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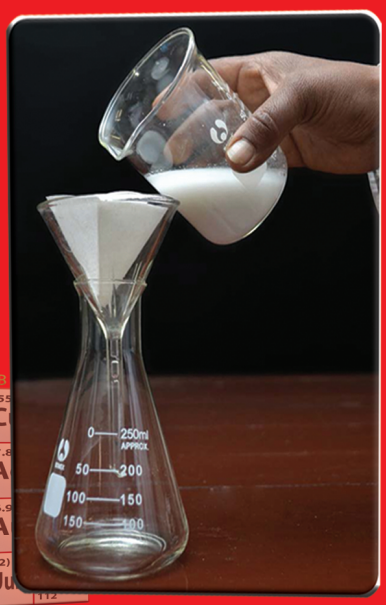
STUDENT TEXTBOOK

Grade 7



FEDERAL DEMOCRATIC REPUBLIC OF ETHIOPIA
MINISTRY OF EDUCATION

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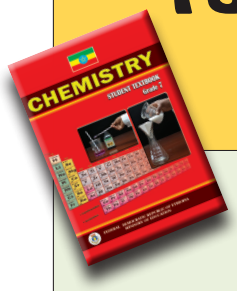

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CHEMISTRY

STUDENT TEXTBOOK

GRADE 7

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FEDERAL DEMOCRATIC REPUBLIC OF ETHIOPIA

MINISTRY OF EDUCATION

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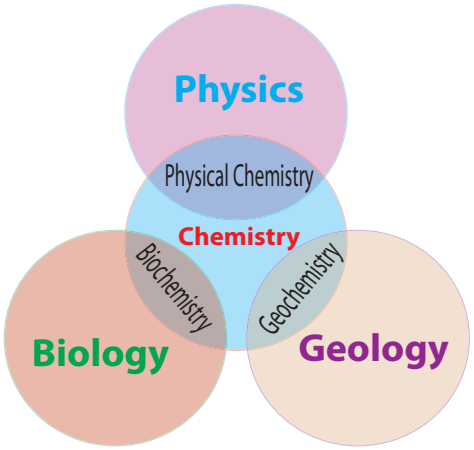
UNIT 1

CHEMISTRY AND ITS IMPORTANCE



MAIN CONTENTS

1.1 DEFINITION AND ESSENCE OF CHEMISTRY

1.2 RELATIONSHIP BETWEEN CHEMISTRY AND OTHER NATURAL SCIENCES

1.3 ROLE PLAYED BY CHEMISTRY IN PRODUCTION AND SOCIETY

1.4 SOME COMMON CHEMICAL INDUSTRIES IN ETHIOPIA

⇨ *Unit Review*

UNIT OUTCOMES

After completing this unit, you will be able to:

- ✓ explain what chemistry is and describe its essence;
- ✓ describe the relationship between chemistry and other natural sciences;
- ✓ appreciate the application of chemistry in production;
- ✓ describe some common chemical industries in Ethiopia
- ✓ describe scientific enquiry skills along this unit: observing, communicating, asking questions and making generalizations.

START-UP ACTIVITY

Form a group and perform the following tasks.

Your teacher will provide you with the following materials which are commonly found in your environment:

water, sand, charcoal, ash, paper, salt, sugar, chalk and soap

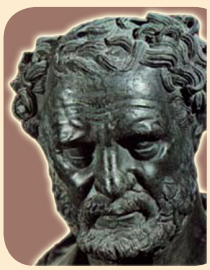
Observe the forms, colors, odors of each material. Also notice what you feel while rubbing it between your thumb and forefingers.

1 How do these materials differ from each other?

2 Why does each material differ from the others?

After the discussion share your ideas with the rest of the class.

HISTORICAL NOTE



Democritus (460-370 B.C.)

The Greek Philosopher Democritus proposed the concept of the atom more than two thousand years ago. He spent the wealth he inherited from his father on travel to distant countries, to satisfy his thirst for knowledge. He travelled to Asia, was even said to have reached India and Ethiopia.

1.1 DEFINITION AND ESSENCE OF CHEMISTRY

After completing this section, you will be able to:

- ✓ define chemistry; and
- ✓ explain the essence of chemistry.

Definition of Chemistry

ACTIVITY 1.1

Form a group and discuss the general concepts of the following phrases and the inter-relationship between them.

- ⇨ natural science
- ⇨ behavior of materials
- ⇨ study of materials
- ⇨ study of nature

From your discussion define:

i natural science

ii chemistry

Figure 1.1: **Some of the common substances around us**

ACTIVITY 1.2

Based on *Figure 1.1*, discuss the following in your group.

1. Which of the materials (substances) are liquids and which of them are solids at room temperature?
2. What differences do you observe between:
   a. water and milk?
   b. sugar and table salt?
3. What does tea contain?

After your discussion share your ideas with the rest of the class.

Chemistry answers questions similar to those that you examined in Activity 1.2 and to other related questions. Chemistry is a branch of natural science which deals with the properties, composition, structure and transformation of substances. When we talk about behavior of substances like color, odor, and physical state, we describe their *properties*. When we consider the particles that make up a given substance, we describe its *composition*. Similarly, when we deal with the way the components of a substance are put together or arranged, we consider the *structure* of the substance. When we deal with the changes a substance undergoes, we describe its *transformation*.

Essence of Chemistry

ACTIVITY 1.3

Discuss in groups and share your ideas with the rest of the class.

1. What pictures does the word "chemistry" bring to your mind related to your everyday life?
2. *Figure 1.2* illustrates some activities related to chemistry. Can you suggest some others?

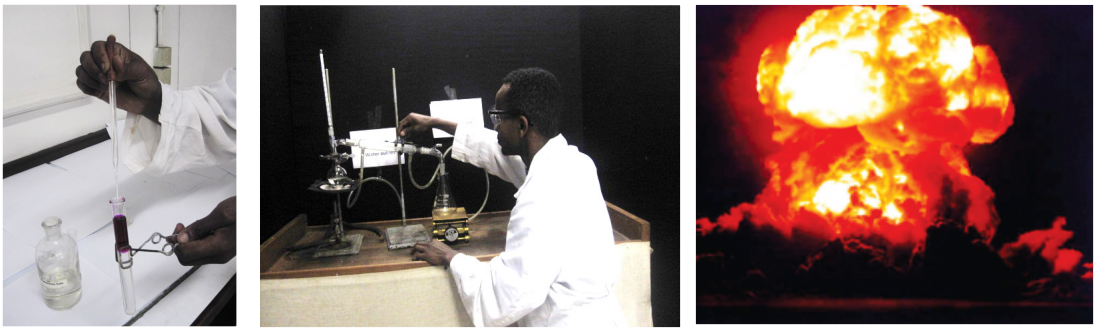


Figure 1.2: **Some activities related to chemistry**

Chemistry is an experimental science. It is mainly based on scientific laws that need observations and measurements. Therefore, to do a scientific study of substances, experiments should be done. Experiments are planned activities carried out using certain equipment, apparatus and chemicals.

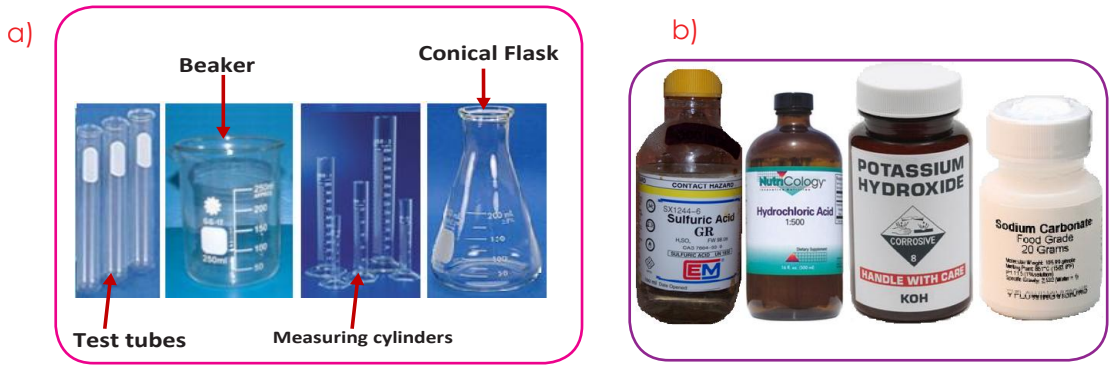


Figure 1.3: a) **some equipments** b) **some chemicals used in the Chemistry Laboratory**

Figure 1.3 shows some common equipment and chemicals used in the chemistry laboratory.

Using these equipment and chemicals, scientists perform laboratory experiments.

Here are some basic skills and steps of experiments:

- *Observations and measurements are made during experiments.*
- *During and after the experiments the results are recorded.*
- *These results are presented in systematic ways – for example; as charts, graphs, and tables of data.*
- *Collected data are carefully analyzed to make conclusions and to formulate a theory.*

The essence of chemistry refers to its most important qualities such as:

- *Satisfying social needs by producing new materials.*
- *Searching for solutions to problems of mankind.*
- *Relying only on experimentally proved facts.*

Exercise 1.1

1 List some applications of chemistry in your daily life.

2 What do we mean by the terms:

a experiment b laboratory c chemistry

3 What are some of the activities performed during Experiment?

1.2 Relationship Between Chemistry and Other Natural Sciences

After completing this section, you will be able to:

- ✓ discuss the relationships of chemistry with physics, biology and geology.

Activity 1.4

Consider water in a bucket that is kept outdoors. Three students are interested in analyzing this water in the following different aspects:

- ⇨ The first student wants to study the microorganisms that might be found in the water.
- ⇨ The second student wants to investigate the amounts of force required to lift the bucket and to carry it over various distances, and also to study the interaction of light rays with the water.
- ⇨ The third student wants to study the tastes, odors and changes of substances when they are dissolved in the water.

Questions:

1 Which one of the areas of studies described above is related to the field of:

a chemistry b biology c physics

2 Give short descriptions of physics, biology and geology.

Natural science is the study of nature and natural laws. It includes fields such as chemistry, biology, physics and geology. These fields of study in natural science are closely interrelated. There are no distinct boundaries between them. Chemistry and biology are closely related branches of natural science. For example, both biology and chemistry are integrated in biochemistry which studies the chemical composition, structure and the reactions of compounds found in living organisms. Chemistry and physics are also overlapping physical sciences.

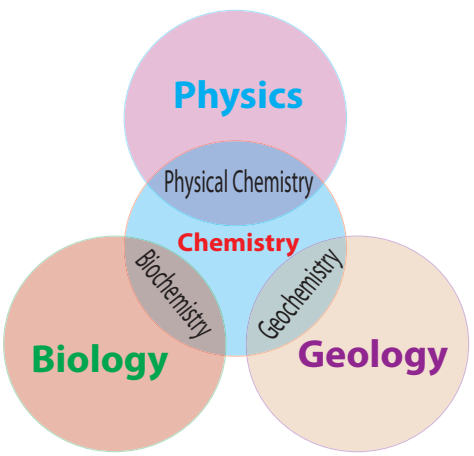


Figure 1.4: **The relationships between Chemistry and other Natural Sciences**

They make use of the same laws of nature to gain a better understanding of the properties and behavior of matter. Therefore, we have such combined disciplines as *biochemistry*, *physical chemistry*, *geochemistry* and the like.

Exercise 1.2

I ***Write 'True' for the correct statements and 'False' for the wrong statements.***

1 Biology and geology share a common area in the study of animal remains such as "Lucy" in order to understand the evolution of human beings.

2 Studying the process and the amount of energy produced by burning substances like benzene is the role of physics and biology.

II ***Give short answers.***

3 Which branches of natural science are concerned with the study of plant nutrients and their role in plant growth?

4 What branch of science is most directly concerned with:

a the composition of rocks

b the classification of trees

c identifying contaminants in food

d investigating the intensity of light

e the production of plastics

1.3 Role Played by Chemistry in Production and Society

After completing this section, you will be able to:

- ✓ describe the application of chemistry in the field of agriculture, medicine, food production and building construction.

Activity 1.5

Discuss in groups and present your opinion to the class.

1 Write down at least five examples of materials you use in everyday life produced as a result of the expertise of chemistry (chemists).

2 What chemical products are used by farmers?

3 What do you know about air pollution?

4 How can chemistry help people in your locality to have clean water?

What are the contributions of chemistry in improving the way of life of mankind in the modern world?

Chemistry plays an important role in our daily life. It is mainly concerned with the production of new materials of desirable properties and qualities to satisfy social needs. Chemistry plays an important role in agriculture. Farmers use agricultural chemicals like fertilizers, pesticides and herbicides to get more yields from their crops. This, in turn, helps to overcome food scarcity. Similarly chemistry has a role in food processing and preservation.

Chemistry is widely applied in the production of medicines and drugs that are used to cure diseases like paracetamol, chloroquine, etc.

Chemistry helps the construction industry in the production of materials like cement, limestone, steel, iron, aluminium, glass and paints.

The other important role of chemistry is the refining of petroleum to get a variety of fuels for motor vehicles, household and industrial purposes. Chemistry also helps in manufacturing various products such as cosmetics, textiles, dyes, soaps and detergents, plastics, rubber and a variety of metals, non-metals, acids, bases, alcoholic and non-alcoholic beverages, dry cells and car batteries. From these examples we can conclude that any manufacturing activity requires chemistry.

It is also applied in the economical utilization of natural resources and in finding alternative products in place of scarce natural resources. Furthermore, chemistry is involved in discovering the causes and effects of environmental pollutions thus contributing to overcome pollution problems.

Exercise 1.3

1 What is the role of chemistry in agriculture?

2 What is the contribution of chemistry in overcoming health problems?

3 What are the materials made by chemists for use in washing clothes and cooking materials?

4 What do you think life on earth would be like if chemistry had not been put to practical use?

1.4 Some Common Chemical Industries in Ethiopia

After completing this section, you will be able to:

- ✓ name some chemical industries in Ethiopia and their products;
- ✓ visit a local chemical industry and present a report to the class in groups.

ACTIVITY 1.6

Discuss in groups and present your opinion to the class.

1 What is a chemical industry?

2 Name some chemical industries in Ethiopia, their products and the places where they are found.

What pictures, ideas or feelings does the word "chemical" create in your mind? Are sugar, water and drugs chemicals?

Unfortunately, the word chemical is often associated with substances that create undesirable effects such as pollution, cancer, poisoning and harmful burning. A substance that is a "*chemical*" is not by definition, harmful. In fact, no material or substance is "*free of chemicals*". The word chemical means any substance produced by or using processes which involve changes in atoms or molecules. For example sugar, water, acid, base and drugs are chemicals.

A chemical industry is a plant or a factory involved in a manufacturing activity that converts raw materials in to desirable finished or semi-finished products. Some chemical industries use naturally available substances as raw materials to manufacture their products. In contrast, some chemical industries utilize materials produced by other industries as raw materials in their manufacturing processes.

Table 1.1 **Some common chemical industries in Ethiopia**

No	Product	Location of the industry
1	Cement	Muger, Diredawa, Mekele (Mosobo), Derba
2	Sugar	Metehara, Wonji, Finchaa
3	Soap	Repi, Gulele
4	Paper and Pulp	Wonji
5	Pharmaceuticals	Addis Ababa, Adigrat
6	Sulphuric acid and aluminium sulphate	Awash Melkasa
7	Caustic soda	Zeway
8	Soda ash	Bulbula
9	Tyre	Addis Ababa
10	Textile	Kobolcha, Hawassa, Arba Minch, Bahir Dar, Dire Dawa, Almeda (Adwa)

a)

b)

Figure 1.5: a) **Kombolcha metal factory** b) **Saba marble factory**

Project Work

Your teacher will arrange a visit to a chemical industry found in the locality where you live in. After the visit, you are expected to present a report to your classmates. So, during your visit, strictly follow the explanation that the representative of the industry will make to you. Feel free to ask questions to get information. You may ask some questions like:

i the raw materials the industry uses.
ii from where it gets the raw materials.
iii the chemical process used in the production.
iv what finished products it manufactures.

Unit Review

Check List

Competencies given below are expected to be achieved in this unit by students. You are required to respond by saying Yes or No. Put a tick (✓) mark under "Yes" column if you are able to perform the competency or under "No" column if you are unable to perform the competency.

This would help to evaluate yourself and you can revise the parts of topics for which the competencies are not met.

№	Can I	Yes	No
1	Define chemistry?		
2	Explain the essence of chemistry?		
3	Discuss the relationship of chemistry with physics, biology and geology?		
4	Describe the application of chemistry in the field of agriculture, medicine, food production and building construction?		
5	Name some common chemical industries in Ethiopia and their products?		
6	Visit a local chemical industry and present it to the class in group?		

Key Terms

- Biology
- Chemical
- Chemical industry
- Chemist
- Chemistry
- Essence of chemistry
- Fertilizers
- Finished products
- Herbicides
- Geology
- Natural science
- Pesticides
- Physics
- Raw materials

Unit Summary

- ✓ Natural science is a branch of science that studies natural laws governing living and non-living things.
- ✓ The main branches of natural science are chemistry, physics, biology and geology.
- ✓ Chemistry is a branch of natural science that studies the composition, properties, structure and transformation of substances.
- ✓ The branches of natural science share common areas of study.
- ✓ The essence of chemistry refers to the application of chemistry in the production of substances to satisfy social needs.
- ✓ Chemistry plays important roles in the production of new substances that satisfy social needs.
- ✓ Chemistry has applications in the fields of agriculture, medicine, industry, construction, and food processing and preservation.
- ✓ Chemical industry is a plant or a factory involved in the manufacturing of finished or semi-finished products.
- ✓ The chemical industries in Ethiopia manufacture a variety of chemical products: soaps and detergents, beverages, glass, cement, sugar, paper and pulp, textile, rubber, plastics, etc.

Review Exercise on Unit 1

I ***Write 'True' for the correct statements and 'False' for the wrong statements.***

1 Natural science is the study of nature and natural laws.

2 Chemistry has no role in solving the problems of mankind.

3 Physics and chemistry do not share common areas of study.

4 Chemistry and geology, in common, study the composition, properties and structure of minerals.

5 The term chemical refers only to substances that are harmful and dangerous.

II ***Chosse the correct answer from the given alternatives.***

6 Limestone consists of the elements calcium, carbon and oxygen. This statement describes the:

A structure of limestone
B transformation of limestone
C composition of limestone
D uses of limestone

7 Which chemicals serve as plant nutrients when added to the soil to increase its crop-producing potential?

A pesticides
B cosmetics
C soaps and detergents
D fertilizers

8 The substances used by farmers to control the damages caused by insects on their crops are:

A herbicides
B fertilizers
C pesticides
D perfumes

9 The branches of natural science studying the composition of compounds, and the processes taking place in organisms, respectively, are:

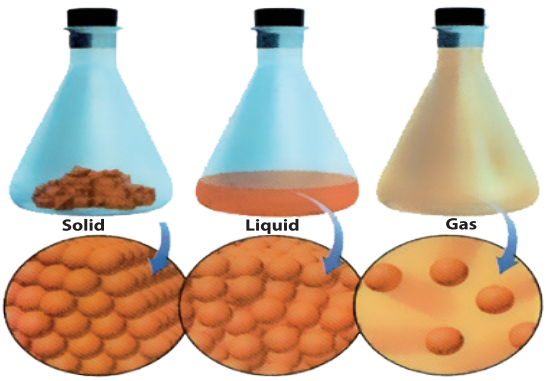
A chemistry and biology
B physics and geology
C biology and physics
D biology and geology

10 The products of chemical industries that are used to care for the skin and make people look more attractive are:

A fertilizers
B cosmetics
C detergents
D herbicides

UNIT 2

SUBSTANCES



MAIN CONTENTS

2.1 PROPERTIES OF SUBSTANCES
2.2 GROUPING SUBSTANCES
2.3 CHANGES AROUND US
2.4 SEPARATION OF MIXTURES AND ITS APPLICATIONS

⇨ *Unit Review*

UNIT OUTCOMES

After completing this unit, you will be able to:

- ✓ describe the properties of substances and identify certain substances using their physical properties;
- ✓ conduct an experiment to differentiate elements, compounds and mixtures;
- ✓ explain physical and chemical changes;
- ✓ describe and demonstrate methods of separation of mixture and apply them in their daily life;
- ✓ demonstrate scientific inquiry skills along this unit: observing, classifying, comparing and contrasting, communicating, asking questions, designing experiments, drawing conclusions, applying concepts and problem solving.

START-UP ACTIVITY

Discuss in groups and present the points of your discussion to the class.

Collect some materials from your environment and bring them to the classroom.

1 Identify and name the materials you collected.

2 What criteria do you use in identifying the materials?

3 Are these materials substances?

HISTORICAL NOTE

Antoine Lavoisier
(1743 - 1794)

In early times, people learned how to make glass, soap, bronze, pottery and many other useful substances. The knowledge spread and enabled the field of work to expand further. However, chemistry was not recognized as a science until the 17th century. Antoine Lavoisier, the "father" of modern chemistry, was one of the pioneer chemists who began the orderly study of this science to bring together all the scattered pieces of information that had been developed.

2.1 PROPERTIES OF SUBSTANCES

After completing this section, you will be able to:

- ✓ define substances;
- ✓ define physical properties;
- ✓ list some physical properties of substances;
- ✓ identify substances based on their physical properties;
- ✓ conduct experiments to identify properties of substances and make group report.

Everything in our environment, whether it is solid, liquid or gas, natural or man made is a form of matter. Matter is anything that occupies space and has mass. Water, air, sugar, milk, soil, animals and plants are some examples of matter. A form of matter possessing constant physical properties under specific conditions is called a *substance*. For example water is a substance because it has constant properties like color, odor, taste, etc.

Physical Properties

ACTIVITY 2.1

Discuss in groups and present your conclusion to the class.

1 How can you identify and differentiate (a) common salt from sugar (b) alcohol from water?

2 Take a sheet of paper and describe it in terms of color and physical state.

3 If you light a match and bring it close to the paper, the paper will start burning. Is the ability of paper to burn a physical property or a chemical property?

What are the color, odor and taste of pure water?

Properties are the characteristics that give a substance its identity and enable us to distinguish one kind of substance from another. No two substances have exactly the same set of properties. To identify a substance, chemists observe two distinct types of properties: *physical* and *chemical properties*.

Physical properties are the characteristics a substance shows without changing into a new substance. These properties are perceived by our sense organs or measured without changing the identity of the substance. Some physical properties are color, melting point, boiling point, density, physical state, and electrical conductivity.

Chemical properties are characteristics that describe the ability of a substance to form new substance. Examples of chemical properties include burning of a substance and rusting of iron.

ACTIVITY 2.2

Perform the following tasks in groups and present your conclusions to the class.

Given the following physical properties of substances: odor, color, taste, melting point, boiling point and density.

1 Which of these physical properties have constant values under specific condition, such as temperature?

2 Which physical properties can be recognized directly by our sense organs?

3 Which of these properties are measured using instruments?

4 What will happen to ice kept in a cup in the classroom?

Some Physical Properties of Substances are Listed Below

1 *Physical Properties Detected by Sense Organs*

ACTIVITY 2.3

Discuss the following phenomena in groups and present your opinion to the rest of the class.

