatic' means something fatty. It is called Aliphatic Hydrocarbon because this type of hydrocarbon is mainly obtained from animal fat. Aliphatic Hydrocarbons are of two types - (i) Open Chain Hydrocarbon and (ii) Closed Chain Hydrocarbon.

(i) Open Chain Hydrocarbon

These hydrocarbons are called Open Chain Hydrocarbons because two terminal carbons of their carbon chains remain in an open state. Example:

Butane: CH_3-CH_2-CH_2-CH_3, Ethene: CH_2=CH_2

Again these Open Chain Hydrocarbons are of two types - Saturated and Unsaturated.

(a) Saturated Open Chain Hydrocarbons: The Open Chain Hydrocarbon which has only carbon-carbon single bond (C-C) is called Saturated Open Chain Hydrocarbon. Example:

Propane: CH_3-CH_2- CH_3, Pentane: CH_3-CH_2-CH_2- CH_2-CH_3

(b) Unsaturated Open Chain Hydrocarbons: The Open Chain Hydrocarbon which has one or more than one carbon-carbon double-bond or carbon-carbon triple-bond is called Unsaturated Open Chain Hydrocarbon. Example: Ethyne (CH=CH)

Unsaturated Open Chain Hydrocarbons may have carbon-carbon single bond besides carbon double-bond or triple-bond.

Based on double-bond or triple-bond, Unsaturated Open Chain Hydrocarbons are again divided into two types- Alkene and Alkyne. In this chapter we will learn about Alkene and Alkyne in details.

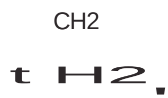
Carbon-Carbon double-bond is present in Alkene. Example: Propene (CH_3-CH= CH_2)

Carbon-Carbon triple-bond is present in Alkyne. Example: Ethyne (CH=CH), Propyne (H_3C-C =CH)

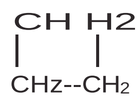
(ii) Closed Chain Hydrocarbons

In this type of Hydrocarbons, the terminal carbons of the carbon chain are connected together and make a sphere or a circle. Chains of different sizes make circles of different sizes. Like Open Chain Hydrocarbons, they may also be of two types, namely Saturated and Unsaturated Closed Chain Hydrocarbons.

Saturated Closed Chain Hydrocarbon:

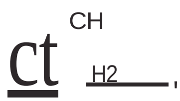


Cyclopropane

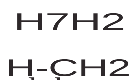


Cyclobutane

Unsaturated Closed Chain Hydrocarbon:



Cyclopropene



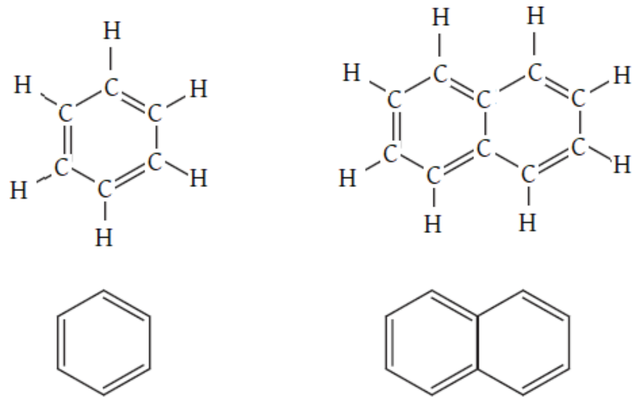
Cyclobutene

Closed Chain Hydrocarbons are sometimes called Alicyclic Hydrocarbons.

11.2.2 Aromatic Hydrocarbons

The word 'Aromatic' is taken from the Greek word Aroma which means scent or fragrance. This was so named because the first aromatic compounds were sweet-smelling. Benzene (CH or Naphthalene (CH is the instance of Aromatic Hydrocarbons.

The aromatic compounds are generally 5, 6 or 7 membered co-planer cyclic compounds. It has alternative double bonds that means there is a carbon-carbon single bond and a then carbon-carbon double bond.



Benzene Naphthalene

Fig 11.02: Aromatic compounds Benzene (CH and Naphthalene (C H

In this chapter our discussion will be limited to mainly aliphatic hydrocarbons.

Homologous Series: The compounds, which have close similarities in their physical and chemical characteristics because of the same active radicals, belong to the same class. These compounds constitute the Homologous Series. All members of the same homologous series can be shown by a common formula. For instance, all compounds of the Alkane homologous series may be presented by C_0H_{20}. Examples of different homologous series are given below:

Table 11.01: Homologous Series.

Homologous Series	General Formula	Names and formulas of some initial members
Alkane	CnH2n+2	Methane (CH_4), Ethane (C_2H_6), Propane (C_3H_8), Butane (C_4H_{10})
Alkene	C_nH2n	Ethene (C_2H_4), Propene (C_3H_6)
Alkyne	C_nH2n-2	Ethyne (C_2Hz), Propyne (C_3H_4)
Alcohol	C_nH2n+10H	Methanol (CH_3-0H), Ethanol ($C_2H_5$0H)
Aldehyde	CnH2n+1CHO	Ethanal (CH_3-CHO), Propanal (C_2H_5CHO)
Carboxylic Acid	CnH2n+1COOH	Ethanoic Acid (CH_3COOH), Propanoic Acid (C2H_5COOH)

11.3 Saturated Hydrocarbons: Alkanes

The hydrocarbons which have carbon-carbon single bond in their carbon chain are called Alkanes. Common formula for alkanes is CnHn+ (n = **1**, 2, 3, 4,..). The name of the first member of this group is Methane. As it is the first member, its common formula n = **1** and its formula is CH_4. The name of the second member (n = 2) is Ethane and its formula is CH It is very difficult to break the carbon-carbon and carbon-hydrogen bond of alkane. That is why, alkanes are chemically inactive to a great extent. For this reason, they are called Paraffin which means lacking affinity. Alkanes generally participate in chemical reactions only under high temperatures, high pressure, or in the presence of a strong catalyst.

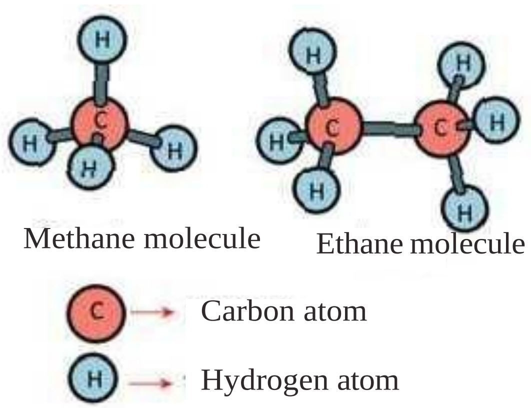


Fig 11.03: Methane and Ethane.

Naming of Alkanes:

Naming of Alkanes in the IUPAC system is as follows:

(i) In straight chain Alkanes, one-carbon Alkanes (CH_4) are named as Methane, two-carbon Alkanes (CH_3-CH_3) as Ethane, three-carbon Alkanes (CH-CH-CH as Propane and four-carbon Alkanes (CH-CH CH-CH as Butane.

(ii) In alkanes, naming is completed by adding (ane) with the ending words formula identifying the Greek number of their carbon number.

Alkyl Group

The single valance radical formed after removing one hydrogen atom from the Alkane is called an Alkyl Radical. As the common formula of Alkane is CnHn+ we can write R-H instead of CnHn+ ifwe want to write it by using Alkyl Radical R where R = CnHn+i·Alkyl Radicals are named by omitting (ane) and adding (yl) with the last part of the name of Alkane from which a hydrogen atom was removed for formation of Alkyl Radicals. For instance, we can say Methyl (CH_3-) from Methane (CH_4), Ethyl (CH_3-CH_2-) from Ethane (C_2H_6), Propyl (CH_3-CH_2-CH_2-) from Propane, Butyl (CH_3-CH_2-CH_2-CH_2-) from Butane, Pentyl (CH_3-CH_2-CH_2-CH_2 CH_2-) from Pentane, etc.

Table 11.01: Carbon numbers, names and formula of Alkanes.

Carbon number of Alkane	Name of Alkane	Formula of Alkane
1	Methane	CH_4
2	Ethane	CHrCH3
3	Propane	CHrCH2-CH3
4	Butane	CHrCH2-CH2-CH3
5	Pentane	CHrCH2-CH2-CH2-CH3
6	Hexane	CHrCH2-CH2-CH2-CH2-CH3
7	Heptane	CHrCH2-CH2-CH2-CH2-CH2-CH3
8	Octane	CHrCH2-CH2-CH2-CH2-CH2-CH2 -CH3
9	Nonane	CHrCH2-CH2-CH2-CH2-CH2 -CH2-CH2-CH3
10	Decane	CHrCH2-CH2-CH2-CH2-CH2-CHz-CHz-CH2-CH3

Preparation of Alkane

From carbon-di-oxide: Methane and water are produced when hydrogen is heated with carbon-di-oxide at 250°C temperature in the presence of nickel catalyst.

$$\underset{\text{Carbon-di-oxide}}{CO_2} + \underset{\text{Hydrogen}}{4H_2} \xrightarrow[250°C]{Ni} \underset{\text{Methane}}{CH_4} + \underset{\text{Water}}{2H_20}$$

From Alkene and Alkyne: Ethane is produced when hydrogen is heated with ethene and ethyne at 180°C- 200°C temperature in presence of nickel catalyst.

$$\underset{\text{Ethene}}{CH2{=}CH2} + \underset{\text{Hydrogen}}{H2} \xrightarrow[180°\ C\text{-}200°\ C]{Ni} \underset{\text{Ethane}}{CHrCH3}$$

$$\underset{\text{Ethyne}}{CH{=}CH} + \underset{\text{Hydrogen}}{2H2} \xrightarrow[180°\ C\text{-}200°\ C]{Ni} \underset{\text{Ethane}}{CHrCH3}$$

From Decarboxylation Reaction: Methane and sodium carbonate are produced when sodium ethanoate is heated with sodium hydroxide in presence of calcium oxide.

$$\underset{\text{Sodium Ethanoate}}{CH_3COONa} + \underset{\text{Sodium Hydroxide}}{NaOH} \xrightarrow{Cao} \underset{\text{Methane}}{} + \underset{\text{Sodium Carbonate}}{Na_2CO_3}$$

Properties of Alkane

Physical Properties: Melting point, boiling point and the physical condition of Saturated hydrocarbons or alkane depends on the carbon number of alkanes. Its physical condition changes with the change of carbon numbers. As the boiling point of the saturated hydrocarbons with carbon number 1-4 is less than the room temperature, they remain in gaseous state. Boiling point of saturated hydrocarbons with carbon number 5-15 is greater than the normal room temperature. So they remain in liquid state. Boiling point of 5-carbon saturated hydrocarbon pentane is 36.1°C. Saturated hydrocarbons which have more than carbon number 16 are solid.

Chemical Properties: As stated earlier, Alkanes are chemically inactive to a great extent. So they do not react with acids, bases, oxidants or reductants. However, they take part in some chemical reactions.

Reaction with Chlorine

Tetrachloro Methane is produced when Chlorine is mixed with Methane in the presence of Ultra Violet (UV) light. This reaction is accomplished in four phases.

CH_4	+	Cl_2	$\xrightarrow{UV}$	CH_3Cl	+	HCl
Methane		Chlorine		Chloro Methane		Hydrogen Chloride
CH_3Cl	+	Cl_2	$\xrightarrow{UV}$	CH_2Cl_2	+	HCl
Chloro Methane		Chlorine		Dichloro Methane		Hydrogen Chloride
CH_2Cl_2	+	Cl_2	$\xrightarrow{UV}$	$CHC1_3$	+	HCl
Dichloro Methane		Chlorine		Trichloro Methane		Hydrogen Chloride
$CHC1_3$	+	Cl_2	$\xrightarrow{UV}$	$CC1_4$	+	HCl
Trichloro Methane		Chlorine		Tetrachloro Methane		Hydrogen Chloride

Combustion Reaction with Oxygen: Methane reacts with oxygen of air and thus carbon-di-oxide, water vapours and heat are produced. This heat is used in cooking.

	+	$2O_2$	$\longrightarrow$		+	H20	+	Heat
Methane		Oxygen		Carbon-di-oxide		Water		Heat

11.4 Unsaturated Hydrocarbons: Alkenes and Alkynes

Alkenes

The bio-compound which has at least one carbon-carbon double bond in its carbon chain is called Alkene. General formula of Alkene is C_nH_{2n}. Alkene is sometimes called Olifin (taken from Greek word Olefiant = oil forming) because its lower members (Ethene, Porpene etc.) produces an oily substance in a reaction with halogen (Cl_2, Br).

Naming of alkenes

In IUPAC system alkenes are named by omitting (ane) and adding (ene) with the names of Alkanes.

Alkane	Alkene	Formula of Alkene
Ethane	Ethene	CH2=CH2
Propane	Propene	CHrCH=CH2

Preparation of Alkene

From Ethyl Chloride: Ethene, sodium chloride and water are produced when water solution of sodium hydroxide is heated with Ethyl chloride.

$$\underset{\text{Ethyl Chloride}}{CH_3\text{-}CH_2Cl} + \underset{\text{Sodium Hydroxide}}{NaOH} \longrightarrow \underset{\text{Ethene}}{CH2{=}CH2} + \underset{\text{Sodium Chloride}}{NaCl} + \underset{\text{Water}}{}$$

From Ethanol: Ethene and water are produced when deep sulphuric acid is heated with Ethanol.

$$\underset{\text{Ethanol}}{CHrCH2\text{-}0H} \longrightarrow \underset{\text{Ethene}}{CH2{=}CH2} + \underset{\text{Water}}{H20}$$

Chemical Properties of Alkene

Due to carbon-carbon double bonds in Alkenes, they are chemically very active. Because one of the bonds is comparatively weaker though another one is stronger, during reaction, the weak bond breaks and takes part in the addition reaction.

Addition of hydrogen: Ethane is produced when Ethene is heated with Hydrogen at 180-200°C temperature.

$$\underset{\text{Ethene}}{CH2 = CH2} + \underset{\text{Hydrogen}}{H2} \xrightarrow[\text{rno-200°c}]{\text{Ni}} \underset{\text{Ethane}}{CHrCH3}$$

Addition of water: At high temperature and high pressure alkene reacts with water vapours in the presence of phosphoric acid to produce alcohol.

$$\underset{\text{Ethene}}{CH_2 = CH_2} + \underset{\text{Water}}{H20} \xrightarrow[\text{phosphoric acid}]{\text{high temperature and high pressure}} \underset{\text{Ethanol}}{CHrCH20H}$$

Alcohol is used as an environment-friendly fuel and a solvent in petroleum industries. So this reaction is very significant.

Addition of bromine: When a solution of red coloured bromine is added to Ethene, Ethene reacts with the solution and produces dibromo ethane. In this reaction the red colour of bromine disappears. All unsaturated hydrocarbons show this reaction. This reaction proves that ethene is an unsaturated compound.

$$\underset{\text{Ethane}}{CH_2 = CH2} + \underset{\text{Bromine}}{Br_2} \longrightarrow \underset{\text{Dibromo ethane}}{CH_2Br\text{-}CH_2Br}$$

Oxidization by Potassium Permanganate (Active or Nascent Oxygen): Ethylene glycol is produced when pink coloured solution of potassium permanganate and potassium hydroxide are added to ethene. In this reaction the pink colour of potassium permanganate disappears. All unsaturated hydrocarbons show this reaction. This reaction proves that ethene is an unsaturated compound.

$$\underset{\text{Ethane}}{CH_2 = CH_2} + \underset{\text{Water}}{H_2O} + [O] \xrightarrow[\text{KOH}]{\text{KMn04}} \underset{\text{Ethylene glycol}}{CH_20H\text{-}CH_20H}$$

Polymerization of Ethene: Polythene is produced when ethene is heated at 1000 atm and 200°C temperature in the presence of a little amount of oxygen. This reaction is called polymerization and in this reaction, Ethene is called monomer.

$$\underset{\text{Ethene}}{nCH_2 = CH2} \xrightarrow[\text{200°C temperature, a little amount of oxygen}]{\text{1000 atm}} \underset{\text{Polythene}}{(\text{-}CH2\text{-}CH2\text{-})n}$$

11.4.2 Alkynes

The bio-compound which has at least one carbon-carbon triple bond (-C=C-) in its carbon chain is called Alkyne. General formula of Alkynes is C_0H_{20-2}. Acetylene (CH=CH) is the smallest straight member of the Alkyne group.