1. Which sense organs help us to detect color, odor and taste?
2. How do you describe the taste of lemon?

The properties of the substance you observed above are properties that can be perceived by the sense organs. Some examples are color, odor and taste.

Color: The color of a substance results from its interaction with light. Substances can be identified by their colors. For example, chalk is white, water is colorless, gold is yellow and so on.

Odor: refers to the property of a substance perceived by the sense of smell. Terms commonly used to describe the odor of a substance are *pungent, fragrant, spicy, fruity* and *odorless*. For example water is odourless, flowers are fragrant, orange smells fruity.

CAUTION!

Care has to be taken in smelling substances as they may be harmful.

Taste: refers to physical properties that can be perceived by the taste buds of the tongue. The taste of a substance is usually described by terms like *sweet, bitter, sour, salty,* and *tasteless*. For example honey is sweet, lemon is sour and table salt tastes salty.

CAUTION!

Tasting can be used to identify substances only if the substance to be tasted is not harmful.

2 *Physical State*

Physical state is the form in which a substance is found under a given conditions such as temperature and pressure. The three physical states of matter are solid, liquid and gas. The same substance may exist in different states at different conditions. For example, water exists as a solid below 0°C, as a liquid between 0°C and 100°C, and as a vapor or gas above 100°C.

3 *Measurable Physical Properties*

ACTIVITY 2.4

Discuss the following activity in groups and present your opinion to the class.

1. What apparatus is used to measure the melting point and boiling point of a substance?
2. What do you call the temperature at which a liquid changes to its solid form?
3. Is the temperature at which the solid form of a substance melts the same as the temperature at which its liquid form changes to the solid state?

Measurable physical properties are the properties of a substance that can be measured using an appropriate apparatus. These physical properties have constant values under specific conditions. Examples are melting point, boiling point, density and electrical conductivity.

Melting Point: is the temperature at which a solid substance changes to its liquid state. For example, ice is the solid form of water. Ice melts to liquid (water) at 0°C. Therefore, the melting point of ice is 0°C.

Boiling Point: is the temperature at which the vapor pressure of the liquid equals the surrounding atmospheric pressure. At sea level water boils at 100°C.

Density: is defined as the mass per unit volume of a substance. It is expressed mathematically as:

$$\text{Density} = \frac{\text{Mass of the substance}}{\text{Volume of the substance}} \quad \text{or} \quad d = \frac{m}{V}$$

Note that to determine the density of a substance we should know its mass and the volume it occupies.

The units of density are kilogram per cubic meter (kg/m^3), kilogram per litre (kg/L), gram per cubic centimeter (g/cm^3) or gram per milliliter (g/mL).

Electrical Conductivity: Electrical conductivity is the ability of a substance to conduct electricity. This is a physical property mostly characteristic of metallic substances such as copper, aluminum, iron, silver and zinc.

Experiment 2.1

Title: Determining the physical properties of a substance.

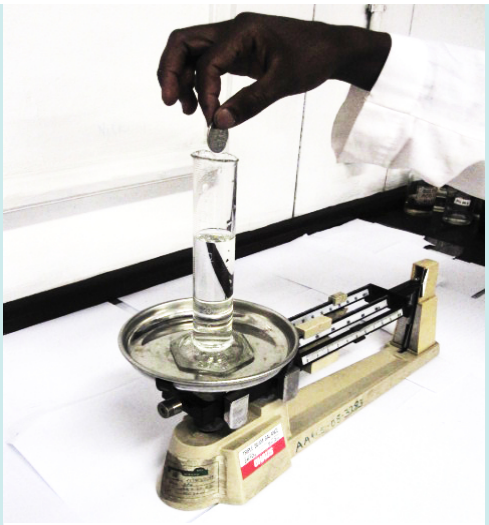
Objective: To determine the density and conductivity of substances.

Materials required: Three fifty cent coins, nails, beam balance, water, measuring cylinder, dry cell, light bulb, two pieces of connecting wires, wood and plastic.

Part A: *Determination of the Density of a Substance*

Procedure

1. Using a beam balance, measure the mass of the three fifty cent coins. Record the mass.
2. Take a measuring cylinder which is large enough for the coin to enter in to it and
   a. pour water into the measuring cylinder to the 50 mL mark.
   b. drop the three coins into the measuring cylinder turn by turn and see the change in the volume of the water after dropping all the coins as shown in *Figure 2.1* and take the reading.



Figuer 2.1 **Determination of density**

Observations and analysis:

i What is the total mass of the three coins?

ii What is the total volume of the three coins?
(Volume of coins = Volume reading after dropping the coins – 50 mL)

iii What is the density of a single fifty cent coin?

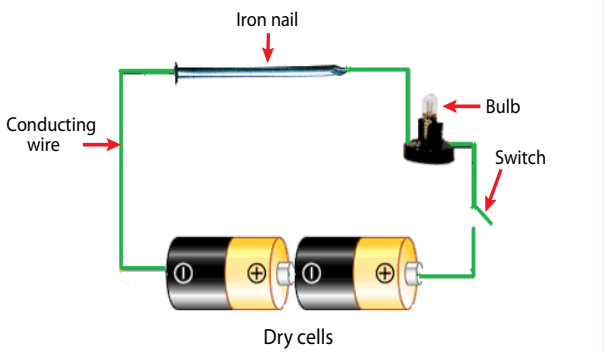
Part B: *Conductivity of a Substance*

Procedure:

1 Take a nail and connect it to the wire.

2 Attach the wires to the positive and negative terminals of the dry cell as shown in *Figure 2.2*.

3 Observe whether the bulb gives light or not.



Figuer 2.2 **Conductivity of a substance**

Observations and analysis:

i Does the bulb give light? What does this indicate?

ii What will happen if the nail is replaced by wood or plastic in this experiment?
Write a report about your observations and present it to the class.

Exercise 2.1

1 If 30 mL of water weighs 30 g, and the same volume of mercury weighs 408 g, calculate the densities of water and mercury.

2 Is tasting an advisable method for identifying substances? Why?

3 What is the difference between ice, liquid water and steam?

4 Do you think plastic and rubber conduct electricity?

Identifying Substances Based on their Physical Properties

Can all the properties of different substances be identical?

Every substance has a specific set of physical properties. These physical properties are used to differentiate one substance from others. Two different substances may have similar physical properties. However, all their physical properties cannot be identical.

Experiment 2.2

Title: Identifying unknown substances based on their physical properties.

Objective: To investigate the physical state, color and solubility of substances.

Materials Required: Five unknown substance, water, five small beakers, spatula and glass rod.

Your teacher will provide you five small beakers with five substances: Use the following procedure to identify the substances.

Procedure:

1 Examine each of the five substances and record your observation regarding their state and color.

2 Take the five small beakers and add 50 mL water to each beaker. Then add a spatula full of each of the substances to each beakers. Stir the mixture in each of the five beakers with a glass rod and observe the results.

Observation and Analysis:

Copy the following table in your exercise book and record your observations.

Substance	State	Color	Solubility in water
A			
B			
C			
D			
E			

Write a report about your observation and present it to the class.

ACTIVITY 2.5

Discuss the activity in groups and present your findings to the class.

Table 2.1 **Physical properties of selected elements**

Elements	Melting point/°C	Boiling point/°C	Density (g/cm³)
Mercury	–39	357	13.5
Aluminium	660	2467	2.7
Copper	1085	2570	9.0
Iron	1530	2861	7.9
Bromine	–7.2	58.5	3.10

Among the elements listed in *Table 2.1* identify the element(s):

i With the highest melting point

ii With the lowest density

iii Which melts at 1085°C and has a density 9.0 g/cm³.

iv Which are liquids at room temperature.

The elements we know as metals vary in color, density, state, magnetic property and electrical conductivity.

Experiment 2.3

Title: Identification of metals on the basis of physical properties.

Objective: To identify metals by observing their physical properties.

Materials Required: Mercury, copper, iron, aluminium, lead, sodium metal, and a magnet.

Procedure:

1 Take a magnet and check if the above metals are attracted by a magnet (*except mercury*). Which metals are attracted by the magnet and which one of them are not?

2 Examine each metal carefully. Copy the following table in your exercise book and record your observations. Your record should include color, state and whether the metal is light or heavy, magnetic or non-magnetic.

Metals	Observed physical properties		
	Color	State	Magnetic or non-magnetic
Mercury			
Copper			
Iron			
Aluminium			
Lead			

Observations and Analysis:

i Which metal is liquid and has a silvery-white color?

ii Which metal can be identified by its reddish-brown color?

iii Which metal is light, silvery-white and not attracted by a magnet?

iv Which metal is grayish in color and has a high density?

Write a report and present to the class.

Exercise 2.2

I ***Write True for correct statements and False for wrong statements.***

1 Air does not occupy space and has no mass. So it is not a substance.

2 Water exists in different states below 0°C and at 50°C.

3 The properties of a substance that can be observed without altering its identity are physical properties.

4 The ability of iron to conduct electricity is a chemical property of iron.

5 Two different substances can have the same set of properties.

6 The temperature at which a solid melts is the same as the temperature at which its liquid form solidifies.

7 Physical properties are used as a basis of identifying substances.

II ***Multiple choice***

8 Which property of a substance is measurable?

A density C taste
B color D odor

9 The temperature at which a solid changes to its liquid form is:

A boiling point C freezing point
B melting point D condensation temperature

10 A block of iron metal occupies a volume of 20 cm^3 and has a mass of 157.2 g. What is the density of iron?

A 15.72 g/cm^3 C 3.93 g/cm^3
B 7.86 g/cm^3 D 7.86 g/m^3

11 The physical property of a substance that has no fixed numerical value at a given condition is:

A density C melting point
B boiling point D taste

12 Which phrase describes the taste and color of water respectively?

A bitter and colorless
B sour and white
C sweet and colorless
D tasteless and colorless

13 Which one of the following is not a unit of density?

A kg/m^3
B g/cm^3
C kg/m^2
D g/mL

III *Short answer questions*

14 Identify whether the following statements describe a physical or chemical property of a substance.

a Charcoal burns in air to form carbon dioxide.
b Ethyl alcohol boils at 78°C.
c Sulphur is a yellow solid at room temperature.
d Mercury is a silvery-white liquid metal.
e Silver is the best conductor of electricity.
f Iron rusts in the presence of moisture and air to form an oxide.
g Benzene is an inflammable liquid.

15 Given samples of the following pairs of substances, name two physical properties that could be used to distinguish between the materials in each pair.

a Cork and lead
b Copper and silver
c Water and benzene
d Sulphur and iron

2.2 GROUPING SUBSTANCES

After completing this section, you will be able to:

- ✓ classify substances into pure substances and mixtures;
- ✓ define pure substances;
- ✓ define elements and compounds;
- ✓ classify elements as metals, non-metals and metalloids;
- ✓ give examples of metals, non-metals and metalloids;
- ✓ explain the differences between elements and compounds;
- ✓ carry out an experiment in groups to distinguish compound and mixtures;

- ✓ classify compounds as oxides, acids, bases and salts;
- ✓ give examples of oxides, acids, bases and salts;
- ✓ define mixtures;
- ✓ define homogeneous and heterogeneous mixtures;
- ✓ give examples of homogeneous and heterogeneous mixtures; and
- ✓ compare and contrast homogeneous and heterogeneous mixtures.

Why do chemists need to classify substances?

Chemists need to work with pure substances and apply techniques of purification to get these substances. Understanding the chemistry of a substance would be simpler if it is a pure substance.

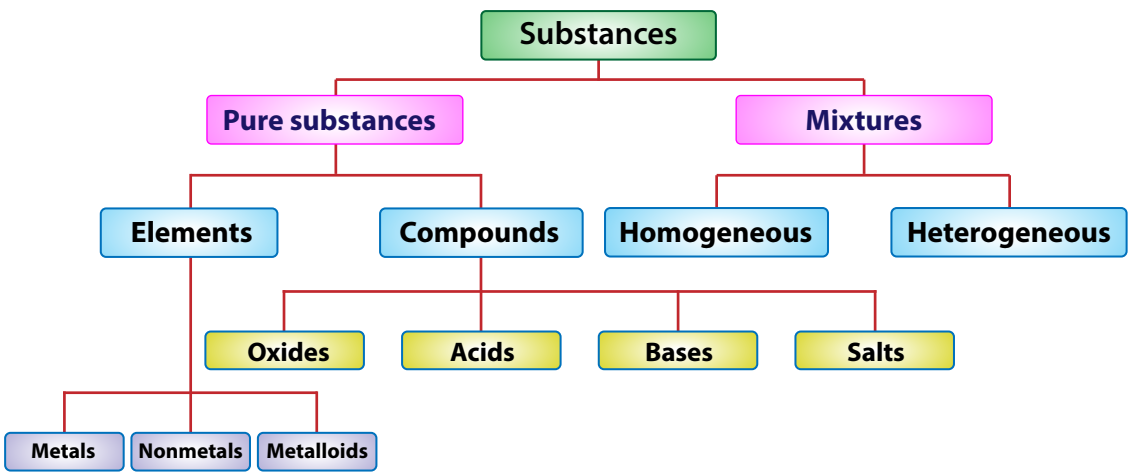
Pure Substances and Mixtures

ACTIVITY 2.6

Perform the following task in groups and present your findings to the class.

Name at least 10 kinds of substances that you see or know. For example, you might list pencil, ink, tap water, window glass, milk, etc. Classify the materials you listed as pure substances or mixtures.

There are various ways of classification of substances in chemistry. At this level, we classify substances based on their composition and properties. Substances are classified as *pure substances* and *mixtures*. A *pure substance* is a form of matter that has constant composition and uniform properties throughout the sample. It may contain either a single component or two or more components.



Figuer 2.3 **Grouping substances**

For example, a block of iron is a pure substance containing only one kind of component. Water is also a pure substance containing two components (hydrogen and oxygen) combined chemically in a definite ratio. Some other common examples of pure substances are oxygen, copper, gold, sugar, table salt and carbondioxide.

Are the properties of a sample of turbid water uniform throughout? What about its composition? Is turbid water a pure substance?

Rock salt is another example. Rock salt contains varying amounts of sodium chloride and rock. In rock salt, sodium chloride and sand have their own properties. The proportion of sodium chloride and sand is not also uniform throughout the sample. This type of substance is called a *mixture*. Mixtures are combinations of two or more components in varying proportions and the components retain their identities. Thus, a mixture does not have constant composition. Tap water, ink, milk and air are also examples of mixtures.

Exercise 2.3

1 List examples of pure substances other than those given above.

2 Explain why we classify bottled water, ink, milk and air as mixtures.

Elements and Compounds

ACTIVITY 2.7

Perform the following tasks in groups and present your findings to the rest of the class.

1 Consider the following pure substances: iron, water, oxygen, copper, gold, sugar, table salt, carbon dioxide, sulphur, carbon, hydrogen, chlorine and mercury.

   a Which of them are elements?

   b Which of them are compounds?

2 Make a list of at least six substances that are in everyday use in your home. For each, state whether it is an element, a compound or a mixture.

Pure substances are classified as *elements* and *compounds*.

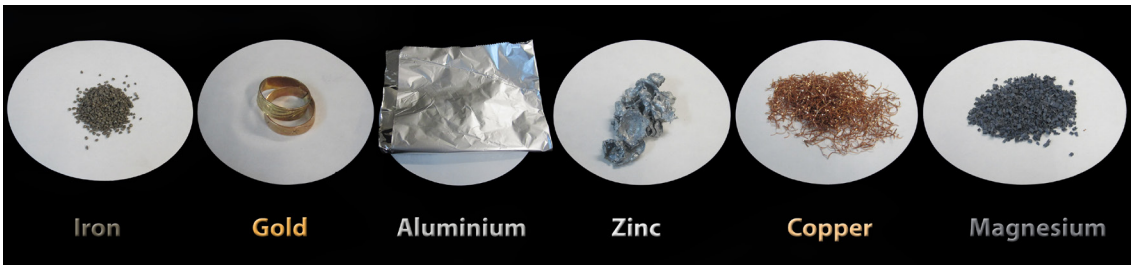
Elements

An *element* is a pure substance that cannot be broken down into simpler substances by ordinary chemical means. An element is composed of only one kind of matter (atoms). For example, the element gold consists of only gold atoms.

At present, more than 115 elements are known. Among these elements, 92 of them occur naturally while the rest are man-made or artificial elements. Elements are classified as *metals*, *non-metals* and *metalloids*.

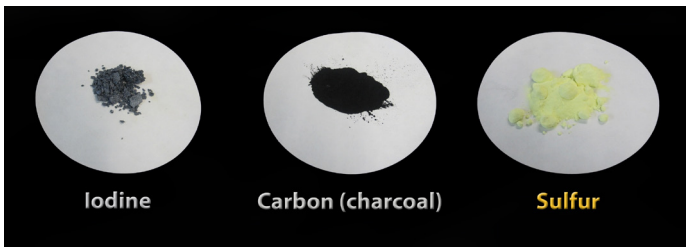
Metals are elements characterized by their shiny appearance (luster), electrical conductivity, malleability and ductility. Malleability is the ability of a substance to be

pressed into sheets when hammered. Ductility is the ability to be drawn into thin wire. All metals are solids at room temperature except *mercury* which is a liquid. They have high melting points and boiling points. Some examples of metals are *gold*, *iron*, *silver*, *copper*, *aluminium, sodium* and *lead*.



Figuer 2.4 **Some common metals**

Non-metals are elements that are not shiny, and are non-conductors of heat and electricity. They are not malleable and ductile. Non-metals generally exist as solids or gases at room temperature. *Bromine* is the only a non-metallic element that is liquid at room temperature. Non metals have relatively, low melting points and boiling points. Carbon, sulphur, flourine and phosphorous are some common examples of nonmetals.



Figuer 2.5 **Some common non-metals**

ACTIVITY 2.8

Do the following activities in groups and present your findings to the class.

Given the following elements: iron, oxygen, copper, gold, sulphur, carbon, hydrogen, silver, chlorine, phosphorus, nitrogen, iodine, zinc, aluminium, lead, sodium, fluorine and calcium.

1 Classify the elements as metals and non-metals. What criteria did you use to differentiate metals from non-metals in your classification?

2 Classify the non-metals as solids and gases at room temperature.

The third group of elements are called *metalloids*. These elements exhibit some properties of metals and some properties of non-metals. They have intermediate characteristics between metals and non-metals and are also known as *semi-metals*. They are *boron*, *silicon*, *germanium*, *arsenic*, *antimony*, *tellurium* and *polonium*.

Compounds

A *compound* is a pure substance composed of two or more elements that are combined chemically in a definite proportion by mass. A compound can be decomposed into two or

more elements by a chemical means. For example, carbondioxide is a compound. It can be decomposed into carbon and oxygen by a chemical means.

Elements can combine with other elements to form compounds. Sodium chloride is formed by the combination of sodium and chlorine elements. Such types of compounds that are formed by the combination of two different elements are called *binary compounds*. Most binary compounds contain metallic and non metallic elements.

ACTIVITY 2.9

Discuss the following activity in groups and present your finding to the class.

From which types of elements are the following compounds formed?

i Potassium chloride

ii Magnesium iodide

iii Iron sulphide

iv Copper oxide

A compound is not a mixture of elements. This is because each element in a compound does not retain its identity. The properties of a compound are completely different from the properties of the elements that make up the compound. For example, sodium chloride is a compound composed of sodium and chlorine. Sodium chloride is a white solid crystal where as sodium is a soft silvery metal and chlorine is a greenish poisonous gas. This is illustrated in *Figure 2.6*.

Figuer 2.6 **Nature of sodium, chlorine, and sodium chloride**

Let's see how to determine whether a given substance is a compound or not. Consider water as an example. Water is a compound because of the following reasons:

i Water is formed by the chemical combination of two elements: hydrogen and oxygen.

ii Water can be decomposed into its constituent elements, hydrogen and oxygen by a chemical means and not by physical processes.

iii The properties of water are completely different from hydrogen and oxygen. For example, water is a liquid whereas hydrogen and oxygen are gases. Water does not burn, but hydrogen burns and oxygen supports combustion.

iv The composition of water is always fixed. In any sample of water, 2 parts of hydrogen combine with 1 part of oxygen (in the ratio H:O = 2:1) to give a definite formula of water, H_2O. This composition does not change, whatever the source of water. i.e., sea water, river water, rain water and tap water all have this same ratio of hydrogen to oxygen.

Thus, all the above characteristics show that water is a compound.

The main difference between elements and compounds are summarized in *Table 2.2*.

Table 2.2 **Differences between Elements and compounds**

Elements	Compounds
⇨ *Composed of one type of atom*	⇨ *Two or more elements chemically combined in a fixed ratio.*
⇨ *Cannot be broken down into simpler substances under normal condition*	⇨ *Can be broken down into simpler substances by chemical means.*
⇨ *Simplest type of matter that retains characteristic properties*	⇨ *Properties differ from those of their constituent elements*

Exercise 2.4

1 Give two reasons that show sugar is a compound.

2 What is the difference between carbon (charcoal) and sugar? Compare and contrast using *Table 2.2*.

Classifications of Compounds

ACTIVITY 2.10

Discuss the following ideas in groups and present your opinion to the class.

1 What is the difference between the tastes of 'lemon' and common salt? What do you think the cause for this difference?

2 Why do you think milk of magnesia (magnesium hydroxide) is given to patients suffering from gastritis?

Compounds can be classified into *oxides*, *acids*, *bases* and *salts*.

Oxides

Oxygen combines with most of the elements, to form compounds known as oxides. Oxides are compounds that consist of oxygen and one other element. Hence, oxides are binary compounds that contain oxygen.

For example, when carbon combines with oxygen, it produces an oxide, known as carbon dioxide. Also, when magnesium burns in air (oxygen), it forms magnesium oxide.

Some examples of oxides are:

- *Iron oxide, Sodium oxide, Copper oxide, and Nitrogen oxide.*

Acids

Acids are substances that release hydrogen ion (H^+) in water solution. The characteristic properties of acids are due to the presence of hydrogen ions. Acids are found in nature or can be prepared in the laboratory. Acids have a sour taste. Vinegar, lemon, grape fruit, and spoilt milk all taste sour due to the presence of acids. For example, fruits like lemon and orange contain citric acid and vinegar contains acetic acid. Carbonic acid formed from carbondioxide dissolved in water is present in some of the soft drinks. Hydrochloric acid, which helps in the digestion of food, is also present in our body. Acids turn blue litmus paper to red. Litmus paper is one of the common indicators. It changes its color to red when added to an acid solution.

Some examples of acids are:

- *Sulphuric acid, Nitric acid, and Phosphoric acid.*

Bases

Bases are substances that release hydroxide ion (OH^-) in water solution. The characteristic properties of bases are due to the presence of hydroxide ions. Bases have a bitter taste They turn red litmus paper to blue. Bases neutralize acids. For example, magnesium hydroxide, known as 'milk of magnesia' is a common antiacid that helps to neutralize excess hydrochloric acid in our stomach. Some bases are soluble and others are insoluble in water. The soluble bases are called *Alkalis*.

Some examples of bases are:

- *Sodium hydroxide, Calcium hydroxide, Potassium hydroxide, and Ammonia solution.*

Salts

Salts are compounds that are formed by the reaction of acids with bases. A great number of salts play an important role in our daily life. For example, common salt (sodium chloride) is essential for life and helps to preserve food.