Naming of alkynes

Alkynes are named by omitting (ane) and adding (yne) with the names of Alkanes. For example, the name of CH=CH is Ethyne, CH_3-C=CH is Porpyne, CH_3-C=C-CH_3 is Butyne-2.

Preparation of Alkyne

From Calcium Carbide: Ethyne and calcium hydroxide are produced when water is added to calcium carbide.

	+	$2H_20$	———	CH::::CH	+ $Ca(OH)_2$
Calcium Carbide		Water		Ethyne	Calcium Hydroxide

Chemical Properties of Alkyne

Alkyne has carbon-carbon triple bonds. One of the bonds is strong while the remaining two bonds are weak. The weak bonds of alkyne break up and take part in the addition reaction.

Addition of Hydrogen: You have already learnt that Ethane is produced when ethyne is heated with hydrogen at l 80°C- 200°C temperature the in presence of nickel catalyst.

CH::::CH	+ $2H_2$	$\xrightarrow[\text{1so-200°c}]{\text{Ni}}$	CHrCH3
Ethyne	Hydrogen		Ethane

Addition of bromine: When a solution of red coloured bromine is added to Ethyne, Ethyne reacts with the solution and produces tetra-bromo ethane. In this reaction the red colour of bromine disappears. This reaction proves that ethyne is an unsaturated compound.

CH=CH	+ $2Br_2$	———	CHBrz-$CHBr_2$
Ethyne	Bromine		Tetra-bromo ethane.

Addition of water: Ethanal is produced when 20% sulfuric acid and 2% mercuric sulphate are added to Ethyne at 80°C temperature.

$$\underset{\text{Ethyne}}{CH{::}CH} + \underset{\text{Water}}{H_20} \xrightarrow[80^0C]{20\%\ H_2SO_4,\ 2\%\ HgSO_4} \underset{\text{Ethanal}}{CH_3CHO}$$

11.s Alcohols, Aldehydes and Fatty Acids

11.5.1 Alcohol

The bio-compounds which have hydroxyl radicals (-OH) are called Alcohols. However, some compounds are not called Alcohol though they have hydroxyl radicals (-OH). Such as- Phenol (C_6H_5-OH). General formula of alcohol is $C_nH_{2n+1}OH$. The first member of this class is Methanol (CH_3-OH), second member is Ethanol (CH_3-CH_2-OH). Alcohols can be symbolized by R-OH, where R is the alkyl radical. The initial members of this class are colour-less liquid substances and mix with water in all proportions.

Naming: Alcohols are named by omitting 'e' and adding (ol) with the names of Alkanes. Example: Ethanol (CH_3CH_2OH).

Preparation of Alcohol

From Ethyl Bromide: Ethanol and sodium bromide are produced when liquid solution of sodium hydroxide is added with bromo ethane and heated.

$$\underset{\text{Bromo Ethane}}{CHrCH_2Br} + \underset{\text{Sodium Hydroxide}}{NaOH} \longrightarrow \underset{\text{Ethanol}}{CHrCH_20H} + \underset{\text{Sodium Bromide}}{NaBr}$$

11.5.2 Aldehyde

The bio-compounds which have aldehyde group (-CHO) are called aldehyde.

Naming: Aldehydes are named by omitting 'e' and adding (al) with the names of alkanes. For example, propanal (CH_3CH_2CHO). The name of the first member of this class is methanal (H-CHO).

Preparation of Aldehyde

Addition of water: Ethanal is produced when solution of 20% sulfuric acid and 2% mercuric sulfate are added to Ethyne at 80°C temperature.

$$\underset{\text{Ethyne}}{CH{=}CH} + \underset{\text{Water}}{H_20} \xrightarrow[SO^0C]{20\%\ H_2S04,\ 2\%\ HgS04} \underset{\text{Ethanal}}{CH_3CHO}$$

Fig 11.04: Different dead bodies of animals preserved in Formalin.

Formalin: 40% of the liquid solution of formaldehyde is called formalin. Formalin contains 40% Methanol and 60% water. Formalin is widely used in laboratories. It is used for preserving the dead bodies of different animals.

11.5.3 Organic acid or Fatty Acid

The compounds which have carboxylic group (-COOH) are called Organic acids or Fatty Acids. General formula of fatty acid is CnH_2n+_1COOH. It is symbolized by R-COOH in short.

Naming: Fatty Acids are named by omitting 'e' and adding (oic acid) with the names of Alkanes. Example: Ethanoic acid.

Preparation of Fatty Acids

From Ethanal: Ethanoic acid 1s produced when light sulfuric acid and potassium dichromate are added with ethanal. (At first, potassium dichromate reacts with sulfuric acid and produces nascent oxygen, which later reacts with ethanal and produces ethanoic acid.)

$$\underset{\text{Ethanal}}{CHrCHO} + \underset{\text{Nascent oxygen}}{[O]} \xrightarrow{K_2Cr_2O_7 + H_2SO_4} \underset{\text{Ethanoic acid}}{CHrCOOH}$$

Chemical Properties of Fatty Acids

Acidic Properties: All fatty acids are weak acids. Fatty acids are slightly ionized in liquid solution. Aqueous solution of fatty acids turns the blue colour litmus into red colour. Fatty acids produce salt and water in reactions with base/alkali. For example, ethanoic acid reacts with liquid solution of sodium hydroxide and produces sodium ethanoate salt and water.

$$\underset{\text{Ethanoic acid}}{CH_3COOH} + \underset{\text{Sodium hydroxide}}{NaOH} \longrightarrow \underset{\text{Sodium ethanoate}}{CH_3COONa} + \underset{\text{water}}{H_20}$$

Vinegar: 4% to 10% aqueous solution of ethanoic acid is called vinegar. Vinegar is used in making food and as food preservatives. As this solution is slightly acidic, when it is used on food no bacteria can grow. As a result food does not rot.

11.5.4 Preparation of alcohol, aldehyde and organic acids from hydrocarbons

You have learnt about different preparation processes of alcohol, aldehyde and organic acids. The main constituent of petroleum is hydrocarbon (alkane, alkene and alkyne) and alcohol, aldehyde and organic acids can also be prepared from this hydrocarbon.

(i) Saturated hydrocarbon or alkane reacts with halogen and in presence of sunlight and produces alkyl halide. You have already learnt how chlorine reacts with methane in the presence of ultraviolet rays from sunlight. Alkene reacts with hydrogen bromide in presence of hydrogen peroxide and produces alkyl bromide. In reaction with the aqueous solution of sodium hydroxide, alkylhalide turns into alcohol. When this alcohol is oxidised by a strong oxidant ($K_2Cr_2O_7$) and H_2SO_4) at first aldehyde/ketone is produced and later it turns into organic acid.

(ii) Alkene reacts with water vapour (H_2O) at 300°C temperature and 60 atmosphere pressure in the presence of phosphoric acid to produce alcohol. Alkyne (ethyne) reacts with water in the presence of 2% mercuric sulphate ($HgSO_4$) and 20% sulphuric acid (H_2SO_4) and produces aldehyde. However, due to the toxicity of $HgSO_4$ its use is discouraged in industries. Organic acid is produced when the alkane obtained from petroleum is oxidized by the oxygen of air at high temperature and pressure.

11.6 The Uses of Alcohol, Aldehydes and Organic Acids

Alcohol: Methanol is a toxic chemical substance. Methanol is mainly used in the preparation of other chemical substances. In chemical industries ethanoic acid and aster of different organic acids are produced. Ethanol is mainly used as a solvent in perfume, cosmetics and pharmaceutical industries. Pharmaceutical graded ethanol is used in pharmaceutical industries and rectified spirit is used in homeopathic medicine. 96% liquid solution of ethanol is known as rectified spirit. Ethanol is widely used in perfume industry. Ethanol is made free from odour before using in perfume. Except pharmaceuticals and food industries, rectified spirit before using in other industries is mixed with little amounts of methanol to make it toxic. This is called methylated spirit. It is used to burnish wood and metallic furniture. Now in Brazil ethanol is used in motor engine as fuel instead of fossil fuel.

Alcohol can be prepared from starch (rice, wheat, potato and com) by fermentation. Besides, ethanol can be obtained in the same way from the molasses (by-product of sugar).

Keru & Co at Darshona in Bangladesh produces ethanol and meets the demands of the country. If we use ethanol as fuel, the demand on fossil fuel will be decreased and on the other hand environment can be kept pollution free.

Aldehydes: Different kinds of plastic materials are made from aldehyde by the polymerization reaction. Delrin polymer is produced when liquid solution of methanol is heated at a very low pressure. Delrin is used to make chairs, dining tables, buckets etc.

Condensation polymerization reaction of formaldehyde and urea produces Urea-formaldehyde resin which is used to prepare household appliances like plates, drinking water pots, mugs etc.

Organic acids: Organic acids are weaker than inorganic acids. Organic acids are edible constituents. We take organic acids as food with lemon juice (citric acid), tamarind (tartaric acid), curd (lactic acid). Having the capability of destroying bacteria, organic acids are used as food preservative. 4% to 10% liquid solution of ethanoic acid is known as vinegar. Vinegar is used to preserve sauce and pickles.

11.7 Polymers

The reaction in which innumerable tiny molecules of any substances are attached with each other and form a large molecule is called a polymerization reaction. Each of the tiny molecules which take part in the polymerization reaction is called a monomer and the large molecule formed because of the reaction is called a polymer molecule. When two monomers join each other, it is called a dimer, when three monomers join one another, it is called a trimer. In this way when many monomers join one another, then polymer is formed. The main element of our food is protein, which is also a polymer of amino acid.

Polymers can be classified in many ways. However, according to their structure, polymers are of two kinds, such as Addition Polymer and Condensation Polymer.

11.7.1 Addition Polymers

The polymerization reaction m which the monomer molecules are directly connected to one another and form a long-chained polymer is called an addition polymerization reaction. The polymer which is formed in an addition polymerization reaction is called an addition polymer.

Addition Polymerization Reactions: Polythene is produced when ethene is heated in the presence of a little amount of oxygen at 1000 atmosphere pressure and 200°C temperature. This reaction is called Addition Polymerization Reaction. In this reaction, ethene is called monomer.

$$\underset{\text{Ethene}}{nCH_2 = CH_2} \xrightarrow[\text{200°c temperature, little amount of oxygen}]{\text{1000 atm pressure}} \underset{\text{Polythene}}{(-CHz-CHz-)n}$$

Polypropene: Polypropene is produced when propene is heated in the presence of titanium chloride at 140atm pressure and 120°C temperature.

$$\underset{\text{Propene}}{nCH_2{=}CH(CH_3)} \xrightarrow[\text{120°c, titanium chloride}]{\text{140 atm pressure}} \underset{\text{Polypropene}}{[-CHz-CH(CH_3)-]n}$$

Polypropene is stronger and thicker than polythene and can withstand high heat. Ropes, pipes, carpets etc. can be made of Polypropene.

Polyvinyl Chloride or PVC: Polyvinyl Chloride or PVC is produced when vinyl chloride is heated at high pressure and high temperature in the presence of organic peroxide. This polymer is widely used for manufacturing various types of pipes, wires, and even medical devices.

$$\underset{\text{Vinyl chloride}}{nCH_2 = CHCl} \xrightarrow[\text{Organic peroxide}]{\text{high pressure, high temperature}} \underset{\text{Polyvinyl Chloride}}{-(CHz-CHCl)-n}$$

11.7.2 Condensation Polymers

The polymerization reaction in which the monomer molecules release small molecules such as H_20, CO_2 etc during their joining one another is called the condensation polymerization reaction. Nylon 6:6 polymer is produced in the condensation polymerization reaction.

Production of Nylon 6:6: Nylon 6:6 is produced when adipic acid is heated with hexamethelene di-amene in the presence of titanium oxide.

$$\underset{\text{Adipic acid}}{nHOOC-(CH_2)_4-COOH} + \underset{\text{Hexamethelene di-amine}}{nNH_2-(CH_2)_6-NH_2} \xrightarrow{Ti0_2}$$

$$\underset{\text{Nylon 6:6}}{(-OC-(CH_2)_4-CONH-(CH_2)_6-NH-)n} + \underset{\text{Water}}{2nH_20}$$

Based on the sources, Polymers can be further divided into two: Natural Polymer and Synthetic Polymer or Plastic.

Natural Polymers

Many polymers are produced naturally, such as cellulose and starch in plants. Both of them are natural polymers which are formed from many glucose molecules.

Protein is a polymer of amino acid. Astringent juice of rubber trees is a natural polymer. Rubber is cultivated in the Hill tracks, Cox's bazaar, Hobigonj, Sylhet and Tangail districts of our country. In industries plastic is being synthesized several times more than natural rubber.

Table 11.03: Different Polimers, Properties and Uses.

Name of the polymer	Formula of monomer	Properties of polymer	Uses
Polyethylene	$CH_2=CH_2$	Cannot be cut easily, durable	Plastic bag, plastic sheet
Polypropene	$CH_2=CH-CH_3$	Cannot be cut easily, durable	Plastic rope, plastic bottle
Polyvinyl chloride(PVC)	$CH_2=CHC1$	Hard , solid and less flexible than polyethylene	Water pipe, electric insulator
Nylon 6:6	$HOOC-(CH_2)_4-COOH$ '8 $H_2N-(CH_2)_6-NH_2$	Glittering, durable, flexible	Artificial cloths, rope, tooth brush

Synthetic polymer or plastic

Plastic is hard, light, cheap and available in any colour. Plastic can be melted and be given any shape by molding. The word plastic has come from the Greek word 'Plastikos' which means possible to melt. Many of us make various materials by melting rejected plastic parts. It is dangerous because burning or melting of plastic products by heating produces many toxic gases. Plastic is widely used to produce various products like pots for keeping foods, packets, ballpens, chairs, tables, motor parts, water tanks, bowls, buckets, mugs etc.

11.7.3 Advantages and disadvantages of using plastic

In the present world, synthetic polymers like plastic are widely used. The uses of these type of products has many advantages. On the other hand, plastic products are a threat to our environment. These type of products have become a part and parcel of our daily life. That is why we cannot keep away from these products. We can overcome these disadvantages to some extent if we can use them in a proper way.

Advantages: Our daily necessary materials like utensils, different kinds of pipes, containers, and bags are made from plastic materials. Earlier, metals, natural fibers like cotton, jute, wood were used to make these products. Plastic is thicker than these. We can make materials of different sizes by shaping plastic as we wish and we can make them attractive by using colours on them.

Disadvantages: The greatest disadvantage of using plastic is that it is harmful for the environment. The things which we dump in soil or water decompose by reacting with bacteria or oxygen of the atmosphere or other substances in water or soil and they maintain the balance of the environment. But plastic products are neither decomposed by bacteria nor react with other substances. That is why they remain the same when they are dumped on soil or water. As a result they pollute the soil or water and spoil the balance of the environment.

Our responsibilities: We should not dump plastic products indiscriminately; rather we should preserve them for reuse by recycling. On the other hand, we should increase the use of wood, metal, natural fibre. Scientists are trying to invent decomposable plastic products and they have already become successful in many cases. So it is hoped that decomposable plastic products will be available in the markets instead of existing plastic products, in near future.

11.7.4 Differences between organic compounds and inorganic compounds

The compounds which you have studied in this chapter are all organic compounds. Organic compounds are generally formed by covalent bonding and inorganic compounds are formed by ionic bonding.

Organic compounds	Inorganic compounds
1. Generally, organic compounds must have carbon. Example: Methane (CH_4)	1. Except some exceptions, generally inorganic compounds have no carbon. Example: Hydrogen Sulphide (H_2S)
2. Usually, organic compounds take a long time to react.)	2. Usually, inorganic compounds take lesser time to react.
3. Organic compounds are generally formed by covalent bonding.	3. Inorganic compounds are usually formed by ionic or covalent bonding.

Do by yourself

Activity: Define organic compounds. Taking some organic and inorganic compounds determine their melting points and show the differences.

Think: How to differentiate between organic and inorganic compounds on the basis of deference of ionic and covalent compounds.

Exercise

Multiple choice Questions

1. What is the percentage of ethane in natural gas?

a. 3% b. 4%

c. 6% d. 7%

2. Which of the following compounds can cause the disappearance of red colour of bromine?

a. C_3H_8 b. C_3H_8O

c. C_3H_6O d. C_2H_4

Reaction: $CH_3\text{-}C{\equiv}CH \longrightarrow X \longrightarrow y$

Answer the questions 3 and 4 from the above reaction:

3. What is the name of compound Y?

a. 1,1-di bromopropane b. 2,2-di bromopropane

c. 1,1,2,2-tetrabromopropane d. 1,2-dibromoprapene.