Some examples of salts are:

- *Calcium carbonate, Copper sulphate and Potassium nitrate.*

Exercise 2.5

Classify the following compounds into oxides, acids, bases and salts.

1 Citric acid
2 Sulphur dioxide
3 Potassium hydroxide
4 Sodium sulphate
5 Sodium hydrogen carbonate.

Mixtures

ACTIVITY 2.11

Discuss the following ideas in groups. Present your opinion to the class.

i What is the difference between pure water and a solution of sodium chloride in water.

ii Do you think air is a pure substance or a mixture? Why?

Mixtures are substances that consist of two or more pure substances, in which the substances retain their identity. Mixtures are not pure substances because they have variable composition and no unique set of properties. They can be separated by physical means.

For example, when sodium chloride (common salt) is mixed with water, it forms a salt solution.

This salt solution is a mixture because of the following main reasons:

i The components, salt and water, are simply physically mixed. i.e they are not chemically combined.

ii This salt solution retains many of the properties of its constituents, sodium chloride and water. In other words, the salt solution shows the properties of the salt and the water. For example, the solution is coloreless like water, and also it tastes salty like the original sodium chloride salt.

iii The salt solution can be separated into salt and water by physical processes like evaporation or distillation. You will learn about separation methods in Section 2.4.

Therefore, all the above characteristics confirm that a salt solution is a mixture.

Some examples of mixtures are milk, sea-water, soil, ink, wood, petroleum and alloys.

Experiment 2.4

Title: Distinguishing compounds and mixtures.

Objective: To investigate the difference between a compound and a mixture.

Materials Required: Magnet, iron filings, powdered sulphur, test tube, Bunsen burner, magnifying glass, tong and beam balance.

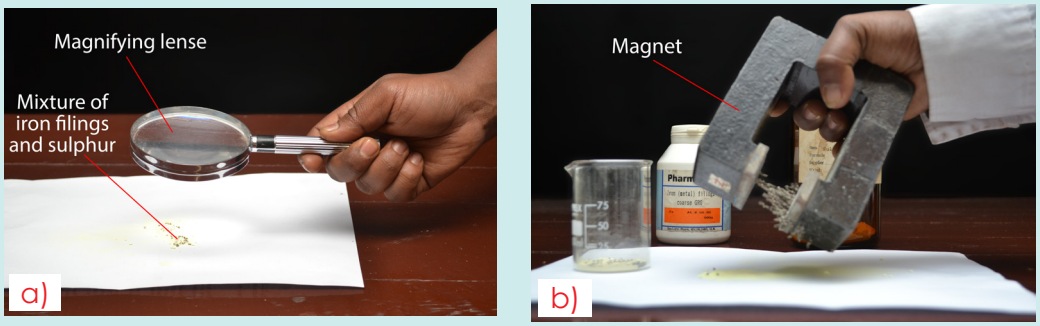
Part I

Procedure:

1 Mix 10 g of iron filings with 6 g of powdered sulphur. Examine the mixture using a magnifying glass as shown in *Figure 2.7(a)*.

2 Place half of this mixture on a sheet of paper. Bring one end of a magnet close to the mixture as shown in *Figure 2.7(b)*.

3 Observe the components of the mixture with a magnifying glass.



Figuer 2.7 **Separating iron from a mixture of iron and sulphur**

Questions:

i What did you observe as you bring the magnet close to the mixture?

ii What did you observe under the magnifying glass?

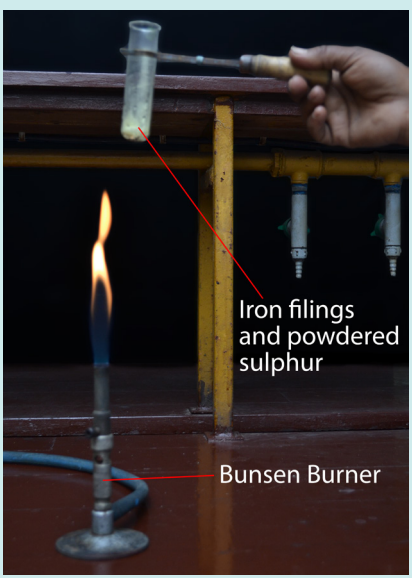
Part II

Procedure:

1 Place the remaining half of the mixture in a test tube. Heat the test tube strongly for a few minutes as shown in *Figure 2.8*.

2 Put off the flame and remove the test tube. After the reaction stops, break the test tube by plunging the hot end into a beaker of cold water.

3 Take the product formed and powder it. Examine the product under a magnifying glass. Bring a magnet over it.



Figuer 2.8 **The reaction between iron and sulphur**

Questions:

1 Under a magnifying glass, are the iron filings and sulphur seen separately?

2 Is it possible to attract the iron or sulphur by a magnet? Why?

Observations and Analysis:

i Which part of the experiment (Part I or II) indicates a compound? Give your reason.

ii Which part of the experiment (part I or II) indicates a mixture?

The general characteristics of mixtures and compounds are compared in *Table 2.3*.

Table 2.3 **Differences between Compounds and Mixtures**

Compound	Mixture
⇨ *A compound has a fixed composition.*	⇨ *A mixture has a variable composition.*
⇨ *A compound has a new set of properties.*	⇨ *The components of a mixture retain their properties or identities.*
⇨ *A compound has a definite formula.*	⇨ *A mixture does not have a definite formula.*
⇨ *Formed as a result of chemical change.*	⇨ *Formed as a result of physical change.*
⇨ *Its components can only be separated by chemical or electrical means.*	⇨ *Its components can be separated by physical means.*
⇨ *A compound has a fixed melting point, boiling point, etc.*	⇨ *A mixture does not have a definite melting point, boiling point, etc.*
⇨ *Energy in the form of heat or light is released or absorbed.*	⇨ *Usually heat or light energy is not released or absorbed.*

Classifications of Mixtures

ACTIVITY 2.12

Discuss the following phenomenon in groups and present your opinion to the class.

1 When a teaspoon full of salt is added to a cup of warm water, white crystals are seen at the bottom of the cup. Can you see the components of the mixture separately?

2 Now the mixture is stirred until the salt crystals disappear. What is the difference between these two mixtures? (Before and after stirring).

Mixtures are classified into two types: *homogeneous mixtures (solutions)*, and *heterogeneous mixtures*.

Homogeneous Mixture (Solution)

A *homogeneous mixture* (also known as *solution*) is a mixture in which the components cannot be seen by our naked eyes or using a microscope or a magnifying glass. A homogeneous mixture has a uniform composition and properties throughout. It contains

only one phase. A *phase* is a region with a uniform set of properties. A solution is a homogeneous mixture. For example, a mixture of sugar and water (sugar solution) is a homogeneous mixture because all the parts of the solution have the same sugar-water composition. The sugars are totally disperesed into the water and can not be seen separately. Also there is no visible boundary of separation between the sugar and water components in a solution.

In a homogeneous mixture, the proportions of components may vary from sample to sample like in a body of sea water, but each sample is uniform in appearance. Alloys are homogeneous mixtures of metals. For example, brass is an alloy of two metals: copper and zinc.

Table 2.4 **Examples of homogeneous mixtures**

Mixtures	Examples
⇨ *Solution of solid in liquid*	*Sea water, sugar in water, salt solution*
⇨ *Solution of two miscible liquids*	*Alcohol and water, benzene and kerosene*
⇨ *Solution of gas in liquid*	*Soft drinks, mineral water, soda water*
⇨ *Mixture of gas in gas*	*Air*
⇨ *Alloy of two solid metals*	*Brass (mixture of copper and zinc) bronze (mixture of copper and tin)*

Heterogeneous Mixtures

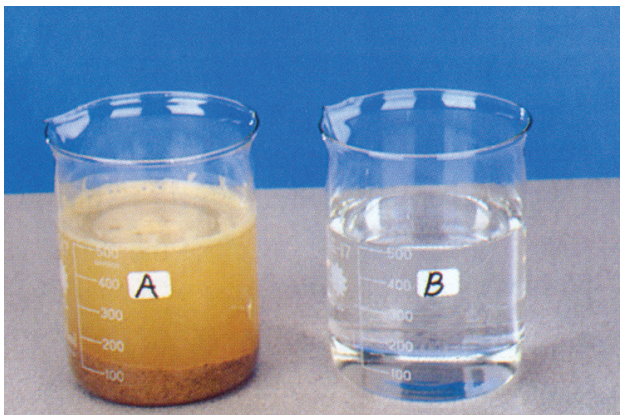
A mixture that does not have a uniform composition throughout is known as a *heterogeneous mixture*. The components of a heterogeneous mixture can be identified by our naked eyes or with the help of a microscope or a magnifying glass. They contain more than one phase.

For example, a mixture of sand and iron filings is a heterogeneous mixture. This is because the sand particles remain visible and physically separated. Blood is also a heterogeneous mixture of plasma, red blood cells, white blood cells, etc that can be seen using a microscope.

Table 2.5 **Examples of heterogeneous mixtures**

Mixture	Examples
⇨ *Insoluble solid in liquid*	*Mixture of sand and water, river water, muddy water*
⇨ *Two immiscible liquids*	*Benzene and water, oil and water*
⇨ *Solid in gas*	*Dusty air, smoke*

Figure 2.9 Illustrates homogenous and heterogeneous mixtures of substances as shown below.



Figuer 2.9 **Mixtures A) heterogeneous B) Homogenous**

ACTIVITY 2.13

Discuss the following activity in groups and present your opinion to the class.

In your daily life, you are familiar with most of the following substances. Which of them is a compound, a homogeneous mixture or a heterogeneous mixture. Give your reason for each case.

1. Vegetable soup
2. Orange juice
3. Tea (shai)
4. 'Doro wott'
5. Calcium carbonate ('chalk')
6. A bottle of soft drink
7. Cooking oil

Table 2.6 **Differences between homogenous and heterogeneous mixtures**

Homogeneous mixture	Heterogeneous mixture
⇨ *It has a uniform composition throughout*	⇨ *It does not have a uniform composition throughout.*
⇨ *It has no visible boundaries of separation between the components*	⇨ *It has visible boundaries of separation between the components*
⇨ *Its components cannot be seen by our naked eyes or by microscope*	⇨ *Its components can be identified by our naked eyes*
⇨ *It consists of only one phase*	⇨ *It contains more than one phase*

Exercise 2.6

1. Identify wether the following are pure substances or mixtures.
   - a Sea water
   - b Gold
   - c Chalk
   - d Oil
   - e Blood
   - f Alcohol (ethanol)

2 Classify each of the following as an element, a compound or a mixture.

a	Milk	d	Sugar	g	Ink
b	Salt	e	Silver	h	Air
c	Wood	f	Paper	i	Pure water

3 Which of the following are homogeneous mixtures, and which of them are heterogeneous mixtures?

a	Milk	e	Mixture of salt and sugar
b	blood	f	Sugar dissolved in Tea
c	Soil	g	Mixture of alcohol and water
d	Mixture of oil and water		

4 Give two reasons to support why water is a compound and not a mixture.

2.3 CHANGES AROUND US

After completing this section, you will be able to:

- ✓ define physical changes;
- ✓ give examples of physical changes;
- ✓ define chemical changes;
- ✓ give example of chemical changes;
- ✓ distinguish the physical and chemical changes using their characteristics and
- ✓ conduct some simple activities to show physical and chemical changes and write group report.

ACTIVITY 2.14

Discuss the following phenomena in groups and present your opinion to the class.

Place a piece of chocolate or candy in your mouth and wait for a few minutes. Notice the changes carefully.

i What happens to the chocolate or candy?

ii Is there any change that occurs before and after you put the chocolate or candy in your mouth? Explain.

The substances in our environment constantly undergo changes. The decay of plants and animals, the burning of gasoline, the evaporation of lakes and seas, and the melting of snow are some of the changes that occur in our environment. Most of the changes in substances are classified into physical and chemical changes.

Physical Changes

Changes that do not alter the composition of the substances are called physical changes. In physical changes, the original substance can be recovered or the change can easily be reversed. Changes like melting, freezing, dissolving and evaporating are physical changes. This is because in all of these changes new substances with new properties are not formed. In other words, the same original substances are observed before and after the changes.

Physical changes can be classified into three. These are

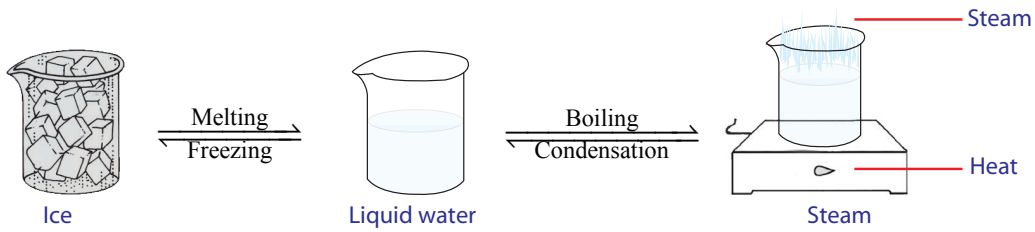
- The changes of state,
- Solution (dissolving) and
- Mechanical changes

I *Change of State*

We know that matter exists in three physical states or forms: solid, liquid and gaseous states. By varying the temperature, substances can be changed from one physical state to another. Such type of a change is a physical change. Let's take water as an example. Water exists in solid (ice), liquid (water) and gaseous states. When ice is heated, it melts to liquid water, and on further heating the water changes to steam. Liquid water looks different from ice or steam. But the composition and identity of the original substance does not change because it is still water whatever its state is. Consider the following changes of states of water.

$$\text{ice} \underset{\text{cool}}{\overset{\text{heat}}{\rightleftharpoons}} \text{liquid water} \underset{\text{cool}}{\overset{\text{heat}}{\rightleftharpoons}} \text{steam}$$

By heating or cooling water, it is possible to convert liquid water in either direction. These changes of state indicate that the change is reversible.



Figuer 2.10 **Physical changes in the appearance and state of water**

II *Solution (Dissolving Substances)*

The process of dissolving a substance in water to form a solution is a physical change. For example, when common salt is dissolved in water, a clear salt solution is formed. If this mixture is heated, the water is evaporated, and the original salt remains as a residue. Thus, in the process of dissolution, no new substances are produced.

III *Mechanical Changes*

Mechanical changes brought about by breaking, hammering, powdering, tearing and cutting of substances are physical changes. Mechanical changes involve changes in the size and shape of the material. Example powdering of chalk.

Characteristics of a Physical Change

- *It is a change in the physical property of the substance*
- *No new substance is formed (the identity of the substance does not change)*
- *The change is easy to reverse (It is a reversible process)*
- *No change in the mass of the substance is involved*
- *No change in composition occurs*
- *Energy changes (heat changes) are not necessarily involved*

Chemical Changes

ACTIVITY 2.15

Discuss the following phenomena in groups and present your opinion to the class.

In your home, you may have observed the formation of rust on the surface of knives or nails that are made of iron.

i Why is rust formed on the surfaces of knives or nails?

ii Using any process, do you think that this knife or nail can be reversed into the original condition? Explain.

If a piece of paper is burned in air, two observable products are formed: an ash and a smoke. These substances have different properties and composition from the original material. After burning, the composition of the sample is changed because it no longer exists as a paper. Such type of change that results in the formation of new substances with new properties and composition is known as a *chemical change*. A chemical change is a chemical property of a substance. The change is generally difficult to reverse. Some common examples of chemical changes are digestion of food, growth of plants, burning of wood, rusting of iron, decaying of food and exploding of gun powder.

Characteristics of a Chemical Change

- *New substances with new properties are formed*
- *It is a change in the chemical property of the substance*
- *It is a change in the composition of the substance involved*
- *It is difficult to reverse the change*
- *A change in the masses of the substances is involved.*
- *Energy change (heat change) is involved.*

Experiment 2.5

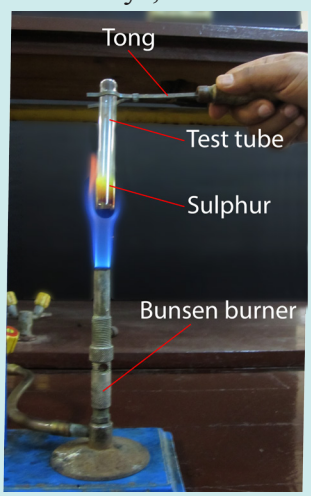
Title: Melting sulphur.

Objective: To determine whether the melting of sulphur is a physical or a chemical change.

Materials required: Test tube, watch glass, Bunsen burner, tong, powdered sulphur.

Procedure:

1 Put powdered sulphur to half a test tube
2 Heat the test tube gently until all the sulphur melts as shown in *Figure 2.11*.
3 Observe the color of the molten sulphur
4 Pour the molten sulphur on a watch glass and allow it to cool.
5 Let the watch glass stay for some days, and observe the change again.



Figuer 2.11 **Melting sulphur**

Observations and Analysis

i Name all the colors of sulphur you observed before and after the experiment.
ii Is the change physical or chemical?

Exercise 2.7

Choose the best answer from the given alternatives.

1 Which statement describes a chemical change?
- A Alcohol evaporates
- B Water vapor forms snowflakes
- C Table salt (NaCl) is crushed into powder.
- D Glucose ($C_6H_{12}O_6$) and oxygen produce CO_2 and H_2O.

2 Which process is an example of a physical change
- A Burning of wood
- B Rusting of iron
- C Melting of ice
- D Explosion of gun powder

Experiment 2.6

Title: Rusting of iron.

Objective: To investigate the type of change that occurs during rusting of iron.

Materials Required: Iron nails, test tube,

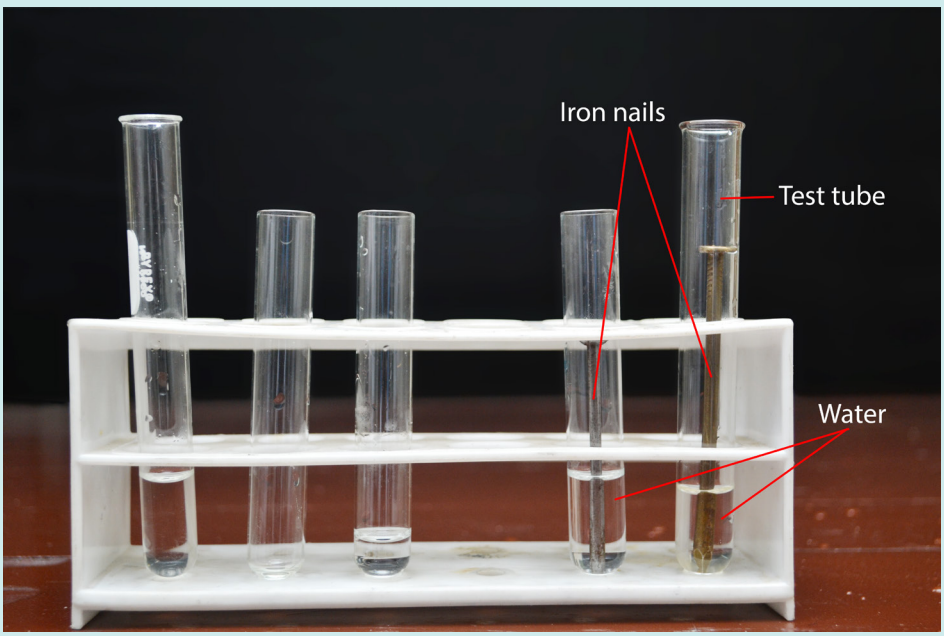
Procedure:

1 Pour some amount of tap water into the test tube.

2 Put 3 or 4 clean and shiny iron nails into the test tube as shown in *Figure 2.12*.

3 Let the test tube stay for a few days in open air.

4 Observe the change that takes place.



Figuer 2.12 **Rusting of iron**

Observation and Analysis:

i What happened to the surface of the iron nail?

ii What color do you observe on the iron nail?

iii Is the change physical or chemical? Why?

Activity 2.16

Discuss the following idea in groups, and present your opinion to the rest of the class.

To decide whether a change in a substance is a chemical or a physical change, the basic question we have to ask is "Does the substance change its composition or just change its form (state)?"

i Do you agree with the above idea? Give your reason.

ii Give one example for a change in composition and another for a change in form.

Experiment 2.7

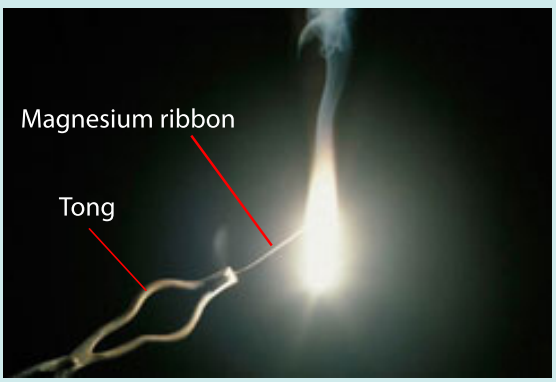
Title: Burning magnesium ribbon.

Objective: To investigate the change that occurs during burning of magnesium.

Materials Required: Crucible, tong, magnesium ribbon.

Procedure:

1 Take about 7 cm of magnesium ribbon.
2 Notice the properties of magnesium.
3 Hold the magnesium ribbon with tongs and burn it in the crucible as shown in *Figure 2.13*.
4 Collect the substance formed in the crucible, and observe the color. Will it burn if heated again?
5 Compare the properties of magnesium and the product formed.



Figuer 2.13 **Burning of Magnesium**

Fill the following table based on your experimental result.

Properties	Before burning	After burning
Color		
State (form)		
Appearance		
Ductility		

Observation and Analysis:

i Is there a change in the composition of the magnesium ribbon after burning?
ii Will the product burn if it is heated again? Explain.
iii What type of change does the experiment indicate?

Exercise 2.8

1 Classify the following as a chemical or physical change.
   i Melting of iron
   ii Souring of milk
   iii Formation of clouds in the atmosphere

iv The compression of a spring

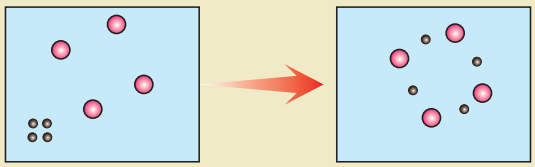
v Freezing of ice cream

vi Lighting a candle

vii Evaporation of alcohol

2 Which diagram represents a physical change and which of them represents a chemical change?

i



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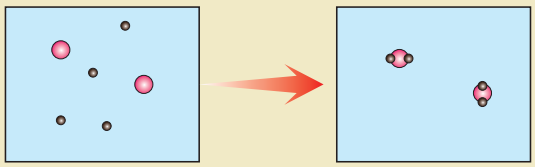

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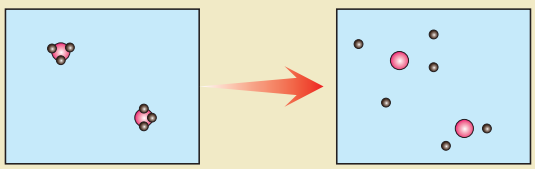

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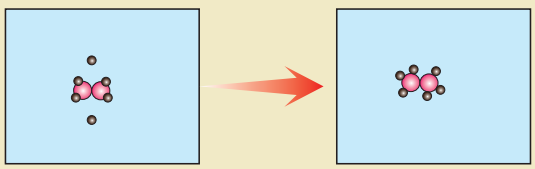


= *an atom of an element*

= *an atom of a different element*

2.4 SEPARATION OF MIXTURES AND ITS APPLICATION

After completing this section, you will be able to:

- ✓ list methods of separation of mixtures;
- ✓ explain methods of separation of mixtures;
- ✓ give some specific examples of mixtures that can be separated by filtration, decantation, simple distillation, magnetic separation and using separatory funnel;
- ✓ name apparatuses used in decantation, filtration, simple distillation, using separatory funnel; and
- ✓ assemble apparatuses used in decantation, filtration, simple distillation, separatory funnel.

ACTIVITY 2.17

Discuss the following ideas in group and present your opinion to the class.

You are familiar with some methods of separating mixtures from Integrated Science from Grade 6.

1 Mention some of the methods you recall.

2 What method is used to separate fine flour and coarse particles?

3 What is the difference between filtering and decanting?

4 Can you suggest a method employed to separate salt dissolved in water?

Can you mention some mixtures and the methods used to separate them into their components?

Most of the substances around us exist in the form of mixtures. However, these mixtures can be separated into pure substances using various separation techniques. The methods used to separate mixtures are mainly physical processes. This is because the substances in a mixture are physically combined.

Some of the methods used to separate mixtures are filtration, evaporation, magnetic separation, decantation and distillation. Note that the methods for the separation of mixtures into their components depend on the differences in the density, melting point, boiling point, solubility, etc. of the components.

The most important separation techniques for a given mixture depend on:

- *the type of mixture, and*
- *which substance in a mixture we are more interested in.*

For example, in a mixture of salt solution, if we need to separate only the salt, evaporation can be used. But to get both salt and water separately the distillation process is applied.

We will discuss some of the methods that are used to separate the components of *solid-solid*, *solid-liquid* and *liquid-liquid mixtures*.

I *Magnetic Separation*

Magnetic separation is used to separate magnetic and non magnetic substances in a mixture. If you bring a magnet close to a heterogeneous mixture, the magnetic components are attracted by the magnet and easily attached to it. For example, if sand is mixed with iron filings the mixture is heterogeneous. To separate the iron filings from the sand, you can use a magnet. The iron filings (*magnetic component*) are attracted by the magnet, while the sand does not. A mixture of iron filings and sulfur is also separated using this method.

Experiment 2.8

Title: Separation of a mixture using a magnet.

Objective: To separate a mixture of iron filings and sulfur using a magnet.

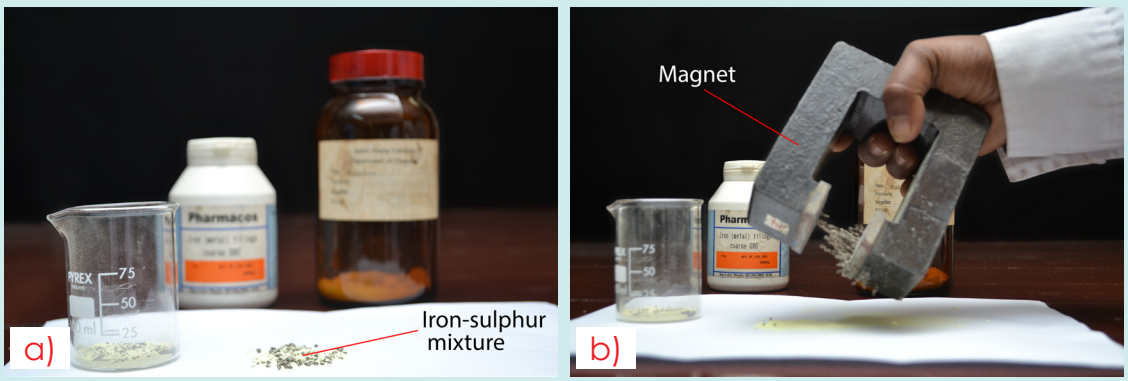
Materials Required: Magnet, iron filings, powdered sulphur, beaker, sheet of paper, spatula.

Procedure:

1 Take two spatulas of each of iron filings and powdered sulphur, and mix them thoroughly, in a beaker

2 Place some of this mixture on a sheet of paper as shown in *Figure 2.14(a)*.

3 Bring a magnet close to the mixture as shown in *Figure 2.14(b)*.



Figuer 2.14 **Magnetic separation**

Observations and Analysis:

i Which component of the mixture is attached to the magnet?

ii What can you conclude from the experiment?

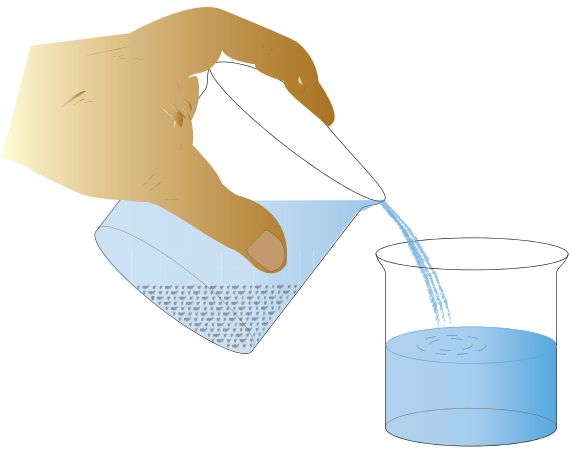
II *Decantation*

What technique is used to get a cup of clear coffee as it is poured from coffee pot ("jebena") as shown in *Figure 2.15*?

Figuer 2.15 **Separation by Decantation**

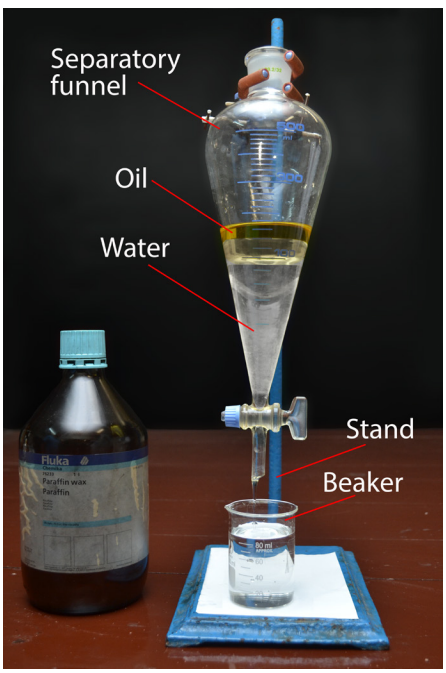
This method of separation is used when one component of a mixture is a liquid and the other one is an insoluble solid denser than the liquid component. For example, a mixture of sand and water can be separated using decantation.

During the decantation process, first the mixture is allowed to stand in a beaker for some time. The insoluble solid settles down to the bottom of the beaker. This is called *sedimentation*. The liquid above the solid can be poured carefully into another beaker as shown in *Figure 2.16*. Such a method of separation is called *decantation*.



Figuer 2.16 **Decantation of solids from a solid-liquid mixture**

The decantation process is also used to separate two immiscible liquids like oil and water. Immiscible liquids do not mix and thus they form two layers. A mixture of oil and water can be separated using a separatory funnel. When the mixture is poured into a separatory funnel, the oil and water separate into two distinct layers as shown in *Figure 2.17*. Since water is denser than oil, it is collected at the bottom of the funnel.



Figuer 2.17 **Separating a mixture of oil and water**

III *Filtration*

ACTIVITY 2.18

Form a group and discuss the following concepts. Present your opinion to the class.

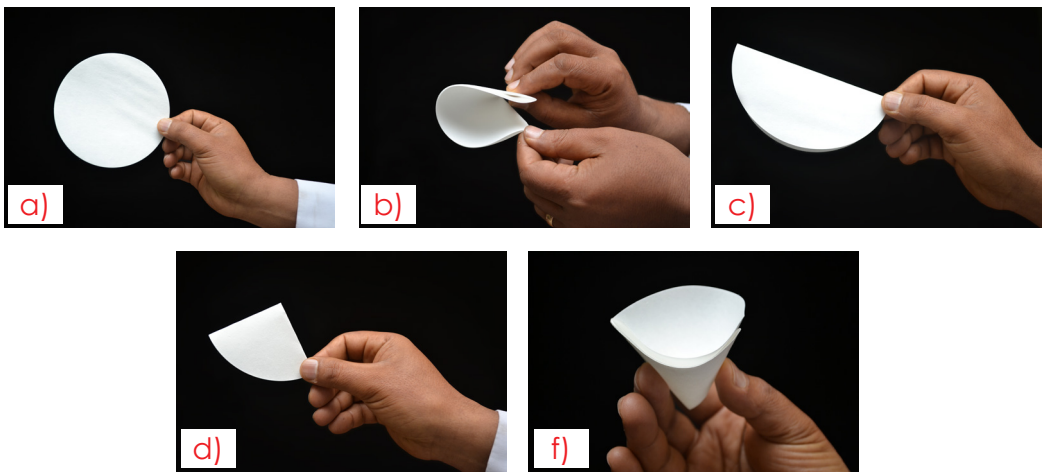
Consider a mixture of water, sand, and oil.

i How many phases are present?

ii How can you separate this mixture into the individual components?

Filtration is a method used to separate the components of a mixture containing an insoluble solid and a liquid. When the mixture of solid and liquid is poured into a filtering material the liquid passes through it and the solid is retained. In the laboratory, a filtration process is performed by pouring the mixture into a funnel fitted with a filter paper.

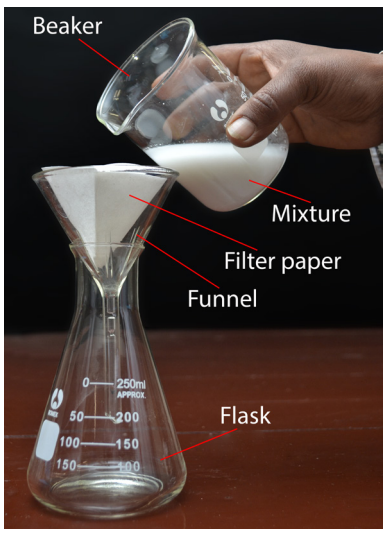
Figure 2.18 illustrates how the filter paper is folded. Begin by folding the filter paper in half, then fold in half again. Open the folded paper into a cone. Finally, place the filter paper cone in the funnel.



Figuer 2.18 **Folding a filter paper**

A filter paper has a lot of fine holes that allow only the liquid to pass through, but not the solid particles. The liquid which passes through the filter paper is called the *filtrate*, and the solid which remains on the filter paper is known as the *residue*. *Figure 2.19* illustrates a filtration process.

Filtration can be used to separate mixtures like soil and water, sand and salt solution, powdered chalk and water, etc. In practical application, filteration is a key step in the purification of the tap water you drink.



Figuer 2.19 **Filtration**

Experiment 2.9

Title: Filtration.

Objective: To separate a mixture of chalk and water by filtration.

Materials Required: Beakers, filter paper, funnel, flask, powdered chalk.

Procedure:

1 Put powdered chalk in a beaker containing water, and stir to dissolve it.

2 Pour the mixture into the funnel fitted with a filter paper and collect the filtrate in the flask as shown in *Figure 2.19*.

3 Observe the result.

Observations and Analysis:

i Does the powdered chalk dissolve in water?

ii Which substance is collected in the flask?

iii Which substance remains on the filter paper?

IV *Evaporation*

Activity 2.19

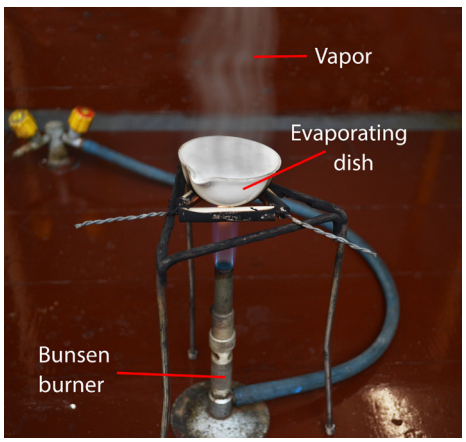
Perform the following activity in groups, and present your findings to the class.

Take a beaker full of water outside your classroom and keep it in sunlight. Wait for a day to observe a change.

a What happened to the level of the water in the beaker? Increased, decreased or remains the same? Explain.

b What can you conclude from this phenomenon?

Evaporation is a method used to separate a soluble solid from a liquid in a solution. For example, sea water is a solution of salts. When it is heated on an evaporating dish, the level of the liquid slowly decreases. This is because some of the water changes into vapor. This vapor will then escape into the atmosphere, leaving behind the salts as shown in *Figure 2.20*. This process of escaping of water in the form of vapor is called evaporation.



Figuer 2.20 **Evaporation of a solution**

Experiment 2.10

Title: Evaporation

Objective: To separate salt from a salt solution.

Materials Required: Burner, evaporating dish, wire gauze, salt, beaker, watch glass, beam balance, measuring cylinder.

Procedure:

1 Dissolve about 10 g of common salt in 30 mL of tap water in a beaker.

2 Pour the salt solution in an evaporating dish as shown in *Figure 2.20*.

3 Boil the solution until all the liquid evaporates and observe the results.

Observations and Analysis:

i What did you observe in the evaporating dish?

ii What would happen to the level of the liquid if the evaporating dish is covered with a watch glass? Is evaporation possible?

V *Simple Distillation*

Activity 2.20

Discuss the following concept in groups and present your opinion to the class.

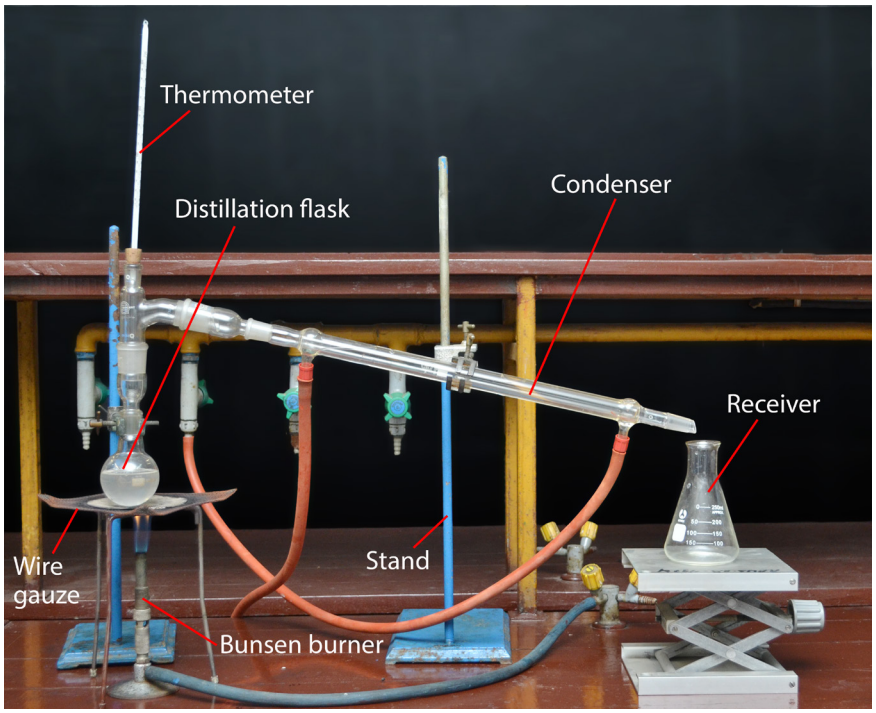
You are given a homogeneous mixture like sugar solution and you are asked to separate and collect the sugar crystal and water separately.

i Is it possible to separate them by evaporation? If not, why?

ii Can you suggest any other separation method?

Distillation is a method of separating the components of a liquid mixture or a soluble solid from a liquid in a solution. It consists of both evaporation (boiling) and condensation processes.

In the distillation process, the separation of a mixture is based on the difference in the boiling points of the components. During distillation, when the mixture is heated in the distillation flask, the liquid with low boiling point is vaporized first. This vapor is passed through a cooling tube, called a *condenser*, where it is condensed into a liquid as shown in *Figure 2.21*. The liquid is then collected in a receiver. This clear liquid is known as a *distillate*.



Figuer 2.21 **Simple distillation**

For example, to get pure water from sea water, simple distillation can be used. When a sample of sea water is heated in a distillation flask, the water vaporizes and boils off at a much lower temperature than the salt. The vapor is condensed to a pure liquid water and collected in the receiver. The salt remains as a residue in the distillation flask.

ACTIVITY 2.21

Discuss the following phenomenon in groups, and present your ideas to the class.

Name the technique and describe the procedure you would use to separate each of the following mixtures into two components.

1 Table salt and charcoal.

2 Kerosene and water.

3 Crushed ice and crushed glass.

4 Hot water and butter.

Experiment 2.11

Title: Simple distillation.

Objective: To separate water from salt solution.

Materials Required: distillation flask, condenser, Wire gauze, Bunsen burner, conical flask, beaker.

Procedure:

1 Dissolve about 40 g of common salt in 150 mL of pure water.

2 Set up the distillation apparatus as shown in *Figure 2.21*.

3 Add 100 mL of the salt solution into the distillation flask.

4 Put a porous material or sand (*boiling chips if there are any*) in the flask.

5 Heat the distillation flask gently and observe the results.

Observations and Analysis:

i What is collected in the receiver (conical flask) and what remains in the distillation flask?

ii Give the names of the apparatus used for the evaporation and condensation processes in the experiment?

iii Why is the condenser connected two tap water in a simple distillation set up?

A mixture of two miscible liquids can also be separated by *simple distillation*. Liquids which mix with each other to form a solution are called *miscible liquids*. The mixture of alcohol and water, benzene and oil are some examples of miscible liquids.

Consider a mixture of alcohol and water. Ethanol, which is an alcohol boils at 78°C, and water boils at 100°C. When the mixture is heated, the alcohol, which has the lower boiling point vaporizes more rapidly than the water. The vapor of alcohol passes through the condenser and then collected as a distillate in the receiver.

Exercise 2.9

How would you separate the following mixtures? Describe the separation techniques in each case.

1 Sand from water

2 Alcohol from water

3 Components in muddy water

4 Two colorless liquids

5 Sand from salt

Separation of mixtures may require combination of two or more techniques. For example, a mixture of common salt and sand can be separated by using the process of dissolving, filtration and evaporation. The first stage of separation is adding water to the mixture. The salt dissolves in water and forms a solution, but not the sand. Then by using filtration, the sand can be separated from the salt solution. Finally evaporation of the filtrate will cause the water to escape leaving the salt behind.

ACTIVITY 2.22

Discuss the following tasks in groups and present your conclusion to the class.

The following mixtures can be separated using a combination of separation techniques. List down all the possible separation techniques and give your reasons in each case.

i Mixture of sugar and sand

ii Mixture of common salt and clay

iii Mixture of oil, water and sand.

Project Work

Separation of mixtures using local materials

Take used common dry cell (dry batteries) and hammer it slowly so that the inside mixture can be obtained.

The black powder inside the dry cells consists of a mixture of powdered carbon, manganese (IV) oxide and ammonium chloride. By using any local materials that are found around you, try to separate this mixture into their components.

Hint:

Both powdered carbon and manganese (IV) oxide are insoluble in water whereas ammonium chloride is soluble in water.

Write a group report:

In your report indicate the separation techniques and the materials used during the separation processes.

Unit Review

Check List

Competencies given below are expected to be achieved in this unit by students. You are required to respond by saying Yes or No. Put a tick (✓) mark under "Yes" column if you are able to perform the competency or under "No" column if you are unable to perform the competency.

This would help to evaluate yourself and you can revise the parts of topics for which the competencies are not met.

№	Can I	Yes	No
1	Define substances?		
2	Define physical properties?		
3	List some physical properties of substances?		
4	Identify substances based on their physical properties?		
5	Conduct experiments to identify properties of substances and make group report?		
6	Classify substances into pure substances and mixtures?		
7	Define pure substance?		
8	Define elements and compounds?		
9	Classify elements as metals, non-metals and metalloids?		
10	Give examples of metals, non-metals and metalloids?		
11	Explain the differences between elements and compounds?		
12	Carryout an experiment in group to distinguish compound and mixture?		
13	Classify compounds as oxides, acids, bases and salts?		
14	Give examples of oxides, acids, bases and salts?		
15	Define mixtures?		
16	Define Homogenous and Heterogeneous mixtures Give examples of Homogeneous and Heterogeneous mixtures?		
17	Compare and contrast homogenous and heterogeneous mixtures?		
18	Define physical changes?		
19	Give examples of physical changes?		
20	Define chemical changes?		

21	Give examples of chemical changes?		
22	Distinguish the physical and chemical changes using their characteristics?		
23	Conduct some simple activities to show physical and chemical changes and write group report?		
24	List methods of separation of mixtures?		
25	Explain methods of separation of mixtures?		
26	Give some specific examples of mixtures that can be separated by filtration, decantation, simple distillation, magnetic separation and using separatory funnel?		
27	Name apparatuses used in decantation, filtration, simple distillation, using separatory funnel?		
28	Assemble apparatuses used in decantation, filtration, simple distillation, separatory funnel?		
29	Perform simple activities in group to carry out the separation of mixtures using local materials and write a group report?		

Key Terms

- Acids
- Bases
- Chemical change
- Chemical property
- Compounds
- Decantation
- Distillation
- Elements
- Evaporation
- Filtration
- Heterogeneous mixtures
- Homogeneous mixtures
- Magnetic separation
- Metalloids
- Metals
- Mixtures
- Non metals
- Oxides
- Physical change
- Physical property
- Salts
- Sedimentation
- Substances

UNIT SUMMARY

- ✓ A substance is a form of matter possessing constant properties under specific conditions.
- ✓ Properties of substances are subdivided into physical and chemical properties.
- ✓ Physical properties of a substance describe the characteristics of the substance that are related to physical changes.
- ✓ Substances can be identified based on their physical properties such as state, color, odor, taste, hardness, density, melting and boiling points.
- ✓ Chemical properties describe the characteristics of a substance related to chemical changes.
- ✓ Substances can be classified as pure substances and mixtures.

- ✓ Elements and compounds are pure substances, and have constant composition and uniform properties.
- ✓ An element is a substance that cannot be broken down into simpler form by chemical means.
- ✓ A compound is a substance composed of two or more elements chemically combined in a fixed proportion.
- ✓ Elements are classified into metals, non metals and metalloids.
- ✓ Oxides, acids, bases and salts are groups of compounds.
- ✓ A mixture is a substance which consists of two or more pure substances that are mixed together physically.
- ✓ Mixtures are classified into homogeneous and heterogeneous mixtures.
- ✓ Substances undergo two types of changes: physical and chemical changes.
- ✓ Physical changes are changes that do not result in the formation of new substances with new properties.
- ✓ Chemical changes are the changes in the composition of substances.
- ✓ Mixtures can be separated into their components using different methods such as magnetic separation, filtration, decantation, evaporation and distillation.