4. In the stem X compound -

i) gives an addition reaction

ii) is used to produce plastic

iii) is less reactive than Y

Which one of the followings is correct?

a. i and ii b. ii and iiii

c. i and iii d. i,ii and iii

Creative Question

1. In the months of March-June huge amount of potato rots in Bangladesh due to lack of preservation. Ethanol can be prepared from the potato by the following reaction.

$$\text{Starch} \xrightarrow[\text{Water}]{\text{Enzyme (diastage and maltoze)}} \text{Glucose} \xrightarrow{\text{enzyme (zymage)}} \text{Ethanol}$$

a. What is the main constituent of petroleum?

b. Why are alkenes more reactive than alkanes? Explain.

c. Give a description of the preparation of methane from potato.

d. Analysis of the possibilities of using excess potato as an alternate to fossil fuel.

2. A gas is converted to different products by the reactions i to iii successively.

$$\text{(i)} \quad 2CH_4 \longrightarrow HC{::::}CH + H_2$$

$$\text{(ii)} \quad HC{::::}CH + HCl \longrightarrow CH_2{=}CHC1$$

$$\text{(iii)} \quad nCH_2{=}CHCl \xrightarrow{\text{Polymerization}} \text{-(CHz-CHCl)-n}$$

a. What is a hydrocarbon?

b. Why is benzene an aromatic hydrocarbon?

c. What type of reaction is number ii ? Explain

d. Analyze the possibilities of diversification of uses of the first reactant gas in the stem.

3.

$$\underset{}{X} + \underset{\text{Sodium hydroxide}}{NaOH} \longrightarrow \underset{\text{Sodium ethanoate}}{CH_3COONa} + \underset{\text{water}}{H_20}$$

a. What is an aromatic hydrocarbon?

b. How is ethyne prepared from calcium carbide? Write with the reaction

c. Complete the reaction in the stem.

d. Is the X compound an acid? Analyze.

Chapter Twelve
Chemistry in Our Lives

Some good looking soaps decorated with natural fruits.

We use different kinds of fertilizers in soil to boost its fertility. This fertilizer is mainly made of chemical substances. We add baking soda with flour to inflate bread, use vinegar or other food preservatives to preserve foods for a long time at home and all these are chemical substances. Again, industrial discharges which pollute the environment are also chemical substances. Chemical substances play roles in every phase of our lives. This chapter will focus on the preparation process of these chemical substances, their properties, uses etc.

By the end of this chapter we will be able to -

- explain the importance of collection, properties and uses of some household food materials.
- describe the importance of pH in determining suitability of cosmetic materials at home.
- explain the preparation of household cleaning substances and mechanisms of cleaning.
- control the pH value of soil in agriculture using appropriate compounds.
- explain the ways of processing agricultural products.
- explain the means of preserving agricultural commodities.
- explain the harmful effect of chemical waste by knowing it.
- prepare soap by using chemical substances.
- exhibit the de-colorization process of bleaching powder.
- give opinion spontaneously with confidence about the appropriate use of chemical substances to prevent the pollution of soil, water and air.
- show interest about using health conscious commodities.
- show interest about using hygienic foods.
- show the role of baking powder in food products by experiment.

12.1 Domestic Chemistry/ House hold Chemistry

We use different kinds of chemical substances such as table salt, baking powder, vinegar, soft drinks in our houses.

Table Salt or Edible salt

Huge amounts of table salt or sodium chloride (NaCl) along with a little quantity of some other salts including NaCl, $MgC1_2$ are dissolved in sea water. Again sufficient sodium chloride is found underground as minerals. In our country table salt is extracted from sea water. Salt cultivators in the coastal areas of our country make dams around square or rectangular land of different sizes and keep a small empty space there. When tide water enters through this space, the water is contained inside by closing the entry point. When this water evaporates in the presence of heat of sunlight, salts become visible. This method is called salt harvesting. The salt collected through the harvesting process is processed into edible salt through different processes in factories.

Fig 12.01: Salt harvesting in the coastal area.

The salt collected through harvesting process contains sand. When this salt is mixed with water in a pot, the salt is dissolved in water but the sand remains at the bottom of the pot. Then the salt-water solution is separated through filtration. Again when this solution is heated, the water vaporizes but the salt remains at the bottom of the pot. In this way, the processed salt is packed and sent to different places for sale. We need different types of ions like Na^+,K^+ etc for smooth running of all activities in our body. If there is lack of Na^+in our body due to any reason, this deficiency is filled up by taking NaCl with water.

Uses of NaCl: NaCl is used for different purposes, such as-

(i) We take curry with rice. The curry does not taste good if we do not use NaCl in it.

(ii) NaCl is used in industries to prepare NaOH compound

(iii) NaCl is used in drug industries to manufacture salines for diarrhoea or dehydration.

Baking Powder

Chemical name of baking soda or table soda is sodium hydrogen carbonate (NaHCOJ Baking soda is also called sodium bicarbonate. Baking powder is produced when tartaric acid ($C_4H_6O_6$) is mixed with baking soda ($NaHCO_3$). Baking powder is usually used in making cakes.

Preparation of Baking Soda

Baking Soda can be prepared from ammoma gas, salt, water and carbon-di- oxide. At first, saturated solution of NaCl is prepared by dissolving NaCl in water. Again this solution is saturated by blowing NH_3 gas into the saturated solution. Then carbon-di-oxide gas is blown into the NaCl solution saturated by NH_3. At this stage, at first CO_2, NH_3, H_2O together produce Ammonium Hydrogen Carbonate (NH4HCOJ Then the ammonium hydrogen carbonate reacts with sodium chloride and produces sodium hydrogen carbonate or baking soda.

$$CO_2 + NH_3 + H_2O \longrightarrow NH_4HC03$$

$$NH_4HCO_3 + NaCl \longrightarrow NaHC03 + NH_4Cl$$

Baking soda is separated from the reaction pot and then tartaric acid is mixed with it. This mixture is called baking powder.

Uses of Baking Soda

During making cakes, baking powder is mixed with the flour of cake and heated. Baking soda reacts with tartaric acid ($C_4H_6O_6$) in the mixture and produces sodium tartaret ($C_4H_4Na_2O_6$), CO_2 gas and H_2O. Cakes rise up because of this CO_2 gas.

$$2NaHCO_3 + C_4H_6O_6 \longrightarrow C_4H_4Na_2O_6 + 2CO_2 + 2H_2O$$

One type of fungus named 'Yeast' is also used at home or in bakery to inflate bread. To do this initially yeast is added to a solution of sugar. If dough is made with this mixture and kept in a warm place, carbon-di-oxide is produced because of aerobic respiration of the yeast. This carbon-di-oxide helps the cakes to swell up. When bread is baked in an oven after sufficient swelling, the yeast dies due to the heat and swelling process of bread stops.

Individual Task

Mix baking powder and yeast with flour separately and keep it for some time and make cakes with it. Compare the two cakes. If there is difference between the cakes, explain the causes.

Vinegar

4% to 10% liquid solution of ethanoic acid is called Vinegar. Vinegar is a liquid substance. Vinegar is generally used in making pickles.

Preparation of Vinegar

Vinegar or acetic acid or ethanoic acid (CH_3COOH) is prepared by blowing the bubble of oxygen gas into ethanol and acitobactor kept in a steel pot at 25°C to 35°C temperature.

$$CH_3CH_2OH + 0_2 \xrightarrow[\text{25-30°C}]{\text{Acitobactor}} CH_3COOH + H_2O$$

Roles of vinegar in preserving food

Pickles rot when bacteria attacks them. Bacteria cannot attacks pickles if vinegar is applied to them. The main element of vinegar is ethanoic acid. When vinegar is applied to pickles, the protein released by ethanoic acid damages the H+bacteria and as a result, the foods remains safe from the attack of bacteria. In this way food is preserved by using vinegar.

Soft Drinks

Soft drinks are prepared when carbon dioxide gas is dissolved in water at cold temperatures and high pressures. Carbon dioxide and water react in soft drinks and produce H_2CO_3. People take soft drinks for digestion of food. However, there is no scientific evidence for it.