REVIEW EXERCISE ON UNIT 2

I ***Write true for the correct statements and false for the wrong statements.***

1 A physical change is a change in the composition of a substance.

2 A homogeneous mixture always contains only one phase.

3 Atoms combine chemically to form elements.

4 Two different substances can not have similar physical properties.

5 Acids, bases and salts are all compounds.

6 The properties of a substance that can be observed without altering its identity are physical properties.

7 The ability of iron to conduct electricity is a chemical property of iron.

8 The temperature at which a solid melts is the same as the temperature at which its liquid solidifies (freezes).

9 Physical properties are used as a basis for identifying substances.

II *Choice the best answer form the given alternatives.*

10 Which one of the following is not a pure substance?

A Diamond
B Oxygen
C Water
D Milk

11 Which of the following is a compound?

A Iron
B Alloy
C Rock salt
D Sugar

12 Which one of the following does not involve a change of state?

A Freezing
B Melting
C Expansion
D Boiling

13 Which one of the following processes does not help in separation of mixtures?

A Filtration
B Distillation
C Melting
D Sieving

14 The apparatus used to separate two immiscible liquids is

A separatory funnel
B condenser
C filter funnel
D filter paper

15 The two stages that take place during distillation are

A filtration followed by evaporation
B evaporation followed by condensation
C condensation followed by evaporation
D filtration followed by condensation

16 The process of settling of suspended particles is known as

A decantation
B distillation
C sedimentation
D magnetic separation

17 The substance that can not be further decomposed by ordinary chemical means is

A water
B gold
C sugar
D air

III *Give short answers for each of the following questions.*

18 What is the difference between a physical and a chemical change?

19 How could you distinguish a compound from a mixture? Give three characteristics for each case.

20 Which physical properties can be used to distinguish water from alcohol?

21 How would you distinguish between homogenous and heterogeneous mixtures? Give three examples for each case.

22 Identify whether the following statements describe a physical or a chemical property of a substance.

a Charcoal burns in air to form carbon dioxide.

b Ethyl alcohol boils at 78°C.

c Sulphur is a yellow solid at room temperature.

d Mercury is a silvery-white liquid metal.

e Silver is the best conductor of electricity.

f Iron rusts in the presence of moisture and air to form an oxide.

g Benzene is an inflammable liquid.

23 Which of the following are chemical changes and which of them are physical change?

a hammering aluminium into thin sheets

b dissolving table salt in water

c melting gold to make jewelry

d burning of wood

e grinding of maize

f tearing of paper

24 What apparatuses are used to carry out the following processes?

a filtration

b evaporation

c distillation

25 Given samples of the following pairs of substances, name two physical properties that could be used to distinguish between the materials in each pair.

a Cork and lead

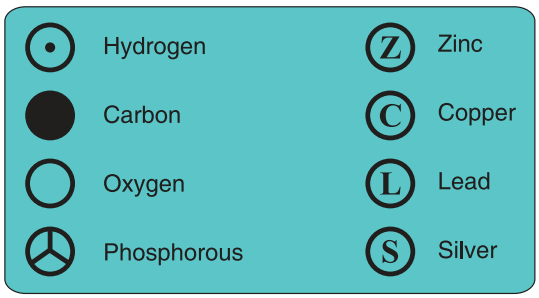
b Copper and silver

c Water and benzene

d Sulphur and iron

UNIT 3

THE LANGUAGE OF CHEMISTRY



MAIN CONTENTS

3.1 SYMBOLS OF ELEMENTS
3.2 CHEMICAL FORMULAS
3.3 QUALITATIVE AND QUANTITATIVE SIGNIFICANCE OF SYMBOLS AND FORMULAS
3.4 SIMPLE CHEMICAL REACTIONS AND EQUATIONS
⇨ *Unit Review*

UNIT OUTCOMES

After completing this unit, you will be able to:

- ✓ write symbols of some common elements and give names from their symbols;
- ✓ write the formulas of diatomic elements and simple compounds;
- ✓ name simple common compounds;
- ✓ explain the qualitative and quantitative meanings of chemical symbols and formulas;
- ✓ write simple chemical reactions and change word equation to formula equation;
- ✓ balance simple chemical equations by using inspection and LCM methods;
- ✓ describe scientific enquiry skills along this unit: Classifying, comparing and contrasting, communicating, asking questions, drawing conclusion and applying concepts.

START-UP ACTIVITY

Form a group and do the following tasks.

Learning the language of chemistry is like learning English language. Use the following terms to answer questions number 1 and 2 below:

Language of Chemistry	English Language
i) Symbol	a) Sentence
ii) Formula	b) Alphabet
iii) Equation	c) Word

1 Match the terms from the language of chemistry with the terms from English language. Support your matching by giving reasons.

2 From which terms we must start in learning the language of chemistry and English language.

After the discussion, share your ideas with the class.

HISTORICAL NOTE

John Dalton (1766-1844)

When the study of chemistry started, one of the exercises which gave a lot of fascination and challenge to the chemists is the writing of chemical symbols, formulas and equations. The real father of modern chemistry could well be considered to be the Englishman, John Dalton (1766 - 1844), who proposed his famous atomic theory of matter and also gave symbols to some elements and compounds.

3.1 SYMBOLS OF ELEMENTS

By the end of this section, you will be able to:

- ✓ define chemical symbols;
- ✓ write symbols of some common elements; and
- ✓ write the names of elements from their symbols.

ACTIVITY 3.1

Discuss in groups and share your ideas with the rest of the class.

1 Why are students given roll numbers by their homeroom teachers?

2 What is the relationship between students' name and their roll numbers?

3 How could you relate roll numbers of students with symbols of elements?

In the language of chemistry, each known pure substance, whether an element or compound, has its own unique name, symbol or formula. Chemists use chemical symbols in place of the names of the elements because they are much easier. They help chemists in writing chemical formulas and equations. The symbols and formulas are designed in such a way that they are internationally accepted. Therefore, they enable all chemists in the world to communicate easily.

Symbol is a short hand notation for the chemical name of an element. Examples: Nitrogen, N, Aluminium, Al, etc.

A chemical symbol is usually the first letter of the English or Latin name of the element. For example, H stands for hydrogen, O stands for oxygen and K represents potassium. In the case of potassium, the symbol is derived from the Latin name, *kalium*.

Why are not all elements symbolized by the first letter of their names?

The names of some elements such as carbon, calcium, chlorine and copper begin with the same letter "C". Therefore we cannot use the letter "C" as a symbol for all these elements. Hence two letters are used for all these elements except one. The first letter "C" is assigned as a symbol for carbon. The other elements are represented by two letter symbols. Thus the symbols for these elements will be Ca for calcium, Cl for chlorine and Cu for copper (Latin name: *Cuprum*).

The first letter of a symbol is always capitalized, but the second letter is not.

The symbols of some elements derived from their English names are given in *Table 3.1*.

Table 3.1 **Symbols of some elements derived from English names**

Name of the Element	Symbol
Boron	B
Fluorine	F
Sulphur	S
Helium	He
Magnesium	Mg

The symbols and Latin names of some elements are given in *Table 3.2*.

Table 3.2 **The symbols and Latin names of some elements**

Element	Latin Name	Symbol
Silver	Argentum	Ag
Sodium	Natrium	Na
Iron	Ferrum	Fe
Lead	Plumbum	Pb
Mercury	Hydrargyrum	Hg
Tin	Stannum	Sn
Gold	Aurum	Au

Exercise 3.1

1 Which of the following is the correct chemical symbol for Aluminium?

a AL b Al c aL d al

2 Fill the missing symbols and names of the elements in the following table.

Name of the Element	Symbol
Oxygen	
	K
Carbon	
	P
Zinc	

Name of the Element	Symbol
	Ba
Sodium	
	He
Fluorine	
	B

3.2 CHEMICAL FORMULAS

By the end of this section, you will be able to:

- ✓ define chemical formulas;
- ✓ list formulas of elements that are diatomic molecules;
- ✓ define valence numbers as the combining power of an atom;
- ✓ write formulas of some binary compounds;
- ✓ name binary compounds;
- ✓ define polyatomic ions;
- ✓ give examples of polyatomic ions;
- ✓ list the valence number of common elements and polyatomic ions;
- ✓ write the chemical formulas of common compounds that contain polyatomic ions; and
- ✓ name compounds containing polyatomic ions.

ACTIVITY 3.2

Discuss in groups and share your ideas with the rest of the class.

What do the notations, Co and CO represents in chemistry?

In Unit 2, you studied that a compound is a substance which consists of two or more elements chemically combined together. The chemical formula of a compound represents this combination.

The formula of a substance is the symbolic representation of its composition. Formulas can be classified as formulas of elements and formulas of compounds.

The formula of an element consists of one kind of symbol whereas the formula of a compound contains the symbols of two or more different elements.

Examples:

- *Formula of an element:* H_2
- *Formula of a compound:* NaCl.

Formulas of Diatomic Elements

Do you know the elements that exist as diatomic molecules?

A molecule of an element is an atom or a group of atoms that exists freely in nature. Accordingly elements may exist as monoatomic, diatomic or polyatomic molecules. Except the nobel gases, all elements do not exist as atoms. The elements helium, neon, argon, krypton, xenon and radon are known as *noble gases*. Because they exist uncombined as single atoms, they are monoatomic molecules. Their formulas are the same as their symbols. The hydrogen molecule is a diatomic molecule because it contains only two atoms. It is represented by the formula H_2. Other elements that normally exist as diatomic molecules are nitrogen, oxygen, fluorine, chlorine, bromine and iodine. *Table 3.3* shows the symbols and formulas of diatomic elements.

Table 3.3 **Chemical symbols and formulas of diatomic elements**

Name	Chemical Symbol	Chemical Formula
Hydrogen	H	H_2
Nitrogen	N	N_2
Oxygen	O	O_2
Fluorine	F	F_2
Chlorine	Cl	Cl_2
Bromine	Br	Br_2
Iodine	I	I_2

Molecules containing more than two atoms are called Polyatomic molecules. Ozone (O_3), Phosphorus (P_4) and Sulphur (S_8) are examples of polyatomic molecules.

ACTIVITY 3.3

Perform the following matching activity in groups and present your findings to the class.

What type of analogy can you find in the following groups of items (*vehicles* and *molecules*)? Match item 'A' with item 'B' according to the analogy you found. You may compare the number of wheels in the vehicles with the number of atoms in the molecules.

Item 'A' (vehicles)	Item 'B' (molecules)
i) Bicycle 	A) Phosphorus, P_4
ii) Tricycle or Bajaj 	B) Nitrogen, N_2
iii) Car 	C) Ozone, O_3

Valence Number

It is easy to write the formula of a compound if we know the combining power of the elements or polyatomic ions involved. The combining power of an element is its relative capacity to combine with other elements. This combining power of an element is called *valence number*.

In compounds containing hydrogen, whose valence number is 1, the valence number of the element is the number of hydrogen atoms that combine with one atom of the element. For example in HCl one atom of chlorine combines with one atom of hydrogen, the valence number of chlorine is 1. Since one atom of oxygen combines with two atoms of hydrogen to form water, H_2O, the valence number of oxygen is 2. Similarly, one atom of nitrogen combines with three atoms of hydrogen to form ammonia, NH_3. Therefore, the valence number of nitrogen is 3.

The valence numbers of most common elements are either 1, 2, or 3. Some elements have more than one valence number, which is different combining powers under different conditions. Common examples of these elements are iron, copper, lead and tin. One atom of iron can combine with either 2 or 3 atoms of chlorine. If the valence numbers of iron is 2 it forms $FeCl_2$ and is written as iron (II) chloride. If the valence number of iron is 3, it forms $FeCl_3$ and is written as iron (III) chloride. Copper and oxygen form Cu_2O and CuO, in which copper has valence numbers 1 and 2 respectively. Valence numbers of some common elements are shown in *Table 3.4*.

Table 3.4 **Valence numbers of some common elements**

Element	Valence Number 1		Valence number 2		Valence number 3	
	Name	Symbol	Name	Symbol	Name	Symbol
Metals	Sodium	Na	Calcium	Ca	Aluminium	Al
	Potassium	K	Magnesium	Mg	Iron (III)	Fe
	Silver	Ag	Zinc	Zn		
	Copper (I)	Cu	Iron (II)	Fe		
Non-metals	Hydrogen	H	Oxygen	O	Nitrogen	N
	Chlorine	Cl	Sulphur	S		
	Bromine	Br				

Common elements with valence number higher than three are carbon (valence number, 4) and phosphorus (valence number, 5).

ACTIVITY 3.4

Discuss in groups and share your ideas to the class.

What is the principle behind using valence number in writing a formula?

Exercise 3.2

1 Which of the following elements exists as a diatomic molecule?

A Carbon B Sulphur C Bromine D Neon

2 What is the valence number of

A Sulphur in H_2S

B Phosphorus in PH_3

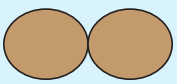
C Carbon in CH_4

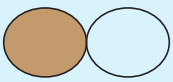
Formulas of Binary Compounds

ACTIVITY 3.5

Discuss in groups and share your ideas with the class.

Which of the following models can represent a binary compound? Why?

A 

B 

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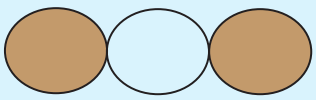
D 

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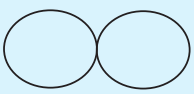
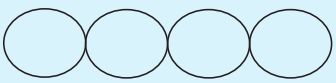
F 

G 

Note that  and  models represent two kinds of elements.

Binary compounds contain atoms of two different elements. Sodium chloride (NaCl), Hydrogen bromide (HBr) and Copper (II) oxide (CuO) are some examples of binary compounds.

The formulas of binary compounds in which the metallic and nonmetallic elements have the same valence numbers are simply represented by the symbols of the elements. This is because the combining powers of the elements are balanced. For example,

⇨ *The formula of potassium chloride is KCl because the valence numbers of both K and Cl is 1.*

➪ *The formula of calcium oxide is CaO because the valence numbers of both Ca and O is 2.*

However, the formulas of binary compounds in which the constituent elements have different valence numbers are written in a way that balances the combining powers of the elements. For example, let us see how to write the formula of magnesium fluoride.Since Mg has a combining power of 2 and F has a combining power of 1, we need two fluorine atoms to go with one magnesium atom. Hence the formula is MgF_2.

The other simpler method of writing formulas of binary compounds is shown in the following steps:

Step 1: Write down the symbols for the elements in the compound.

Let us consider some examples:

i	Sodium Oxide	Na	O
ii	Calcium Chloride	Ca	Cl
iii	Aluminium Oxide	Al	O

Step 2: Write the valence numbers above the symbols.

i $Na^1\ O^2$ ii $Ca^2\ Cl^1$ iii $Al^3\ O^2$

Step 3: Now criss cross the valence numbers and put the numbers below the symbols.

i $Na^1 \times O^2 \Rightarrow Na_2O$. Thus, the formula of sodium oxide is Na_2O.

ii $Ca^2 \times Cl^1 \Rightarrow CaCl_2$. Thus, the formula of calcium chloride is $CaCl_2$.

iii $Al^3 \times O^2 \Rightarrow Al_2O_3$. Thus, the formula of aluminium oxide is Al_2O_3.

Note:

If the valence numbers of the elements in the compound are equal, simplify and write the simplest formula of the compound. For example, the formula of magnesium oxide is MgO and not Mg_2O_2.

Example:

Write the formulas for the following binary compounds.

a	Barium nitride	c	Magnesium oxide
b	Potassium iodide	d	Aluminium chloride

Solution:

a Barium has a valence number 2 and nitrogen has a valence number 3. To balance their combining powers, criss cross their valence numbers as follows:

$Ba^2 \times N^3$

Thus the formula of barium nitride is Ba_3N_2.

b Since both potassium and iodine have valence numbers 1, the formula of potassium iodide is KI.

c Since both magnesium and oxygen have valence numbers 2, the formula of magnesium oxide is MgO.

d Aluminium has a valence number 3 and chlorine has a valence number 1. To balance their combining powers, crisscross their valence numbers as follows:

$Al^{3} \times Cl^{1}$

Thus, the formula of aluminium chloride is $AlCl_3$

Naming Binary Compounds

ACTIVITY 3.6

Discuss in groups and share your ideas with the class.

1 How many compounds do you know so far? Can you memorize their names easily?

2 Up to how many names of compounds is it possible to memorize?

3 Today the number of known compounds is over 13 million. Do you think there should be a systematic way of naming compounds?

The two constituent elements of binary compounds are usually metals and nonmetals. For example, NaBr, CaO and $AlCl_3$. There are also binary compounds which consist of non-metallic elements only. For example, H_2O, CO_2 and NH_3.

Rules in Naming Binary Compounds:

1 The name of a binary compound is the combination of the names of the two constituent elements.

2 For binary compounds that consist of metals and non-metals, the metal is named first followed by the non metal.

3 The suffix *-ide* replaces the last letters of the name of the non-metal. For example, chlorine is changed to chloride. *Table 3.5* gives the names of some of these non-metals in binary compounds.

Table 3.5 Names of non metallic elements in binary compounds

Non-metallic Element	Name in Binary Compound
Fluorine	Fluoride
Bromine	Bromide
Iodine	Iodide
Oxygen	Oxide
Nitrogen	Nitride
Sulphur	Sulphide
Hydrogen	Hydride

Examples:

- ⇨ KI – *potassium iodide*
- ⇨ Mg_3N_2 – *Magnesium nitride*
- ⇨ CaH_2 – *Calcium hydride*

4 If the metal has variable valence numbers, the valence number of the metal used in the formula should be placed in parenthesis using capital Roman numerals after the name of the metal.

Examples:

- ⇨ Cu_2O – *Copper (I) Oxide*
- ⇨ $FeCl_2$ – *Iron (II) Chloride*

5 If the binary compound consists of non-metallic elements only, we name the first element in the formula followed by the name of the second element with the suffix *-ide*.

Examples:

- ⇨ HCl – *Hydrogen chloride*
- ⇨ HBr – *Hydrogen bromide*
- ⇨ SiC – *Silicon carbide*

It is quite common for a pair of elements to form several different compounds. In naming such compounds, we use the Greek prefixes to denote the number of atoms of each element. Note that a prefix is a group of letters added at the beginning of a word.

Table 3.6 **Greek prefixes used in naming binary molecular compounds**

Prefix	Meaning	Prefix	Meaning
Mono-	1	*Penta-*	5
Di-	2	*Hexa-*	6
Tri-	3	*Hepta-*	7
Tetra-	4	*Octa-*	8

Consider the following examples:

CO	–	*Carbon monoxide*
CO_2	–	*Carbon dioxide*
SO_2	–	*Sulphur dioxide*
SO_3	–	*Sulphur trioxide*
N_2O	–	*Dinitrogen monoxide*
NO_2	–	*Nitrogen dioxide*
N_2O_4	–	*Dinitrogen tetroxide*

P_2O_3 – *Diphosphorus trioxide*

P_2O_5 – *Diphosphorus pentoxide*

The following guidelines are helpful in naming compounds with prefixes:

- ⇨ *The prefix "mono" may be omitted for the first element. For example, PCl_3 is named phosphorus trichloride, not monophosphorus trichloride. Thus the absence of a prefix for the first element usually means there is only one atom of that element present in the molecule.*
- ⇨ *For "oxides", the ending "a" in the prefix is sometimes omitted. For example, N_2O_4 is named dinitrogen tetroxide rather than dinitrogen tetraoxide.*

Exceptions to the use of Greek prefixes are binary molecular compounds containing hydrogen. Traditionally, many of these compounds are called either by their common names or by names that do not specifically indicate the number of H atoms:

H_2O – *Water*

NH_3 – *Ammonia*

PH_3 – *Phosphine*

H_2S – *Hydrogen sulphide*

Example:

Name the following binary molecular compounds.

a $SiCl_4$ b N_2O_5 c NF_3

Solution:

a Because there are four chlorine atoms, the name of compound is silicon tetrachloride

b There are two nitrogen atoms and five oxygen atoms. Thus, the name of compound is dinitrogen pentoxide.

c Since there are three fluorine atoms, the name of compound is nitrogen trifluoride.

Exercise 3.3

1 The valence number of a metallic element X is 3. What is the formula of its oxide?

2 Name the following binary compounds

A Ca_3N_2 D SO_2

B $AlCl_3$ E NO

C MgS F PCl_3

3 Write the formula of the binary compounds made up of

A Magnesium and chlorine
B Aluminium and bromine
C Potassium and Oxygen
D Calcium and Oxygen

Polyatomic Ions

A polyatomic ion is a group of atoms that exists in several compounds but does not exist on its own. Nitrate, NO_3^- is an example of a polyatomic ion that consists of nitrogen and oxygen atoms. Its valence number is 1. Nitrate exists in compounds like silver nitrate ($AgNO_3$) but not by itself. Other examples of polyatomic ions and their valence numbers are given in Table 3.7. Polyatomic ions are sometimes called *radicals*.

Table 3.7 **Valence numbers of some polyatomic ions**

	Valence Number 1		Valence Number 2		Valence Number 3	
	Name	Symbol	Name	Symbol	Name	Symbol
Polyatomic Ions	Hydroxide	OH^-	Carbonate	CO_3^{2-}	Phosphate	PO_4^{3-}
	Nitrate	NO_3^-	Sulphate	SO_4^{2-}		
	Hydrogen Carbonate	HCO_3^-				
	Hydrogen Sulphate	HSO_4^-				
	Ammonium	NH_4^+				

Writing Chemical Formulas

We can write formulas of compounds if we know the symbols and valence numbers of the elements and the polyatomic ions. To write formulas of compounds that contain polyatomic ions, follow the same steps you used for writing formulas of binary compounds. Refer to *Table 3.7* for the valence numbers of polyatomic ions.

Refer steps of writing formulas from page 62.

For example, to write the formula of aluminium sulphate:

Step 1: Al SO_4

Step 2: Al^3 SO_4^2

Step 3: $Al_2^3 \times SO_4^2 \Rightarrow Al_2(SO_4)_3$.

Thus, the formula of aluminium sulphate is $Al_2(SO_4)_3$

Example:

Write the chemical formulas for the following compounds:

a Calcium phosphate
b Iron (III) sulphate
c Aluminium hydroxide

Solution:

a Calcium has a valence number 2 and phosphate ion has valence number 3.

To balance their combining powers, crisscross their valence numbers as shown below.

$Ca^{2} \times {}^{3}(PO_4)$

Thus the formula of calcium phosphate is $Ca_3(PO_4)_2$.

b Iron (III) has a valence number 3 and carbonate ion has a valence number 2. To balance their combining powers, crisscross their valence numbers as shown below.

$Fe^{3} \times {}^{2}(SO_4)$

Thus the formula of iron (III) sulphate is $Fe_2(SO_4)_3$.

c Aluminium has a valence number 3 and hydroxide ion has a valence number 1.

$Al^{3} \times {}^{1}(OH)$

Thus the formula of aluminium hydroxide is $Al(OH)_3$.

Naming Simple Chemical Compounds

In naming chemical compounds that contain polyatomic ions, the name of the metal or ammonium ion is written first, followed by the name of the polyatomic ion.

Example:

Name the following compounds.

a $CaCO_3$
b $Mg(OH)_2$
c $BaSO_4$
d $Cu(NO_3)_2$
e $(NH_4)_2SO_4$

Solution:

Our source of references are *Tables 3.4* and *3.7*. We need to identify the metals or ammonium ion and the polyatomic ions. We also need to identify the metals with variable valence numbers.

a The metal is Ca (calcium) and the polyatomic ion is CO_3^{2-} (carbonate). Therefore the name of compound is calcium carbonate.

b The metal is Mg (magnesium) and the polyatomic ion is OH^- (hydroxide). Therefore the name of compound is magnesium hydroxide.

c The metal is Ba (barium) and the polyatomic ion is SO_4^{2-} (sulphate). Therefore the name of compound is barium sulphate.

d The metal is Cu (Copper) which has variable valence numbers. The polyatomic ion is (nitrate). From the formula, $Cu(NO_3)_2$, we can deduce that copper has a valence number 2. Therefore, the name of compound is copper (II) nitrate.

e The positive ion is (ammonium ion) and the negative is (sulphate ion). Therefore, the name of compound is ammonium sulphate.

Exercise 3.4

1 Write chemical formulas for the following compounds.

a Potassium Hydroxide
b Ammonium Sulphate
c Magnesium Carbonate
d Magnesium phosphate

2 Name the following compounds

a Li_2SO_4
b $(NH_4)_3PO_4$
c $Ca(NO_3)_2$
d $Fe(NO_3)_2$

3.3 Qualitative and Quantitative Significance of Symbols and Formulas

By the end of this section, you will be able to:

- ✓ define subscript and explain its significance;
- ✓ define coefficient and explain its significance;
- ✓ describe the qualitative meanings of chemical symbols and formulas; and
- ✓ explain the quantitative meanings of chemical symbols and formulas.

Activity 3.7

Discuss the following phenomenon in groups and present your findings to the class.

If a glass of water is left in open air for two days, what changes would it undergo in terms of quality and quantity?

Symbols and formulas describe both qualitative and quantitative aspects of the substances.

Qualitatively a symbol represents the identity (kind) of the element. For example, the symbol N represents an atom of nitrogen. No other element can be represented by the symbol N.

Quantitatively a symbol represents the number of atoms of the elements.

Examples:

- ⇨ *H stands for one atom of hydrogen.*
- ⇨ *Na stands for one atom of sodium.*

Qualitatively a formula represents the kinds or types of elements involved in forming a compound.

Examples:

- *A water molecule,* H_2O*, contains the elements hydrogen and oxygen.*
- *The compound sodium nitrate,* $NaNO_3$*, contains the elements sodium, nitrogen and oxygen.*

A formula stands for one molecule (*formula unit*) of an element or a compound.

Examples:

- CO_2 *represents one molecule of carbondioxide*
- P_4 *indicates one molecule of phosphorous.*

A number written in front of a symbol or a formula is called a *coefficient*. It shows the number of atoms or molecules or formula units of the substances.

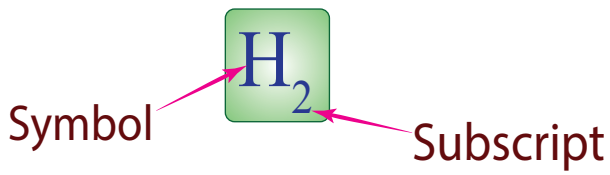
Examples:

- 3Fe *represents 3 atoms of iron*
- 2H *means 2 atoms of hydrogen (Note that:* 2H *differs from* H_2*)*
- $5N_2$ *means 5 molecules of nitrogen*

Note that the coefficient multiplies the whole atoms of the elements in the formula, not only the first element. For example, $2HNO_3$ represents two molecules of nitric acid which contains 2 atoms of hydrogen, 2 atoms of nitrogen and 6 atoms of oxygen.

Subscripts are used in writing formulas. A subscript is a number written at the bottom right hand side of a symbol. In the formula of an element, the subscript qualitatively shows the element is in a molecular form. For example Cl_2 is a chlorine molecule, P_4 is a phosphorus molecule and S_8 is a sulphur molecule. Quantitatively a subscript in a formula stands for the number of atoms in the formula.

H_2 indicates a molecule of hydrogen which contains 2 atoms. The general notation is shown below using hydrogen molecule as an example.



Exercise 3.5

1 Fill the blank spaces in the table given below.

	Chemical Symbol or Formula	Qualitative Meaning	Quantitative Meaning
a	$2Cl_2$	-	-
b	4Cl	-	-
c	$3S_8$	-	-
d	$5MgF_2$	-	-

2 Quantitatively, the formula $5Br_2$ represents

A 5 atoms of bromine
B 2 molecules of bromine
C 5 molecules of bromine
D 10 molecules of bromine

3.4 Simple Chemical Reactions and Equations

By the end of this section, you will be able to:

- ✓ define chemical reaction;
- ✓ conduct an experiment to show simple chemical reaction;
- ✓ state the law of conservation of mass;
- ✓ explain inspection and LCM (least common multiple) methods of balancing equation;
- ✓ convert word chemical equation into formula equation;
- ✓ balance simple chemical equation by inspection; and
- ✓ balance simple chemical equation by LCM (least common multiple) method.

Activity 3.8

Discuss in groups and share your ideas with the rest of the class.

What do you observe when a bundle of wood is burning during a "campfire ceremony'?

Hint:

Discuss this phenomenon by considering the light, heat, smoke, and the ash produced during the campfire.

Figuer 3.1 **Burning of wood in campfire**

Simple Chemical Reaction

You are already familiar with chemical changes in Unit 2. In chemical changes, the composition and properties of the substances change and we conclude that a chemical reaction has taken place. You will encounter many types of chemical reactions in chemistry.

A chemical reaction is a process in which a substance is changed into one or more new substances.

The substances that take part in a chemical reaction are called *reactants*. The substances formed as a result of a chemical reaction are called *products*. In a chemical reaction reactants are transformed into products as shown below.

Reactants ⟶ Products

Reactants are always written on the left hand side of the arrow. We put a plus sign (+) in between if there are two or more reactants. The "+" sign means "*combines with*" or "*reacts with*". The arrow is directed from reactant(s) to product (s) to mean "produces" or "*gives*" or "*yields*". The product is written on the right hand side by putting "+" sign if there are two or more products.

For example, when carbon burns in air (oxygen) it produces carbondioxide.

$$\underbrace{\text{Carbon} + \text{Oxygen}}_{\text{Reactants}} \longrightarrow \underbrace{\text{Carbondioxide}}_{\text{Product}}$$

Experiment 3.1

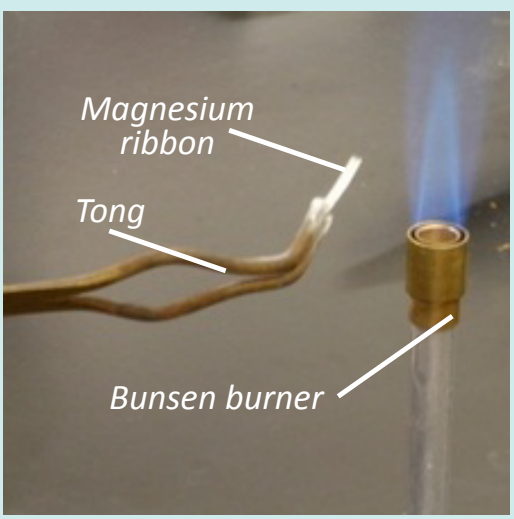
Title: Simple chemical reaction.

Objective: To study simple chemical reaction by burning magnesium in air.

Materials and Chemicals required: Bunsen burner, match, tong, crucible and magnesium ribbon.

Procedure:

- *Hold a magnesium ribbon with a tong and heat it on the Bunsen burner.*
- *Collect the product on the crucible.*
- *Record your observations.*



Figuer 3.2 **Burning of magnesium in air**

Observations and Analysis

1 What is the importance of heat for the reaction?

2 What are the reactants?

3 Compare and contrast the properties of the reactants with the product.

The Law of Conservation of Mass

Chemical reactions take place according to the "*laws of chemical reaction or chemical combination*". One of these laws is law of conservation of mass.

The law of conservation of mass states that in all chemical reactions the total mass of the reactants is equal to that of the products. This means atoms cannot be created nor destroyed in a chemical reaction. Hence mass is conserved during a chemical reaction. The law of conservation of mass is also known as the *law of conservation of atoms*.

The law of conservation of mass can be verified by experiments. That is by weighing the reacting substances and the products formed after the reaction is completed.

For example, consider the reaction between hydrogen and oxygen to form water.

$$2H_2 + O_2 \rightarrow 2H_2O$$

The mass of the reactants (H_2 and O_2) and the mass of the product (H_2O) are equal.

Example:

A piece of magnesium wire weighing 2.4 g is placed in a beaker and covered with 15.0 g of dilute hydrochloric acid. The acid reacts with the metal and gives off hydrogen gas, which escapes into the surrounding air. After the reaction, the contents of the beaker weigh 17.2 g. What is the mass of hydrogen gas produced by the reaction?

Solution:

Reactants		*Products*
Magnesium + Hydrochloric acid	⇒	Magnesium chloride + Hydrogen gas
2.4 g + 15 g		17.2 g + x
= 17.4 g		

By the law of conservation of mass,

mass of reactants = mass of products

17.4 g = 17.2 g + x

where x is the mass of hydrogen gas evolved.

Thus, x = 17.4 g – 17.2 g = 0.2 g

Therefore the mass of hydrogen gas is 0.2 g.

Simple Chemical Equations

The most concise way to describe a chemical reaction is to write the symbols and formulas for each substance involved in the form of a chemical equation. A chemical equation summarizes a great deal of information about the substances involved in the chemical reaction. It is not only a qualitative statement describing what substances are involved, but also a quantitative statement, describing how much of each reactant or product is involved.

The representation of a chemical reaction with symbols and formulas of the substances is known as a *chemical equation*. To write the chemical equation for a reaction the word equation is written first.

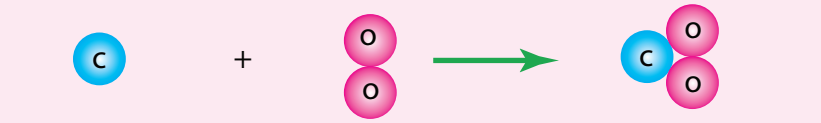
Example:

Write the chemical equation for the burning of carbon in oxygen.

Chemical reaction: Burning of Carbon

Word Equation: Carbon + Oxygen → Carbondioxide

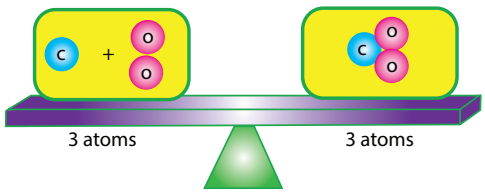
Chemical Equation: $C + O_2 \rightarrow CO_2$



1 atom of Carbon *1 molecule of oxygen* *1 molecule of carbondioxide*

This means that one atom of carbon reacts with one molecule of oxygen to form one molecule of carbondioxide.

This chemical equation obeys the law of conservation of mass or matter since it is balanced.



However, there are many chemical equations that need to be balanced in order to obey the law of conservation of mass. For example, the chemical equation for the reaction between hydrogen and oxygen seems to be complete as it is written below.

$$H_2 + O_2 \rightarrow H_2O$$

However, it is not complete because there are 2 atoms of oxygen on the left hand side and only one atom of oxygen on the right hand side.

Steps in Writing Simple Chemical Equation

To write a chemical equation for a given reaction one can follow the following three steps.

Step 1: Write a word equation for the reaction.

Step 2: Change the word equation to a chemical equation i.e., write the correct symbol or formula for each reactant and product.

Step 3: Balance the equation so that it obeys the law of conservation of mass.

The chemical equation for the reaction between magnesium and oxygen is illustrated as follows.

Step 1: Magnesium + Oxygen → Magnesium oxide . . . (*Word equation*)

Step 2: Mg + O_2 → MgO/Chemical Equation . . . (*Not balanced*)

Step 3: 2Mg + O_2 → 2MgO . . . (*Balanced chemical equation*)

➪ *Note that a chemical equation must represent the experimental facts.*

Balancing Chemical Equation

ACTIVITY 3.9

Perform the following task in groups and present your findings to the class.

Use the analogy of a bicycle, a tricycle and a car-tire to balance an equation. The following information is important. Manufacturer of the tires always sells the tires in pairs (it is not possible to buy a single tire). A body of a bicycle needs two tires to be a complete bicycle; a tricycle needs three tires and a car body needs four tires. Balance the chemical equations for the reactions that take place between the following elements using the above mentioned analogy:

- ➪ Magnesium and chlorine;
- ➪ Aluminium and bromine; and
- ➪ Carbon and fluorine.

Support your explanation by figures.

Note that a balanced chemical equation is an equation in which the total number of atoms on the left hand side is equal to the total number of atoms on the right hand side. This follows from the law of conservation of mass. Chemical equations are balanced by putting the correct coefficients before the symbols or formulas of the substances involved in the reaction. Two of the methods used to balance simple chemical equations are Inspection Method and Least Common Multiple (LCM) Method.

I *Inspection Method*

This method is a trial and error method. The following rules are to be followed.

1. Write the word equation for the reaction.
2. Change the word equation to chemical equation.
3. Check those atoms of elements that are not equal on both sides of the equation and balance them by writing appropriate numbers in front of the symbols and formulas.

Note:

Do not change subscripts of any of the reactants or products.

Example 1:

Balance the equation for the reaction of carbon with a limited amount of oxygen to form carbon monoxide.

Solution:

Here are the steps

Step 1: Carbon + Oxygen → Carbon monoxide

Step 2: C + O_2 → CO

Oxygen is not balanced because there are 2 atoms of oxygen on the left hand side whereas there is only 1 atom of oxygen on the right hand side.

Step 3: To balance the equation:

i Put 2 infront of CO to balance oxygen as follows.

C + O_2 → 2CO

ii Now put 2 infront of C to balance carbon.

That is, 2C + O_2 → 2CO (*balanced*)

Check:

Reactants	Products
2C atoms	2C atoms
2O atoms	2O atoms

Example 2:

Balance the chemical equation for the reaction of zinc with hydrochloric acid to form zinc chloride and hydrogen.

Solution:

Step 1: Zinc + Hydrochloric acid → Zinc chloride + Hydrogen

Step 2: Zn + HCl → $ZnCl_2$ + H_2

Step 3: Hydrogen and chlorine atoms are not balanced because there are 2 atoms of chlorine and two atoms of hydrogen on the right hand side whereas there is only 1 atom of chlorine and 1 atom of hydrogen on the left hand side.

⇨ *To balance the equation, simply put 2 in front of HCl*

Zn + 2HCl → $ZnCl_2$ + H_2

Check:

Reactants	Products
1 Zn atom	1 Zn atom
2 H atoms	2 H atoms
2 Cl atoms	2 Cl atoms

What will happen if you change the subscripts during balancing chemical equations?

II *Least Common Multiple (LCM) Method*

The least common multiple method is a mathematical method of balancing chemical equations. The steps in balancing a chemical equation by the LCM method are shown by the following examples.

Example 1:

Aluminium burns in oxygen to produce aluminium oxide.

Solution:

Step 1: Write the word equation

Aluminium + Oxygen → Aluminium oxide

Step 2: Change the word equation to formula equation

$$Al + O_2 \rightarrow Al_2O_3$$

Step 3: Write the total valence number of each of the elements above their symbols.

$$\overset{3}{Al} + \overset{4}{O_2} \longrightarrow \overset{6}{Al_2}\overset{6}{O_3}$$

Step 4: Find the LCM of the total valence number and write it on the arrow.

$$\overset{3}{Al} + \overset{4}{O_2} \xrightarrow{12} \overset{6}{Al_2}\overset{6}{O_3}$$

Step 5: Divide the LCM by each total valence number and use the dividend as the coefficient for each species in the equation.

$$\frac{12}{3}Al + \frac{12}{4}O_2 \longrightarrow \frac{12}{6}Al_2O_3$$

$$4Al + 3O_2 \longrightarrow 2Al_2O_3 \text{ (balanced)}$$

Check:

Reactants	Products
4 Al atoms	4 Al atoms
6 O atoms	6 O atoms

Example 2:

Balance the equation for the reaction of iron (III) oxide with carbon monoxide to form iron and carbon dioxide.

Solution:

Step 1: Iron (III) oxide + Carbon monoxide → Iron + Carbon dioxide

Step 2: $Fe_2O_3 + CO \longrightarrow Fe + CO_2$

Step 3: $\overset{6}{Fe_2}\overset{6}{O_3} + \overset{2}{C}\overset{2}{O} \longrightarrow \overset{3}{Fe} + \overset{4}{C}\overset{4}{O_2}$

Step 4: $\overset{6}{Fe_2}\overset{6}{O_3} + \overset{2}{C}\overset{2}{O} \xrightarrow{12} \overset{3}{Fe} + \overset{4}{C}\overset{4}{O_2}$

Step 5: $\frac{12}{6} Fe_2O_3 + \frac{12}{2}CO \xrightarrow{12} \frac{12}{3} Fe + \frac{12}{4}CO_2$

$$2Fe_2O_3 + 6CO \longrightarrow 4Fe + 3CO_2$$

Check:

Reactants	Products
4 Fe atoms	4 Fe atoms
6 C atoms	6 C atoms
6 O atoms	6 O atoms

Exercise 3.6

1 Write in words the meaning of the chemical equation $C + O_2 \rightarrow CO_2$

2 Write the chemical equations for the reactions between

a Sulphur and oxygen to form sulphur dioxide

b Iron and sulphur to form iron (II) sulphide.

3 Balance the following chemical equations (you can use either the inspection or LCM method)

a $H_2 + Cu_2O \rightarrow Cu + H_2O$

b $KClO_3 \rightarrow KCl + O_2$

c $Fe + O_2 \rightarrow Fe_2O_3$

d $Mg + HCl \rightarrow MgCl_2 + H_2$

4 State the law of conservation of mass.

Unit Review

CHECK LIST

Competencies given below are expected to be achieved in this unit by students. You are required to respond by saying Yes or No. Put a tick (✓) mark under "Yes" column if you are able to perform the competency or under "No" column if you are unable to perform the competency.

This would help to evaluate yourself and you can revise the parts of topics for which the competencies are not met.

No	Can I	Yes	No
1	Define chemical symbols?		
2	Write symbols of some common elements?		
3	Write the names of elements from their symbols?		
4	Define chemical formulas?		
5	List formulas of elements that are diatomic molecules?		
6	Define valence numbers as the combining power of an atom?		
7	Write formulas of some binary compounds?		
8	Name binary compounds?		
9	Define polyatomic ions?		
10	Give examples of polyatomic ions?		
11	List the valence number of common elements and polyatomic ions?		
12	Write the chemical formulas of common compounds that contain polyatomic ions?		
13	Name compounds containing polyatomic ions?		
14	Define subscript and explain its significance?		
15	Define coefficient and explain its significance?		
16	Describe the qualitative meanings of chemical symbols and formulas?		
17	Explain the quantitative meanings of chemical symbols and formulas?		
18	Define chemical reaction?		
19	Conduct an experiment in group to show simple chemical reaction?		

20	State the law of conservation of mass?		
21	Explain inspection and LCM (Least Common Multiple) methods of balancing equation?		
22	Convert word chemical equation in to formula equation?		
23	Balance simple chemical equation by inspection?		
24	Balance simple chemical equation by L.C.M. (Least Common Multiple)?		

Key Terms

- Binary compound
- Chemical equation
- Chemical formula
- Chemical reaction
- Coefficient
- Diatomic molecule
- Inspection method
- Law of conservation of mass
- Least common multiple method
- Polyatomic ion
- Polyatomic molecule
- Prefix
- Products
- Qualitative meaning
- Quantitative meaning
- Reactants
- Subscript
- Symbol
- Valence number
- Word equation

UNIT SUMMARY

- ✓ A chemical symbol is a short hand notation for the chemical name of an element.
- ✓ The first letter of a symbol is always capitalized, but the next letter is not.
- ✓ A chemical formula is the symbolic representation of a substance giving the ratios of different kinds of atoms in it.
- ✓ The formula of an element consists of one kind of symbol.
- ✓ The formula of a compound consists of two or more kinds of symbols.
- ✓ Molecules containing only two atoms are called diatomic molecules.
- ✓ Molecules containing more than two atoms are called polyatomic molecules.
- ✓ The combining power of an element or polyatomic ion is called valence number.
- ✓ A polyatomic ion is a group of atoms that exists in several compounds but does not exist on its own.

- ✓ The valence numbers of most common elements or polyatomic ions are either 1, 2 or 3.
- ✓ Binary compounds contain atoms of two different elements only.
- ✓ A prefix is a letter or group of letters added to the beginning of a word.
- ✓ The formulas of compounds can be written if the symbols and valence numbers of the constituent elements or polyatomic ions are known.
- ✓ Qualitatively a symbol represents the identify of the element.
- ✓ Quantitatively a symbol represents the number of atoms of the elements.
- ✓ Qualitatively a formula represents the kind of elements involved in making a compound.
- ✓ A formula stands for one molecule or formula unit of a molecule or a compound.
- ✓ A number in front of a symbol or a formula is called a coefficient.
- ✓ A subscript is written on the bottom right hand side of a symbol.
- ✓ A chemical reaction is a process by which a substance(s) is/are changed into one or more new substances.
- ✓ The substances that take part in a chemical reaction are called reactants.
- ✓ In a chemical reaction reactants are transformed into products.
- ✓ The law of conservation of mass states that in all chemical reactions the total mass of the reactants is equal to that of the products.
- ✓ The method of representing a chemical reaction with the help of symbols and formulas of the substances is known as a chemical equation.
- ✓ A balanced chemical equation is an equation in which the total number of atoms of each element on the left hand side is equal to the total number of atoms of the same elements on the right hand side.
- ✓ There are two methods which are used to balance simple chemical equations. They are inspection method and least common multiple (LCM) method.

REVIEW EXERCISE ON UNIT 3

I *Write 'True' for the Correct Statements and 'False' for the Wrong Statements.*

1 A symbol stands for one atom of an element.

2 Polyatomic ions can exist in nature by themselves.

3 In a chemical reaction atoms are neither created nor destroyed.

4 N_2 and 2N have the same meaning.

5 A compound contains two or more elements that are chemically combined together.

II *Choose the Correct Answer from the Given Alternatives.*

6 The chemical symbol for phosphorus is

A Po
B P
C Pt
D K

7 Which of the following is the correct name of $BaBr_2$?

A Boron bromide
B Barium bromide
C Barium dibromide
D Barium (I) bromide

8 Aluminium has a valence number of 3 and sulphur has a valence number of 2. What is the chemical formula for aluminium sulphide?

A Al_2S
B AlS_3
C Al_3S_2
D Al_2S_3

9 The name of NO_2 is

A Nitrogen monoxide
B Nitrogen dioxide
C Nitrogen oxide
D Mononitrogen oxide

10 Quantitatively the formula $3N_2$ represents

A 3 atoms of nitrogen
B 2 molecules of nitrogen
C 3 molecules of nitrogen
D 6 molecules of nitrogen

11 The correct balanced chemical equation for the reaction between iron and oxygen to form iron (III) oxide is

A $2Fe + O_2 \rightarrow 2FeO$
B $3Fe + 2O_2 \rightarrow Fe_3O_4$
C $4Fe + 3O_2 \rightarrow 2Fe_2O_3$
D $Fe + O \rightarrow FeO$

12 The valence number of silicon (Si) in SiH_4 is

A 1
B 2
C 3
D 4

13 All of the following elements can exist as diatomic molecules EXCEPT

A Hydrogen
B Oxygen
C Sodium
D Chlorine

14 The Latin name of sodium is

A Argentum
B Kalium
C Natrium
D Cuprun

15 Consider the following balanced chemical equation;

$$3Mg(OH)_2 + 2H_3PO_4 \rightarrow Mg_3(PO_4)_2 + 6H_2O$$

What is the coefficient of water (H_2O)?