12.2 Chemistry for Cleanliness

A sound mind in a sound body is called good health. We keep our body clean in order to maintain good health. Our mind remains sound if our body is clean. We use cosmetic soaps to keep our body clean. We use washing soda, bleaching powder etc to keep our attire or clothes clean. We use glass cleaner to clean the glass materials in our houses. We use toilet cleaner to keep our toilets clean. The techniques for preparing these toiletries and ways of cleaning are discussed below:

Washing Soda

Sodium Carbonate (Na_2CO_3) is called soda ash. When 10 molecules of water are chemically added to 1 molecule of soda ash, it is called washing soda. Chemical name of washing soda is sodium carbonate deca hydrate ($Na_2CO_3.10H_2O$).

Preparation of Washing Soda

When a large amount of CO_2 is passed through NaOH solution, it produces sodium carbonate which is dissolved in water.

$$ZNaOH + CO_2 \longrightarrow Na_2CO_3 + H_2O$$

There are Na_2CO_3 and water in the reaction pot. Sodium carbonate joins with 10 molecules of water and produces washing soda ($Na_2CO_3.10H_2O$).

$$Na_2CO_3 + 10H_2O \longrightarrow Na_2CO_3.10H_2O$$

Uses of Washing Soda

Washing Soda is used to wash clothes.

Toilet Cleaner

Main ingredient of toilet Cleaner is sodium hydroxide (NaOH). In toilet cleaners, Sodium Hypochlorite (NaOCl) remains mixed up with Sodium Hydroxide. Toilet cleaner is used to clean basin, commode, etc. There are oily materials, protein materials, organic and inorganic materials of different colours and germs and bacteria in toilets, basins, commode etc. When toilet cleaner is applied on toilets, basins, commode etc. sodium hydroxide reacts with oily and protein materials and sodium hypochlorite reacts with substances and germs of different colours and damages the efficiency of these germs and other substances.

Mechanism of cleaning toilet with toilet cleaner

When toilet cleaner is poured on the toilet, different constituents of the toilet cleaner react in different ways. Toilets become clean because of the alkaline property ofNaOH, the main element of the toilet cleaner.

Sodium hypochlorite (NaOCl) of the toilet cleaner reacts with water and turns into Hypochlorous acid (HOCl) which breaks up and produces nascent oxygen. This nascent oxygen transforms colourful substances into colourless ones and kills germs.

$$NaOCl + H_20 \longrightarrow NaOH + HOCl$$

$$HOCl \longrightarrow HCl + [OJ$$

$$\text{Colourful Materials} + [OJ \longrightarrow \text{colourless Materials}$$

$$\text{Germs} + [OJ \longrightarrow \text{Dead Germs}$$

Thus toilet cleaners transform colourful substances into colourless ones and kills germs. Oxygen atom in third brackets refers to nascent oxygen. Nascent Oxygen= [OJ, Nascent oxygen refers to a newly formed, temporary reactive oxygen atom that has not yet combined to form an 02 molecule.

Soap

Generally soap is the sodium salt (R-COONa) of higher fatty acid or Potassium salt (R-COOK) of higher fatty acid. Here R is called an alkyl radical. General formula of R is CnH_2n+i and the value of n is 12 to 18. Example: Formula of Sodium Stearate soap is $C_{17}H_{35}COONa$ and the formula of Potassium Stearate Soap is $C_{17}H_{35}COOK$. Sodium hydroxide or potassium hydroxide reacts with oil or fat and produces soap and glycerine. The procedure of making soap and glycerine is called saponification. If NaCl is added to the mixture of soap and glycerine obtained from the saponification process, glycerine stays at the bottom of the pot and the molecules of soap gather around NaCl and floats up in the form of cakes. It is called soaps cake. The soap cake is filtered by strainers and then poured into moulds to make soaps of different sizes.

Soap is a detergent which is produced from oil or fat and alkali. Based on use, soap is mainly divided into two types- Toilet Soap and Laundry Soap.

Toilet Soap: The soap which is used for cleaning our skin is called Toilet Soap.

Laundry Soap: The soap which is used for washing our clothes is called Laundry Soap.

While preparing soap, glycerine is also produced with soap. Oil, fat or alkali may remain with the mixture of soap and glycerine. Soap is separated from these. If there is excessive oil or fat in the soap during this separation, there remains an oily situation in the soap. When this type of soap is used, it will not make much scum. If there is excessive amount of alkali in the soap, its use is harmful to our body. For this reason, while making in soap industries oil or fat and alkali should be used proportionately so that oil or fat and alkali may react completely. When carboxylic group is connected to a very big carbon chain, that compound is called a higher fatty acid. Fatty acid reacts with alcohol or glycerine and produces ester. If the tri-ester of higher fatty acid and glycerine is in liquid state it is called oil and if in solid state, it is called fat.

Stearic Acid is a saturated fatty acid obtained from the fat in animal bodies. There is a carbon-carbon single bond in saturated fatty acid and there is no double or triple bond. The oil obtained from olives is called olive oil. Olic acid is obtained from olive oil. Olic acid is an unsaturated fatty acid. There is carbon-carbon double or triple bond in unsaturated fatty acids. The quantity of alkali or other bad stuff is more in laundry soap and no scent or antibacterial material is added to it. On the other hand, the quantity of alkali or other bad stuff is less in toilet soap and scent or antibacterial material is added to it.

Detergent

Detergent is also a cleaning material like soap. Detergent usually looks like powder and is also available in liquid form. Sulphuric acid (H_2SO_4) reacts with lauryl alcohol ($C_{12}H_{26}O$) and produces lauryl hydrogen sulphate ($C_{12}H_{26}SO_4$) and water. Sodium hydroxide (NaOH) reacts with this lauryl hydrogen sulphate ($C_{12}H_{26}SO_4$) and produces sodium lauryl sulphate ($C_{12}H_{25}SO_4Na$) and water (H_2O). Sodium lauryl sulphate ($C_{12}H_{25}SO_4Na$) is known as detergent.

$$C_{12}H_{26}O + H_2SO_4 \longrightarrow C_{12}H_{26}SO_4 + H_2O$$

$$C_{12}H_{26}SO_4 + NaOH \longrightarrow C_{12}H_{25}SO_4Na + H_2O$$

Different types of materials are added to detergents in order to make it usable. Sodium Sulphate (Na_2SO_4) is added to detergent to give it the shape of powder.

Cleaning mechanism of soap and detergent

The main work of detergent or soap is to remove oil and dust from clothes through washing with water. Oily substances come out from our body and stick to our clothes. Then dust come in contact with the oily substances and makes dirt.

Soap (R-COONa) or detergent ($C_{12}H_{25}SO_4Na$) 1s a molecule of long chained carbon. In solution state, they dissociate into negatively charged soap (R-COO-) or detergent ion ($C_{12}H_{25}SO_4^-$) and positively charged sodium ion (Na+). There is negative charge at one end of soap or detergent ion. As this negatively charged end is attracted by water, this negative end is known as hydrophilic. The other end of soap or detergent ion dissolves in oil or grease and this end is known as hydrophobic.

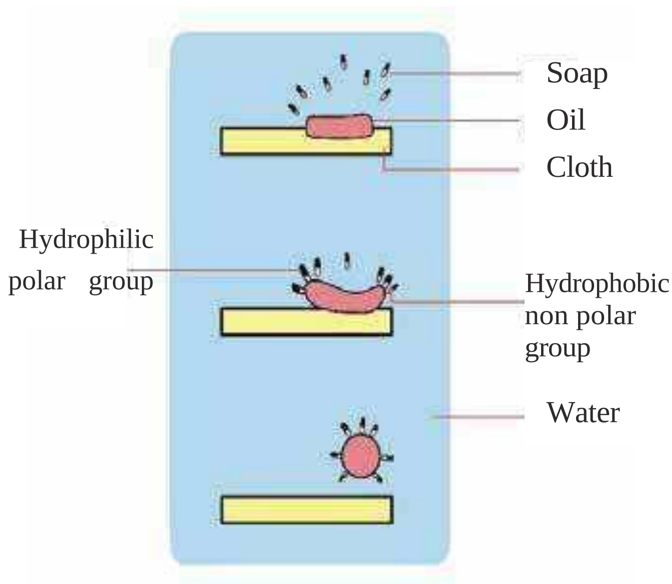


Fig 12.02: Cleaning Mechanism with Soap or Detergent.

When soap or detergent gets comes in contact with oily or greasy dirt of clothes in the presence of water, the hydrophobic part is attracted by the oil or grease and dissolves in it. On the other hand hydrophilic part extends to the water layer. In this condition if clothes are rubbed or twisted, the particles of oily or greasy dirt are completely covered by the negatively charged ion of soap or detergent and a ring of negatively charge ion is formed around the particles of oily or greasy dirt. Then they want to stay at possible maximum distance and form a mixture of oil, soap and water. This mixture is known as scum. When more water is added to this scum, oil and dusts are washed away with the scum. Thus soap washes away dirt.

Differences between soap and detergent.

Soap	Detergent
1. Soap is sodium or potassium salt of long carbon chained fatty acids.	1. Detergent is sodium salt of long carbon benzene sulfonic acid.
2. Soap cannot act well on salt water.	2. Detergent can act well on salt water as well.
3. Soap has less cleaning capacity than detergent.	3. Detergent has less cleaning capacity than soap.

Bad effects of using excess soap or detergent

There are alkali, glycerine, oil, fat etc. in the soap. If soap is used excessively, its alkali affects hands. If clothes are washed on the banks of ponds, pools or rivers, soap scum reacts with the oxygen dissolved in water and reduces the quantity of the dissolved oxygen. If the quantity of dissolved oxygen in water is reduced, aquatic plants and fish living in water die. Thus excess uses of soap pollutes water.

Detergent contains trisodium phosphate ($NalO_4$). This trisodium phosphate works as a good fertilizer for plants to live. As a result, the quantity of plants in the pond increases. As the plants use the dissolved oxygen in water, fishes die out because of the lack of oxygen. Thus excess uses of detergent pollute water.

Use of Toiletries: People use toiletries (soap, cream, shampoo) to clean skin, retain beauty of skin, clean hair and other purposes. As you have learnt earlier, the pH of skin is between 4.8 and 5.5. That means the skin has an acidic nature, which prevents attack or origins of germs on skin. Again, if the pH value of toiletries is more than 4.8 to 5.5, its use reduces acidity of skin which results in damage of skin beauty and increase of germ attack. So there should be relevance in the pH values of toiletries and skin.

Individual Task

Preparation of soap

Hypothesis: Soap is produced by the reaction of oil or fat with alkali. pH value of the produced soap will be more than 7.

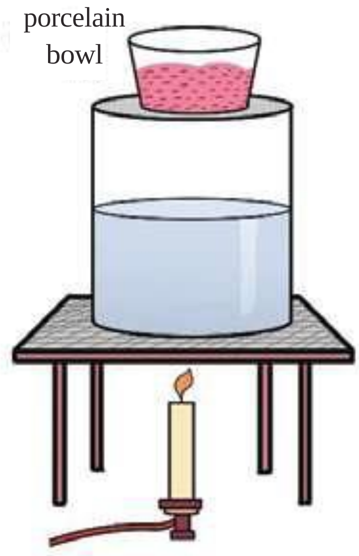


Fig 12.03: Preparation of Soap.

Materials: Coconut oil, Caustic soda, Saturated solution of NaCl, Soap from market, Kerosene oil

Apparatus: Bunsen burner/spirit lamp/ kerosene cooker, 2 beakers of 400 mL, 2 test tubes, one big porcelain bowl, one stirrer, one spatula, one measuring cylinder (10 mL), one funnel, one filter paper.

Safety measures: At high temperature sodium hydroxide is a very corrosive substance. So handle it with care so that no accident occurs by spilling.

Do not use the produced soap on hand or body.

Procedure:

a. Prepare a steam bath in a beaker filled with water and put a porcelain bowl in it as in the figure.

b. Take 5mL coconut oil or 5g fat and 30mL Sodium hydroxide solution in the porcelain bowl.

c. Boil the mixture in the steam bath for 30 minutes and stir it time to time with the stirrer. Add water to maintain the deficit of water due to evaporation. At this time a sticky substance will be formed by removal of oily or fatty materials.

d. Then stop heating and let the mixture cool.

e. Add 50ml saturation solution of NaCl in the cold mixture and let it stay overnight.

f. Next day filter the solution with filter paper and throw away the filtrate let the soap dry.

Test of the produced soap

1. Take a test tube with one third of water and a piece of a specimen soap of yours in it. Shake it well by closing the mouth of the test tube. Observe, is there any foam formed or not?
2. Add 2/3 drops of kerosene in the test tube and shake it well and observe. Explain the result by considering the kerosene as grease.
3. Determine the pH value of your soap.
4. Repeat the above three steps of the experiment with soaps from the market and compare with your soap.

Bleaching Powder

Chemical name of bleaching powder is Calcium Oxychloro Chloride, Ca(OCl)Cl. Bleaching powders is used to remove or make colourless the ink of ball-pen or any other colour which cannot be removed from clothes by detergent or soap. Besides, bleaching powder is also used for killing germs on floors, commodes, basins etc. Bleaching powder is produced when Chlorine gas is passed through the Calcium Hydroxide at 40°C temperature.

$$Ca(OH)_2 + Cl_2 \xrightarrow{40°C} ca(ocl)cl + H20$$

Technique of removing colourful spot on clothes:

Bleaching powder makes the colourful spots of the clothes colourless. This is why bleaching powder is called an anti-pigment. Spot of clothes and bleaching powder both are chemical substances. When water is added to bleaching powder after putting it on the dirt spot of clothes, bleaching powder reacts with water and produces calcium chloride (CaCl) and hypochloras acid (HOCl).

$$Ca(OCl)Cl + H_20 \text{————} CaC1_2 + HOCl$$

HOCl breaks up and produces HCl and nascent oxygen [O]

$$HOCl \text{ --- } HCl + [O]$$

Nascent oxygen [O] reacts with colourful material and makes the colourful materials colourless.

Colourful material + [O] ———— colourless material

Technique of killing germs by bleaching powder

Bleaching powder is used to kill germs on house floors, commodes, basins etc. When water is added to bleaching powder after putting the powder on floor, commode, basin etc, bleaching powder reacts with water and turns into calcium chloride (CaCl) and hypochloras acid (HOCl).

$$Ca(ocl)Cl + H20 \text{————} CaC1_2 + HOCl$$

Hypochloras acid breaks up and produces nascent oxygen [O] which kills germs.

$$HOCl \text{ --- } HCl + [O]$$

Germs+ [O] --- dead germs

Glass Cleaner

The detergent which is used for cleaning glass is called a glass cleaner. When there is oil, fat or grease on glass, they attract dust and makes dirt on glass. To clean glass, such a kind of cleaning material is used which reacts with oil, fat or grease but does not react with sodium silicate or calcium silicate, an element of glass. Glass cleaner is usually prepared by mixing isopropyl alcohol, $CH_3CH(OH)CH_3$ with ammonium hydroxide (NH_4OH) which is prepared by dissolving ammonia gas in water. Ammonium Hydroxide is also known as ammonia solution.

Technique of cleaning glass with glass cleaner

When glass cleaner is applied on glass, NH_4OH reacts with oil, fat or grease on the glass and removes them from the glass. If there is any organic substance on the glass, isopropyl alcohol dissolves the organic substances and removes them from the glass. Mask is to be used on the mouth and nose while cleaning glass with glass cleaner because the ammonium hydroxide of the glass cleaner may enter our nose and mouth.

Laboratory Production of Ammonia gas

Ammonia gas is generally prepared in the laboratory in two ways.

Ammonia is produced in the laboratory by mixing and heating ammonium chloride (NH_4Cl) and calcium oxide (CaO) in a test-tube.