A 1
B 2
C 3
D 6

III *Give short answers for the following questions.*

16 Write chemical formulas for the following compounds.

a Sodium phosphate
b Magnesium iodide
c Sulphur trioxide
d Copper (II) oxide

17 Name the following compounds

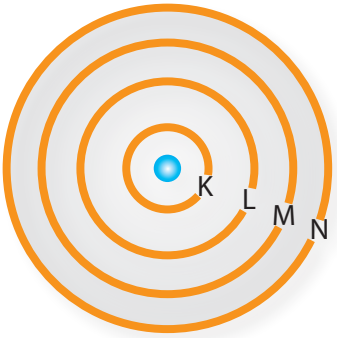
a MgH_2
b $BaSO_4$
c Al_2O_3
d NO

18 Write chemical equations for the following reactions and balance them.

a Aluminium + Iodine → Aluminium iodide
b Sodium + Oxygen → Sodium Oxide
c Potassium + Water → Potassium hydroxide + Hydrogen

UNIT 4

THE STRUCTURE OF SUBSTANCES



MAIN CONTENTS

4.1 HISTORICAL DEVELOPMENT OF THE ATOMIC NATURE OF SUBSTANCES

4.2 ATOMIC THEORY

4.3 THE STRUCTURE OF THE ATOM

4.4 MOLECULES

⇨ *Unit Review*

UNIT OUTCOMES

After completing this unit, you will be able to:

- ✓ narrate the historical development of the atomic nature of substances;
- ✓ state Dalton's Atomic Theory and Modern Atomic Theory;
- ✓ describe the structure of an atom
- ✓ explain the terms like atomic number, mass number, atomic mass and isotope;
- ✓ appreciate the importance of study of subatomic particles in understanding properties of substances;
- ✓ explain the arrangement of electrons in the main energy levels and write the electronic configuration of the first 18 elements;
- ✓ differentiate molecules of elements from molecules of compounds; and
- ✓ demonstrate scientific inquiry skills along this unit: observing, comparing and contrasting, making model, communicating, asking questions.

START-UP ACTIVITY

Your teacher will provide you with the following materials

- Teff or sorghum
- Wheat or corn flour spread on a tray
- A jug of water
- A sheet of paper

Discuss the following questions in groups and report your conclusion to the class.

1. In which of the materials do you see small particles with the naked eye?
2. Which of them do you think are not made of a collection of small particles?
3. What does teff or sorghum look like when viewed from about 3 metres far? Does it look continuous or discontinuous matter?
4. What does water look like when it is gently poured to the ground? Does it look continuous or discontinuous?
5. Is a sheet of paper considered as a collection of particles or entirely one piece?

a) *Pouring water*

b) *Teff* c) *Sorghum*

Figuer 4.1 **Illustration for observing continuity and discretness of matter**

HISTORICAL NOTE

John Dalton
(1766-1844)

John Dalton (1766 –1844) was the son of a poor weaver and had no formal education. Dalton began teaching science at 12 years of age. In 1787, he began his study in meteorology - he kept careful daily weather records for 46 years. This led his interest to study gases of the air and their ultimate components.

4.1 HISTORICAL DEVELOPMENT OF THE ATOMIC NATURE OF SUBSTANCES

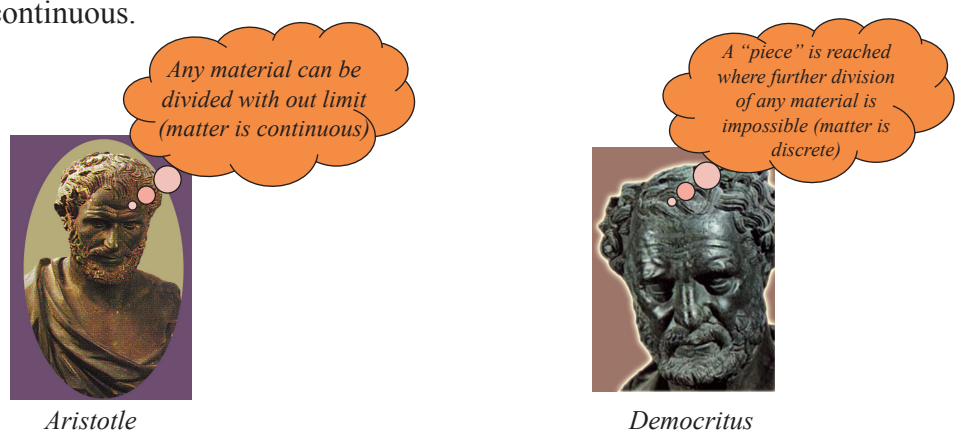
By the end of this section, you will be able to:

- ✓ narrate the historical development of the atomic nature of substances; and
- ✓ compare and contrast the continuity and discreteness (discontinuity) theory of matter.

What would you obtain if you continually divide a piece of chalk?

The ancient Greek philosophers described matter as *continuous* or *discrete.* Some of them argued that matter is continuous i.e., it could be divided endlessly in to smaller pieces. Others believed that matter is discrete; i.e., it can not be infinitely divided.

Democritus (460 - 370 B.C) thought that substances are made up of tiny indivisible particles. If a piece of copper is cut into smaller and smaller pieces one finally reaches a point where it can no longer be divided. He called these particles *atoms*. The word atom has its origin from the Greek word "Atomos" which means indivisible. Thus according to Democritus matter is discrete. On the other hand *Aristotle (384 – 322 B.C)* argued that matter is continuous.



Figuer 4.2 **Ancient debate about the nature of matter.**

Table 4.1 **Comparison between the discrete and continuous theory of matter**

Discreteness of Matter	Continuity of Matter
Democritus	**Aristotle**
⇨ Matter is discrete	Matter is continuous
⇨ There is a limit to which matter is broken	Matter is infinitely divisible
⇨ Believed in the existence of atoms	Rejected the idea of atoms

ACTIVITY 4.1

Form groups and debate on one of the following ideas assigned to your group.

Idea 1: *Matter is continuous.* Idea 2: *Matter is discrete.*

Present your reasons to the class.

Experiment 4.1

Title: Dissolving potassium permanganate in water.

Objective: To investigate the discrete nature of matter.

Materials Required: Beaker, stirring rod, potassium permanganate and spatula.

Procedure:

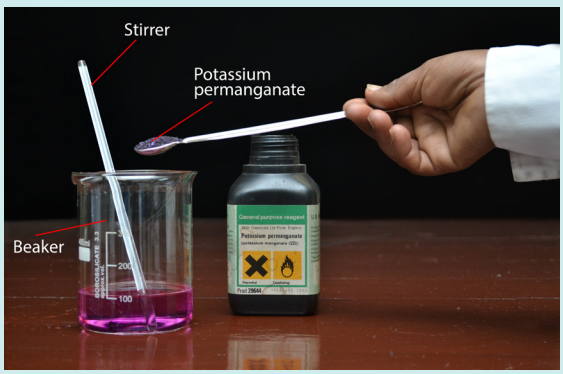
- ⇨ *Dissolve a small crystal of potassium permanagnate in 10 mL water.*
- ⇨ *Pour 5 mL of the solution into a jar or a large beaker.*
- ⇨ *Add 20 mL water to it. What do you observe?*
- ⇨ *Add more water to the solution repeatedly till the purple color disappears.*

Observations and Analysis:

1 What happens to the crystals during dissolution?

2 Do the particles disappear as the color fades out?

3 Do you think that the chemical nature of potassium permanganate is changed during the dissolution process?



Figuer 4.3 **Dissolution of potassium permanganate in water**

What was the basic reason that the idea of Democritus was not accepted by the public?

Exercise 4.1

1 How was the word "atom" introduced to the study of chemistry?

2 What do you mean when you say a substance is continuous?

3 Which theory led to the concept of atoms?

4.2 ATOMIC THEORY

By the end of this section, you will be able to:

- ✓ state Dalton 's Atomic Theory;
- ✓ describe the shortcomings of Daltons atomic theory; and
- ✓ state modern atomic theory.

Dalton's Atomic Theory

Scientific explanations that focus on the existence of atoms are the basis of the atomic theory. A hypothesis is a tentative explanation for an observed scientific law. When a hypothesis is proved by repeated experiments and accepted by a scientific community, it comes to be a theory.

A number of scientists contributed to the development of the atomic theory. However modern atomic concepts began with the work of *John Dalton (1766-1844)* an English scientist. There were two key experimental findings about chemical reactions before the time of Dalton. One of these is the law of conservation of mass. As discussed in Unit 3, the mass of reactants is equal to the mass of products during chemical reactions. The other law is the law of definite composition. According to this law, when a compound is formed, a certain mass of a given element reacts with a fixed mass of the other element. Dalton had to explain these two laws.

Dalton's explanation of these experimental findings led to the revival of Democritus atomic view of matter. Dalton used the idea of Democritus about atoms to explain the law of conservation of mass and the law of definite proportion. He proposed a logical hypothesis about the atomic theory in 1808.

The main points of Dalton's atomic theory are the following:

1 Matter consists of very small particles called atoms.

2 Atoms are indivisible.

3 All atoms of a given element are identical, they have the same mass and properties.

4 Atoms of one element are different from atoms of other elements in mass and other properties.

5 A chemical reaction involves only the separation, combination, or rearrangement of atoms; it does not result in their creation or destruction.

6 Atoms combine in a fixed small whole number ratio to form compounds. For example in carbondioxide one atom of carbon combines with 2 atoms of oxygen, in the ratio 1:2.

To explain Dalton's atomic theory, let us consider substances. As discussed in Unit 2, substances are classified as pure substances and mixtures. Pure substances are further grouped as elements and compounds. For example, copper is an element; whereas, sodium chloride is a compound. Sodium chloride contains sodium and chlorine atoms that are chemically combined. Therefore, copper consists of one type of atoms. But sodium chloride contains two types of atoms.

Dalton thought that atoms are spherical in shape and cannot be broken into smaller pieces.

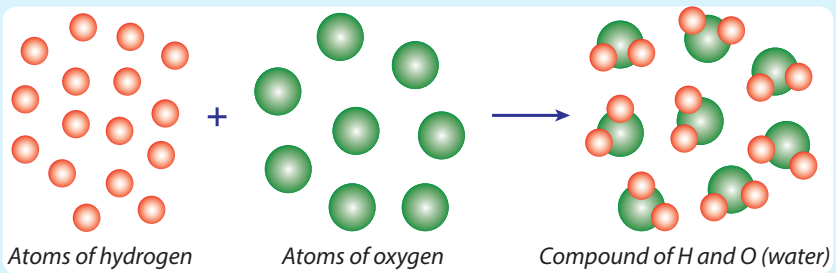
Copper atoms in copper wire *Sodium and chlorine in sodium chloride*

Figuer 4.4 **Illustration of copper and sodium chloride**

As shown in *Figure 4.4*, a copper wire is composed of copper atoms. According to Dalton, all atoms in the copper wire are identical in size and mass. Sodium chloride contains sodium and chlorine. All sodium atoms are identical; all chlorine atoms are also identical. However, sodium atoms are different from chlorine atoms in size, mass, and other properties.

ACTIVITY 4.2

The model shown represents the formation of water from atoms of hydrogen and oxygen.



Figuer 4.5 **Illustration of Dalton's Atomic theory.**

1 Explain how the law of observation of mass is obeyed according to Dalton's atomic theory?

2 How many atoms of hydrogen are required for every atom of oxygen to form water? To which point in Dalton's atomic theory do you relate this?

Shortcomings of Dalton's Atomic Theory

Dalton's atomic theory has certain shortcomings, when evaluated in light of further new experimental findings made after the time of Dalton on the nature of atom.

Because of the discovery of the subatomic particles. Dalton's atomic theory was amended. The following two statements in Dalton's atomic theory were wrong.

i *Atoms are indivisible:* This statement is proved to be wrong because atoms can be divided into subatomic particles.

ii *Atoms of the same element have the same mass:* Atoms of the same element may not have the same mass as explained in the modern atomic theory.

These facts will be explained in the modern atomic theory.

Even though some of Dalton's statements are not entirely correct, the particle nature of matter and the existence of atoms are still now accepted. That is why Dalton is considered as the father of modern atomic theory.

Modern Atomic Theory

ACTIVITY 4.3

Discuss the following ideas based on Dalton's atomic theory.

1 All atoms of oxygen have the same mass. Is this statement true today?

2 Can an atom of oxygen be broken into two halves to make smaller oxygen atoms?

After the time of Dalton further scientific research brought about new discoveries that led to the development of the modern atomic theory.

The following statements describe the main points of the modern atomic theory.

1 An element is made of atoms. An element is composed of small particles called atoms.

2 Atoms are built up from small particles called protons, electrons and neutrons. Thus atoms are divisible and are not the smallest particle of a substance.

3 All atoms of the same element have the same number of protons (and electrons) but may have different number of neutrons. This is due to the existence of isotopes of elements. However atoms of the same element have identical chemical properties. We will discuss about isotopes in the next section.

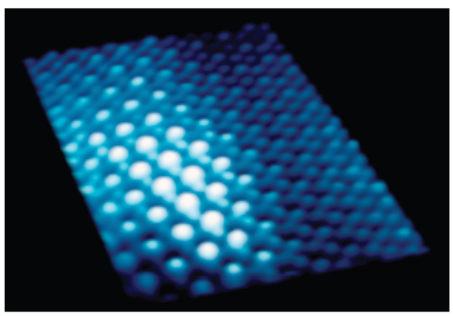
4 Atoms of different elements are different because of the different number of protons. Hence they have different chemical properties.

5 Atoms of different elements combine in small whole numbers to form compounds. For example, water is always composed of 2 atoms of hydrogen and 1 atom of oxygen.

6 In ordinary chemical reactions, atoms are not created, destroyed, or changed but they are rearranged. This statement is in accordance with the law of conservation of mass.

Dalton proposed the existence of atoms based on experimental observations. His hypothesis explained their nature and properties to a large extent. Nowadays, atoms are not mental models. They exist as spherical tiny particles in all substances. Collection of atoms could be seen with a powerful microscope as shown in *Figure 4.6*.

Suppose a pencil lead is composed of pure graphite which is carbon. Then the pencil lead contains only carbon atoms. A tiny dot made by a sharp pencil on a piece of paper would contain billions of carbon atoms in it.



Figuer 4.6 **Image of atoms seen using a powerful microscope.**

ACTIVITY 4.4

Discuss the following ideas based on the modern atomic theory.

1 Is copper atom divisible? If it is divisible, what are the names of the small particles in a copper atom?

2 Aluminium has 13 protons. Is there any other atom of an element that contains 13 protons?

Exercise 4.2

1 List the main ideas included in Dalton's atomic theory.

2 What are the shortcomings of Dalton's atomic theory?

3 According to Dalton, all atoms of carbon must have the same _____.

4 According to the modern atomic theory, atoms can be broken down into _____, _____ and _____.

5 According to the modern atomic theory, atoms of the same element may have different _____.

4.3 THE STRUCTURE OF THE ATOM

By the end of this section, you will be able to:

- ✓ describe the atomic nucleus and electronic shell as the two parts of an atom;
- ✓ define atomic number and mass number;
- ✓ calculate number of protons, electrons and neutrons from atomic number and mass number;
- ✓ define isotopes;
- ✓ give isotopes of hydrogen, chlorine and carbon as examples of isotopes;
- ✓ define atomic mass;
- ✓ define energy levels (atomic shells);
- ✓ represent energy levels (atomic shells) by letters and numbers;
- ✓ describe the maximum number of electrons each energy level (atomic shell) can accommodate;
- ✓ define electronic configuration;
- ✓ write the electronic configuration of the first 18 elements in the main energy levels (atomic shells);
- ✓ show the diagrammatic representation of the first 18 elements;
- ✓ construct an atomic model of one of the first 18 elements;
- ✓ define valence electrons;
- ✓ determine the number of valence electrons of the first 18 elements;
- ✓ define ion; and
- ✓ give examples of positive and negative ions.

The Subatomic Particles

An atom contains three fundamental sub atomic particles: *proton*, *electron* and *neutron*. An atom has a definite number of protons, electrons and neutrons. The structure of the atom describes how these particles are arranged to make an atom.

How are these particles arranged in the atom?

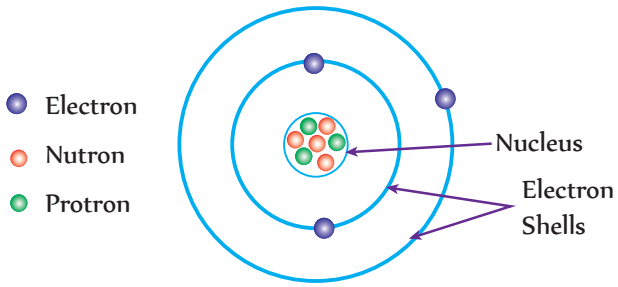
ACTIVITY 4.5

Discuss the following questions and present your opinion to the class.

1 Orange contains a number of seeds and soft matter. Describe how the seeds are arranged to make the fruit.

2 An atom of helium contains two protons, two electrons and two neutrons. Indicate the possible ways of arrangement of these particles in the helium atom.

An atom has two regions: the *atomic nucleus* and the *electronic shell (orbits)*. The nucleus of an atom contains neutrons and protons. Electrons revolve in shells around the nucleus like planets move around the sun. Each electron is located at a certain distance from the nucleus. Almost all the mass of an atom is concentrated in the nucleus. Hence the nucleus is a heavy part of an atom. But the nucleus occupies a very small space as compared to the volume occupied by the electrons. *Figure 4.7* is an illustration of the atomic structure.



Figuer 4.7 **Diagramatic representation of the atom**

Note that shells are paths the electrons take as they move around the nucleus.

In a given atom there are equal number of protons and electrons. For example, hydrogen has one proton and one electron, helium has two protons and two electrons and carbon has six protons and six electrons.

Relative charge and mass of subatomic particles

What is an electrical charge? How many types of charges are known?

There are two types of electrical charges: *positive* and *negative*. Protons are positively charged. Electrons are negatively charged and neutrons are chargeless, i.e., they are neutral. The relative charge of a proton is +1. The electron is assigned a charge of –1. The neutron is assigned zero charge. Since an atom has equal number of protons and electrons, it is electrically neutral.

A sodium atom has 11 protons. How many electrons does it contain?

A proton has a mass of 1.673×10^{-24} g, and a neutron has a mass of 1.675×10^{-24} g. Thus, a proton and a neutron have almost the same mass. Since the mass of an electron is very small, 9.109×10^{-28} g, its mass is assumed to be negligible or approximately zero.

Relative mass: Atoms are extremely small and their masses cannot be described using ordinary mass units, such as grams, milligrams or micrograms. A different scale is used to describe the mass of atomic particles. We use "*relative mass*" to describe their mass. The relative mass of atomic particles is expressed in atomic mass unit (amu). The mass of a proton is not exactly the same as that of a neutron. But according to the relative mass scale they are both assigned a relative mass of 1 amu. The mass of an electron is extremely small as compared to that of the proton and the neutron. Hence, the relative mass of the electron is approximately zero amu. *Table 4.2* summarizes the nature and location of the sub-atomic particles.

Table 4.2 **Nature and location of sub-atomic particles**

Particle	Location	Actual Mass(g)	Relative Mass (amu)	Charge
Proton	Nucleus	1.673×10^{-24}	1	+1
Electron	Shell	9.109×10^{-28}	0	–1
Neutron	Nucleus	1.675×10^{-24}	1	0

Proton: A proton is a tiny positively charged particle found in the nucleus of an atom. Protons are too small to see, even with a powerful microscope. If an atom has the size of a football stadium, then a proton would be smaller than a marble or a pea.

All elements have the same type of protons. A proton of carbon atom, for example, is the same as the protons found in oxygen and aluminum atoms. Thus, all protons are exactly the same. One element differs from another element in the number of protons contained in its atoms. For example, an atom of hydrogen has one proton, oxygen has 8 protons and aluminum has 13 protons.

Electron: Is there any relationship between "electron" and "electricity"? An electron is a tiny negatively charged particle found outside the nucleus of an atom. They are about 2000 times smaller than a proton. Since electrons are found outside the nucleus they are always available at the surface an atom. When you rub materials together, static electricity is observed because of electrons on the surface of the materials.

ACTIVITY 4.6

Do the following task in groups. Present your findings to the class.

Rub your hair or a silky fibre with the tip of a pen. Bring the pen close to pieces of paper

1 What do you observe?

2 Why do they attract each other?

3 What types of charges attract each other?

Figuer 4.8 **A student conducting an experiment using a pen and pieces of paper**

In a given atom, the number of electrons is equal to the number of protons. For instance, an oxygen atom has 8 protons and 8 electrons an atom of aluminum has 13 protons and 13 electrons.

Electrons in one atom are the same as electrons in another atom. As an example, electrons found in oxygen atom are identical with the electrons found in aluminum atom. Thus, all electrons are identical.

Neutrons: A neutron is a tiny neutral particle located in the nucleus of an atom. All neutrons are exactly alike. In many atoms, the number of neutrons is higher than that of protons. For example, there are 3 protons and 4 neutrons in lithium atom; similarly, there are 11 protons and 12 neutrons in sodium atom.

Atomic Number and Mass Number

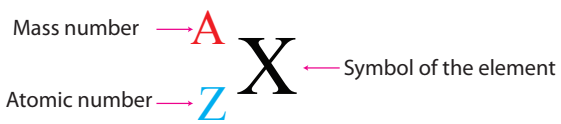
Atomic number is the number of protons in an atom. It is symbolized by "Z".

Atomic number (Z) = Number of protons

Mass number is the sum of protons and neutrons in an atom. It is symbolized by "A". Sodium, for example, contains 11 protons and 12 neutrons. Thus the atomic number of sodium is 11 and its mass number is 23.

Mass number (A) = Number of protons + Number of neutrons.

Atomic number and mass number are commonly given with the symbol of an element, in form look the following representation



For example, carbon, sodium and sulphur can be described as given below using their respective symbols and this notation.

$^{12}_{6}C$, $^{23}_{11}Na$, $^{32}_{16}S$

Exercise 4.3

1 The mass number of chlorine is 35 and its atomic number is 17. Give the number of its protons, electrons and neutrons.

2 Complete the following table.

Notation of the Elements	Number of Protons	Number of Electrons	Number of Neutron	Z	A
$^{24}_{12}Mg$	–	–	–	–	–
–	–	13	14	–	–
–	15	–	–	–	31
–			6	6	–

3 Use a periodic table to tell the atomic number of the following elements.

A Lithium B Boron C Fluorine D Calcium

Isotopes

Atoms of the same element with the same number of protons but different number of neutrons are called *Isotopes*. Isotopes have the same atomic number but different mass numbers. For example, there are three isotopes of carbon. The first isotope contains 6 neutrons. The second contains 7 and the third contains 8 neutrons.

In the designation of isotopes, the mass number is written with a hyphen after the name of the element. For example, the isotopes of carbon with mass numbers 12, 13 and 14 can be written as Carbon–12, Carbon–13 and Carbon–14 respectively. Alternately they can be written as ^{12}C, ^{13}C and ^{14}C.