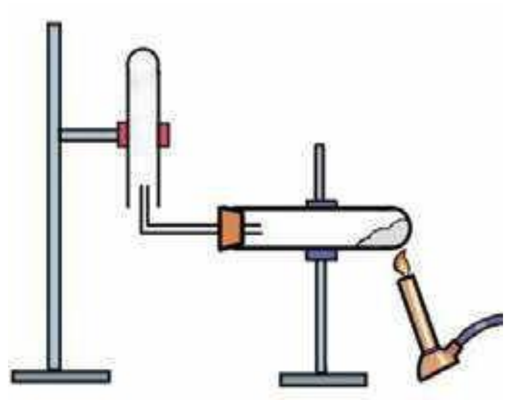


Fig12.04: Preparation of ammonia gas in the laboratory.

$$2NH_4Cl + CaO \longrightarrow 2NH_3 + CaCl_2 + H_2O$$

Or, Ammonia gas, calcium chloride and water are produced when ammonia chloride and slaked lime $Ca(OH)_2$ are mixed and heated in a test-tube.

$$2NH_4Cl(s) + Ca(OH)_2 \xrightarrow{\text{fl}} 2NH_3 + CaCl_2 + 2H_2O$$

Industrial Production of Ammonia Gas

Ammonia gas is produced by the Heber process in industries. Ammonia gas (NH_3) is produced in the Heber process by mixing N_2 and H_2 gases at the ratio of 1:3 and heating the mixture at 450-550°C temperature after adding Fe catalyst. (In 1:3 ratio, N_2 and H_2 refer to taking 3 times more H_2 than *N).* Some heat is also produced while producing ammonia gas. This is an exothermic reaction. In one side, N_2 and H_2 react and produce NH_3. On the other side, some NH_3 gases breaks up and turns into N_2 and H_2 gases. Two reversible arrows are used in this reaction.

$$N_2(g) + 3H_2(g) \xrightarrow[\substack{200\text{-}250\text{ atm} \\ 450°C\text{-}550°C}]{Fe} 2NH_3 + 92\ kJ$$

12.3 Chemistry in Agriculture and Industries

The fertility of soil is enhanced by applying different kinds of chemical substances produced in industries. Lime stone ($CaCO_3$) is a valuable mineral resource. In our country huge quantities of lime stone is found in Sunamgonj district and Saint Martin Island. Various materials are made from lime stone. For example, lime stone is used as the main element for producing cement. If the soil becomes acidic that is the quantity of H+increases in the soil due to any reason, lime stone is applied on that soil in order to reduce the acidity. Lime stone reacts with H+and produces calcium ion (Ca^{2+}), carbon dioxide and water. As a result the acidity of the soil is reduced.

$$CaCO_3 + 2H^+ \longrightarrow Ca^{2+} + CO_2 + H_2O$$

Urea

Urea is a valuable material. At first, ammonium carbamate (NH_2COONH_4) is produced when the mixture of carbon-di-oxide and ammonia gas is heated at a high pressure and l 30°C- l 50°C temperature. Later, the ammonium carbamate is broken and Urea (NH_2-CO-NHz) is produced.

$$CO_2 + 2NH_3 \xrightarrow{Ll} NH_2COONH_4$$
$$NH_2COONH_4 \longrightarrow NH_2\text{-}CO\text{-}NH_2 + H_2O$$

Urea is widely used in industries and agriculture. Melamine polymer is prepared from Urea in industries. Urea is used as fertilizer in agriculture. Urea is applied to soil so that plants can get enough Nitrogen nutrients from the Urea fertilizer. Plants do not directly receive N_2 from air. In the presence of Ureaz Enzyme in soil, Urea reacts with water and produces NH/, OH- and CO_2 Plants absorb this NH/.

$$NH_2\text{-}CO\text{-}NH_2 + 3H_2O \xrightarrow{\text{Ureaz Enzyme}} 2NH_4^+ + 2OH^- + CO_2$$

Ammonium Sulphate

Ammonia reacts with sulphuric acid and produces ammomum sulphate [$(NH_4)_2SO_4$] and water.

$$2NH_3 + H_2SO_4 \longrightarrow (NH_4)_2SO_4 + H_2O$$

Ammonium sulphate is widely used in agriculture. Ammonium sulphate can react with an alkali or base. So when the amount of alkali increases in soil, Ammonium sulphate is used in soil to decrease the amount of alkali. It is a very important nutrient for plants. Plants receive nitrogen and sulphur from it.

Chemicals in Processing Agricultural Commodities

Fruits, vegetables, fishes etc. are called agricultural commodities. The process through which agricultural commodities are kept fresh for a long time or can be saved from decay by using any chemical substance is called processing of agricultural commodities. Use of chemical substances has both merits and demerits. Mangoes get spots when the traders transport them from one place to another by buses, trucks or trains. People do not want to buy these spotted mangoes. For this reason unscrupulous traders buy green mangoes and transport them from one place to another. As a result, the mangoes do not get spots. Then the unscrupulous traders apply aqueous solution of calcium carbide on the mangoes to ripen them. Again, acetylene is prepared by adding water to the calcium carbide (CaCz). This acetylene gas helps in ripening fruits.

CaC2 + ZH20 ———— C2H2 + Ca(OH)2

Besides, mangoes are ripened by this ethylene gas. Ethylene also has a negative impact on our body. Ripening mangoes by carbide means the process of ripening mangoes by acetylene. Normally, ripe fruits release ethylene (a natural hormone) gas, which causes surrounding unripe fruits to ripen.

Chemicals in Preserving Agricultural Commodities

Agricultural commodities are preserved by ice, table salt, vinegar etc. so that the agricultural commodities do not become odorous or so that they do not decay. Fishes are preserved by ice. Vinegar is used to preserve tomatoes, green mangoes, etc. in containers. Vinegar enters our body with food but it does not harm us. Foods are not preserved by formalin because it is harmful material for man and animals. We may even die if formalin enters our body. Hence, formalin should not be used to preserve food. Formalin is used in laboratories to preserve dead animal bodies.

Some Recommended Food Preservatives

The chemical substances which protect food items from bacteria, bad smell, and decay are called food preservatives. Recommended food preservatives are those preservatives which do not harm our body and which are approved as food preservatives by the World Health Organization. The preservatives which harm our body are called unauthorized food preservatives. Sodium Benzoate, benzoic acid, vinegar and solutions of salt and sugar etc are recommended food preservatives. Ethylene, acetylene etc. are unauthorized food preservatives.

Industrial Disposal and Environment Pollution

Industrial disposals pollute the environment. In Bangladesh tannery, paint and pesticide industries dispose different kinds of heavy metal such as chromium (Cr), lead (Pb), mercury (Hg), and cadmium (Cd) as industrial effluent. These heavy metals or effluents enter the soil and water. They also enter the plants that grow on this soil. When we eat fruits from these plants, the heavy metals also enter our body and hurt our kidney and liver. They can even cause death . Again a huge quantity of caustic soda (NaOH) are emitted from soap and detergent factories into the soil and water. IfNaOH goes into water, the level of alkaline in water increases. As a result, aquatic animals and plants cannot live in water properly.

Exercise

Multiple choice questions

1. What is the ratio of hydrogen and nitrogen in ammonia gas production?

a. 1:2 b. 1:3

c. **2:1** d. 3:1

2. $NH_3 + H_2SO_4$ reaction -

(i) is a neutralization reaction

(ii) product is an important nutrient of plants

(iii) pH value of the liquid solution of the product is greater than 7

Which one of the followings is true?

(a) i and ii (b) ii and iii

(c) i and iii (d) i, ii and iii

3. Which one makes the colourful materials colourless?

(a) Na(OH\
(b) Ca(OCl)Cl
(c) HCl
(d) CH_3COOH

4. By which ion is the application of Urea on soil absorbed?

(a) OH-
(b) NH/
(c) H+
(d) Urea

Creative Questions

1. Shawn, a student of class ten, after washing clothes in tube-well water saw that the clothes were not so clear and there was not much foam in the water. When he informed his friend Riyad of the matter, Riyad suggested to him to use a detergent.

(a) What is soap?
(b) What is glass cleaner?
(c) Describe the cleaning mechanism of the first material that Shawn first used to clean his clothes.
(d) Explain with logic why the cleaning material suggested by Riyad was effective.

2. Dr. Chandra's maid servant is taking rest due to her indigestion. Suddenly, the fridge being out of order, Dr. Chandra becomes worried with uncooked fish, meat, salt, baking powder and vinegar which she bought from the market. In the meantime the maid servant feels better by taking baking powder secretly. Knowing this matter, Dr. Chandra forbade her to take it in future.

a. What is the main constituent of the glass cleaner?
b. What is the role of air in ammonia industry in our country?
c. By using which one of the stem did Dr. Chandra ask her maid to preserve fish, meat? Explain.
d. Explain the chemistry, with reaction, about the cure of indigestion of the maid servant in the stem.

The End