The three isotopes of hydrogen have the following common names.

Hydrogen - 1	Protium
Hydrogen - 2	Deutrium
Hydrogen - 3	Tritium

The isotopes of an element are not found in nature in equal distribution. Among the isotopes of a given element, one of them will be found in greater quantity and others in smaller quantity. Among the three isotopes of carbon, for example, ^{12}C is the most abundant. Among the three isotopes of hydrogen, protium is the most common.

Note that since it is the electrons which are responsible for chemical properties, isotopes of an element have the same chemical properties. However, they differ in physical properties such as density.

Atomic Mass

The atomic mass of chlorine is 35.5 and that of copper is 63.5. Does it mean that atoms of these two elements have half a proton or half a neuron? Explain.

As discussed earlier, isotopes have the same number of protons but different number of neutrons. Boron for example, has two isotopes, namely, ^{10}B and ^{11}B. The mass of an atom is the total mass of neutrons and protons. Hence, ^{10}B has a mass of 10 amu and ^{11}B has a mass of 11 amu. However, when we determine the atomic mass of boron, the masses of the two isotopes should be considered.

ACTIVITY 4.7

Discuss the following activity in groups and present to the class.

In the periodic table, the atomic mass of boron is given as 10.8.

1 How does this atomic mass (10.8) differ from the mass number of the isotopes of boron?

2 The mass of which isotope does 10.8 represent?

Atomic mass is the average mass of the isotopes of a given element. For example the two isotopes of chlorine exist in nature in different percentages: 75% of the atoms are ^{35}Cl and 25% are ^{37}Cl. Thus the atomic mass of chlorine is calculated as the average mass of these two isotopes.

$$\text{Average atomic mass of chlorine} = \frac{(75\times35)+(25\times37)}{100} = (0.75 \times 35) + (0.25 \times 37) = 35.5$$

Atomic masses are generally given without unit.

Exercise 4.4

1 Use the following table to answer the questions given below.

Element	Number of Electrons	Number of Protons	Number of Neutrons
A	5	5	6
B	19	19	20
C	5	5	5
D	35	35	46
E	35	35	44

i How many different elements indicated by the letters are listed in the table?

ii Which of them are isotopes of the same element?

2 Hydrogen has 3 isotopes. These are hydrogen with a mass number 1, 2 and 3.

i Write the isotopic notation for these isotopes.

ii How many protons, neutrons and electrons are present in each of these isotopes?

3 Draw diagrams or make models to illustrate the isotopes of hydrogen and carbon.

4 The atomic masses of the two stable isotopes of boron, ^{10}B (20%) and "B (80%) are 10 and 11 respectively. Calculate the average atomic mas of Boron. The percentages in parenthesis denote the relative abundance.

Energy Level

ACTIVITY 4.8

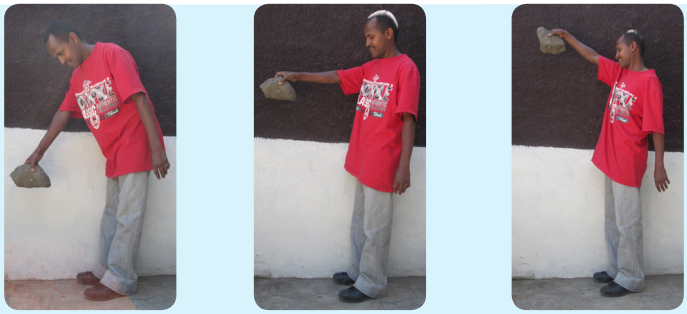
Discuss the following activity in groups and present to the class.

Consider a student dropping 1 kg block from different heights above the ground as shown in Figure 4.9. First from a height of 0.5 m, second from 1 m, and third from 1.5 m.

1 Which block has the highest energy?

2 What relation do you observe between the heights of the blocks and their energies?

3 How do you relate the energy of the blocks with the energy of electrons at different energy levels?



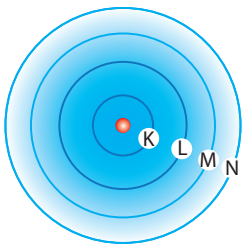
Figuer 4.9 **A student dropping a block from different heights.**

It is already stated that electrons revolve in shells around the nucleus. Electrons are not allowed to occupy all spaces around the nucleus. Only certain orbits are permitted for electrons to revolve around the nucleus. An orbit is the path that an electron takes around the nucleus of an atom. As electrons occupy farther orbits from the nucleus, their energy increases. Any electron on a higher orbit has a greater energy than an electron in a lower orbit. Therefore, the orbits are known as *energy levels*. Each shell represents an energy level. There are a number of shells in an atom.

Atomic shells are represented by letters. They are labeled as K, L, M, N, etc They are also designated by the numbers 1, 2, 3, etc. The 1st shell is the K shell, the 2nd shell is the L shell, the 3rd shell is the M shell and so on.

Table 4.3 **Designation of atomic shells**

Shells	Letters
First shell	K
Second shell	L
Third shell	M
Fourth shell	N



Figuer 4.10 **Atomic shells**

Electronic Configuration

Electronic configuration is the arrangement of electrons in the shells of atoms. Only a limited number of electrons can be placed in each shell. *Table 4.4* summarizes the maximum number of electrons the first four shells of atoms can accommodate.

Table 4.4 **Maximum number of electrons in atomic shells**

Atomic shell	Maximum number of Electrons
First shell (K)	2
Second shell (L)	8
Third shell (M)	18
Fourth shell (N)	32

Electronic configuration is written in the order of energy levels as illustrated using carbon as shown below

$$^{12}_{6}C \Rightarrow K,\ L$$
$$2,\ 4$$

The electronic configurations of the first 10 elements are given in *Table 4.5*.

Table 4.5 **Electronic configuration of the first 10 elements**

Element	Atomic Number	Electronic Configuration	
		K	L
H	1	1	
He	2	2	
Li	3	2	1
Be	4	2	2
B	5	2	3
C	6	2	4
N	7	2	5
O	8	2	6
F	9	2	7
Ne	10	2	8

ACTIVITY 4.9

Form a group and perform the following activity.

Complete the electronic configurations for the elements having atomic numbers 11 - 18 in the table given below.

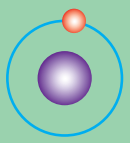
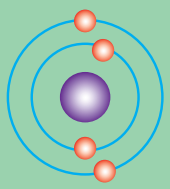
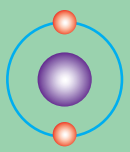
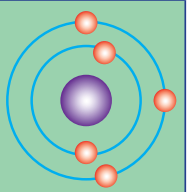
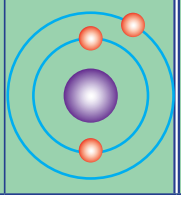
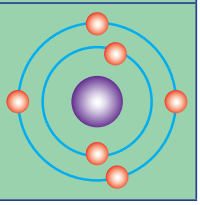
Element	Atomic Number	Electronic Configuration
Na	11	
Mg	12	
Al	13	
Si	14	
P	15	
S	16	
Cl	17	
Ar	18	

Note that the maximum number of electrons in the outer shell of an atom is 8, except helium which has 2 electrons. The maximum number of electrons that can be accommodated in a given shell is already given in *Table 4.4*. Regardless of this fact, the outer shell cannot accommodate more than 8 electrons. Therefore, elements with 8 electrons in their valence shells (including helium with 2 valence electrons) are said to have complete shell of electrons. The M-shell, for instance, can accommodate a maximum of 18 electrons. But when it is an outer shell as in ^{18}Ar, the M-shell is complete or full with only 8 electrons.

Elements that have complete shell of electrons, such as He, Ne and Ar are found at the extreme right hand side of the *periodic table*. You will study the periodic table in Unit 5.

Diagrammatic representations of the electronic configurations of some elements are shown in *Table 4.6*.

Table 4.6 **Diagramatic representations for the electronic configurations of the first 6 elements**

Elements	Atomic Number	Electronic Configuration	Diagrammatic Representation	Elements	Atomic Number	Electronic Configuration	Diagrammatic Representation
H	1	1		Be	4	2,2	
He	2	2		B	5	2, 3	
Li	3	2, 1		C	6	2, 4	

Exercise 4.5

Show the diagrammatic representation of the electronic structure for:

i Nitrogen (z = 7)

ii Oxygen (z = 8)

iii Neon (z = 10)

iv $^{36}_{18}Ar$

v $^{24}_{12}Mg$

vi $^{31}_{15}P$

Project Work

***Constructing atomic models*:**

Your teacher will assign you to construct the atomic models for one of the following elements in your group.

Hint: *You can use styrofoam, wire, chewing gum, and the like for constructing the atomic models.*

i Be

ii N

iii Ne

iv Na

v Al

vi Cl

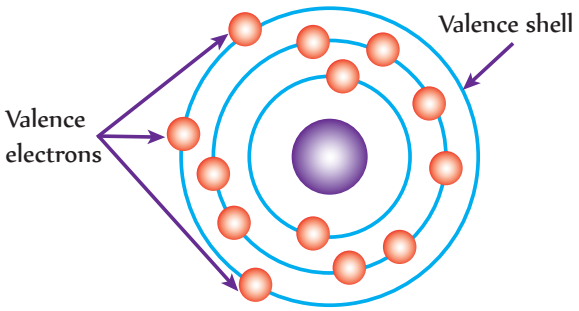
Present your model to the class.

Valence Electrons

Valence electrons are the electrons in the outer most shell of an atom. Similarly, valence shell is the outermost shell of an atom. Valence electrons are involved in forming chemical compounds.

For example, to determine the number of valence electrons of aluminium; write its electronic configuration as

$^{27}_{13}Al$: 2, 8, 3



Figuer 4.11 **Valence electrons**

Since the valence shell of aluminium contains 3 electrons, the number of its valence electrons is 3 as shown in the diagram above.

Let us consider another example. The valence electrons of sulphur can be determined from its electronic configuration as follows, $^{32}_{16}S$: 2, 8, 6. Hence, its valence electrons is 6.

Ion

Atoms are electrically neutral. Do you think that they remain neutral after a chemical reaction?

An ion is an atom or group of atoms that is positively or negatively charged.

For instance a sodium atom having 11 protons and 11 electrons is neutral. In a chemical reaction the valence electron of sodium is removed. As a result sodium is left with 10 electrons. The net charge of protons and electrons is (+11) + (–10) = +1. Hence, sodium ion is positively charged. Its symbolic representation is Na^+ or $^{23}_{11}Na^+$.

Similarity a fluorine atom $^{19}_{9}F$ (2, 7) can gain 1 electron in a chemical reaction. Thus, the net charge on the ion would be (+9) + (–10) = –1 and its symbol is F^- or $^{19}_{9}F$.

Some other examples of ions are listed below.

Positive Ions	Negative Ions
Li^+	F^-
K^+	O^{2-}
Mg^{2+}	N^{3-}
Al^{3+}	Cl^-
H^+	S^{2-}

Exercise 4.6

1 Complete the following table.

Atoms	Number of Electrons	No of Valence Electrons	Atoms	Number of Electrons	No of Valence Electrons
H	1		Ne	10	
He	2		Na	11	
Li	3		Mg	12	
Be	4		Al	13	
B	5		Si	14	
C	6		P	15	
N	7		S	16	
O	8		Cl	17	
F	9		Ar	18	

2 How many electrons are there in each of the following ions?

i Mg^{2+} ii N^{3-} iii F^{-}

3 What is the difference between an ion and an atom?

4.4 MOLECULES

By the end of this section, you will be able to:

- ✓ define molecules;
- ✓ give examples of monatomic, diatomic and polyatomic molecules; and
- ✓ differentiate molecules of elements from molecules of compounds.

Chemical reactions are the transformation of reactants to form new products. Atoms combine to form molecules of elements or molecules of compounds.

A molecule is the smallest particle of an element or a compound that can exist freely in nature. As you were introduced in Unit 3, a molecule is formed when two or more atoms of the same or different elements are combined together chemically.

Molecules of Elements

Molecules of elements can be classified as monoatomic, diatomic and polyatomic. The smallest particle of hydrogen that takes part in a chemical reaction is hydrogen atom. However, the hydrogen atom does not exist freely in nature. It combines with another hydrogen atom to form a hydrogen molecule.

Hydrogen atom + Hydrogen atom → Hydrogen molecule

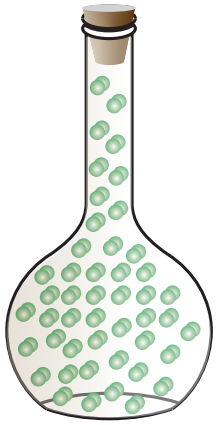
H + H → H_2

Hence, the smallest freely existing particle of hydrogen is a hydrogen molecule. Since two hydrogen atoms form a molecule of hydrogen; hydrogen is said to be a diatomic molecule. Diatomic molecules are molecules that contain two atoms of the element. Can you list the common diatomic elements?

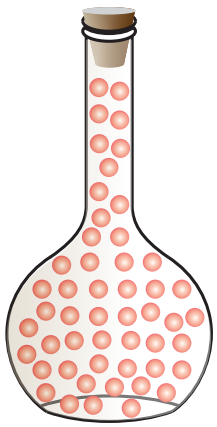
Atoms of some elements do not combine with each other. They exist as monoatomic molecules. He, Ne, Ar, Kr, Xe and Rn are monoatomic molecules.

There are also elements that exist as molecules consisting of three or more atoms. Such molecules are called polyatomic.

Under certain conditions oxygen exists as O_3 (*a triatomic molecule*). Phosphorus exists as P_4 molecule and sulphur exists as S_8 molecule. There are very few polyatomic molecules of elements.



Figuer 4.12 **Representation of hydrogen molecule sealed in a container.**



Figuer 4.13 **Schematic representation of molecules of neon gas sealed in a container**

Molecules of Compounds

ACTIVITY 4.10

Form a group and perform the following activity.

Hydrogen chloride is a binary compound (Refer Unit 3)

i Write its formula.

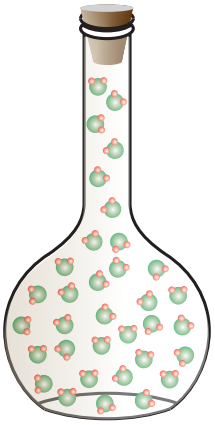
ii Draw models for the two elements and the molecule using coloured pencil.

iii How does the molecule of HCl differ from the molecule of elements.

Atoms of different elements combine to form a compound. For example, two hydrogen atoms combine with one oxygen atom to form a water molecule.

Hydrogen + Oxygen → Water

$2H_2$ + O_2 → $2H_2O$



Figuer 4.14 **Schematic representation of water molecules in steam**

Simillarly N_2 and H_2 form a molecule of a compound called ammonia.

$$N_2 + 3H_2 \rightarrow 2NH_3$$

Exercise 4.7

1 Define a molecule.

2 Consider the molecules shown below.

a Ar

b CO_2

c N_2

d CCl_4

e S_8

i

i What are the constituent elements that make up the molecules?

ii Classify the molecules as monoatomic, diatomic or polyatomic?

iii Which of these molecules are molecules of elements? Which of them are molecules of compounds?

3 What is the difference between H and H_2.

Unit Review

CHECK LIST

Competencies given below are expected to be achieved in this unit by students. You are required to respond by saying Yes or No. Put a tick (✓) mark under "Yes" column if you are able to perform the competency or under "No" column if you are unable to perform the competency.

This would help to evaluate yourself and you can revise the parts of topics for which the competencies are not met.

№	Can I	Yes	No
1	Narrate the historical development of the atomic nature of substances?		
2	Compare and contrast the continuity and discreteness (discontinuity) theory of matter?		
3	State Dalton's atomic theory?		
4	Describe the short comings of Dalton's atomic theory?		
5	State modern atomic theory?		
6	Describe the atomic nucleus and electronic shell as the two parts of an atom?		
7	Define atomic number and mass number?		
8	Calculate number of protons, electrons and neutrons from atomic number and mass number?		
9	Define isotopes?		
10	Give isotopes of hydrogen, chlorine and carbon as examples of isotopes?		
11	Define atomic mass?		
12	Define energy levels (atomic shells)?		
13	Represent energy level (atomic shells) by letters and numbers?		
14	Describe the maximum number of electrons each energy level (atomic shell) can accommodate?		
15	Define electronic configuration?		
16	Write the electronic configuration of the first 18 elements in the main energy levels (atomic shells)?		
17	Show the diagrammatic representation of the first 18 elements?		
18	Construct an atomic model of one of the first 18 elements?		
19	Define valence electrons?		
20	Define ion?		
21	Explain inspection and LCM (Least Common Multiple) methods of balancing equation?		
22	Give examples of positive and negative ions?		

23	Define molecules?		
24	Give examples of monatomic, diatomic and polyatomic molecules?		
25	Differentiate molecules of elements from molecules of compounds.		

Key terms

- Atom
- Atomic mass
- Atomic nucleus
- Atomic number
- Continuous theory
- Diatomic molecule
- Discreteness theory
- Electron
- Electron shell
- Energy level
- Ion
- Isotope
- Mass number
- Molecule
- Monoatomic molecule
- Neutron
- Polyatomic molecule
- Proton
- Valence electrons
- Valence shell

Unit Summary

- ✓ The idea that matter consists of discrete indivisible particles called "atoms" was introduced by Democritus (460-370 BC).
- ✓ Modern chemistry began with Dalton's atomic theory, which states that all matter is composed of tiny, indivisible particles called atoms.
- ✓ According to the modern atomic theory, an atom consists of a very dense central nucleus containing protons and neutrons, with electrons moving around the nucleus at a relatively large distance from it.
- ✓ Protons are positively charged, neutrons have no charge, and electrons are negatively charged.
- ✓ A proton and a neutron have approximately the same mass; but the mass of an electron is negligible.
- ✓ The atomic number of an element is the number of protons in the nucleus of an atom of the element.
- ✓ In an atom, the number of electrons equals the atomic number hence, an atom is electrically neutral.
- ✓ The mass number is the sum of the number of protons and the number of neutrons in the nucleus of an atom.
- ✓ An atom is represented by the notation, ${}^{A}_{Z}X$ in which X is the symbol of an element Z is the atomic number, and A is the mass number.
- ✓ Isotopes are atoms of the same element with the same number of protons but different numbers of neutrons.
- ✓ The atomic mass of an element is the average mass of its isotopes.

- ✓ Electrons occupy certain energy levels outside the nucleus of an atom; these energy levels are also known as atomic shells.
- ✓ The maximum number of electrons that can occupy each of the atomic shells is specified.
- ✓ Electronic configuration is the arrangement of electrons in atomic energy levels.
- ✓ Valence electrons are the electrons in the outer shell of an atom; the outer shell of an atom is also known as valence shell.
- ✓ An ion is an atom or groups of atoms that is positively or negatively charged.
- ✓ A molecule is the smallest particle of an element or a compound that can exist freely in nature.
- ✓ Molecules of elements consist of only one type of atoms and exist as monoatomic, diatomic or polyatomic.
- ✓ Molecules of compounds consist of two or more different type of atoms.

REVIEW EXERCISE ON UNIT 4

I *Choose the best answer.*

1 The idea that matter is continuous was accepted by the public until the time of

A Democritus
B Aristotle
C Dalton
D None

2 Which of the following is NOT true about Dalton's atomic theory?

A Matter consists of tiny particles called atoms.
B All atoms of an element may not be identical in mass.
C The atoms of different elements differ in mass and other properties.
D A chemical reaction involves separation, combination, or rearrangement of atoms.

3 Which of the following has the smallest mass?

A proton
B neutron
C electron
D nucleus

4 The sum of the number of protons and neutrons in an atom is known as

A Atomic number
B Atomic mass
C Mass number
D Number of electron

5 Which of the following atomic energy levels is nearest to the nucleus of an atom?

A K-shell
B L-shell
C M-shell
D N-shell

6 The atomic number of silicon is 14. How many electrons are contained in its second energy level?

A 2 B 8 C 4 D 6

7 What is the number of valence electrons of $^{27}_{13}Al$?

A 4 B 2 C 3 D 1

8 Suppose two atoms, $^{127}_{52}X$ and $^{127}_{53}Y$ are given. Which of the following is true about the two atoms?

A X and Y are atoms of different elements.

B X and Y are atoms of the same element.

C X and Y are isotopes of the same element.

D X and Y have the same number of neutrons.

9 How many electrons does O^{2-} have?

A 2 B 8 C 6 D 10

10 Cl represents

A A compound

B An element

C An ion

D A monatomic molecule

11 $3O_2$ contains

A Three oxygen atoms

B Three oxygen molecules

C Two oxygen atoms

D Six oxygen molecules

II *Fill in the blank space in the following questions.*

12 The concept of the atom was first introduced by _____.

13 _____ and neutrons have approximately the same mass.

14 A certain isotope of P is represented by the symbol $^{31}_{15}P$. Thus, it has _____protons _____ neutrons and _____ electrons.

15 The maximum number of electrons that can occupy the third shell of an atom is _____.

16 Molecules of _____ consist of two or more different type of atoms.

17 Complete the following based on the information given.

A Cl_2 contains _____ chlorine atoms.

B $^{16}_{8}O^{2-}$ contains _____ electrons and _____ Protons.

C H_2O contains _____ hydrogen and _____ oxygen.

D $3H_2$ contains _____ hydrogen atoms.

III *Give short answers for the following questions.*

18 Write the main points in which modern atomic theory differs from Dalton's atomic theory.

19 What are the two main parts of an atom?

20 What are the fundamental sub-atomic particles?

21 What are the subatomic particles contained in the atomic nucleus of an atom?

22 What is the difference between mass number and atomic mass?

23 Complete the following table.

Z	A	Number of Neutron	Number of Proton
-	14	-	7
15	31	-	-
-		14	13

24 What is an isotope?

25 Give two examples of isotopes.

26 Draw the diagrammatic representation for the electronic configuration of

a Al b B c Mg

27 Write the electronic configuration for the elements given

a $^{23}_{11}Na$ b $^{28}_{14}Si$ c $^{35}_{17}Cl$

28 Determine the valence electron(s) for each of the following elements.

a He b F c S

29 List the seven diatomic elements.

30 List the common monatomic molecular elements.

31 Explain the difference between the following.

A Atom and ion.

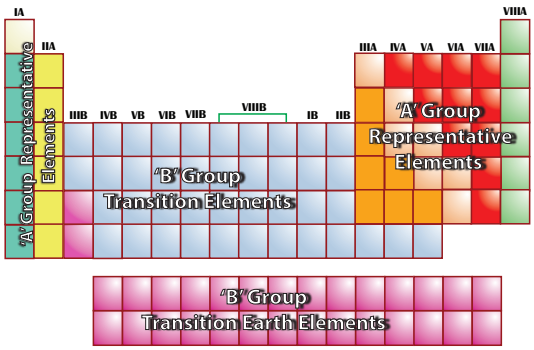
B Molecule and atom.

C Molecule of compound and molecule of element.

D Monatomic molecule and diatomic molecule.

UNIT 5

PERIODIC CLASSIFICATION OF THE ELEMENTS



MAIN CONTENTS

5.1 HISTORICAL DEVELOPMENT OF PERIODIC CLASSIFICATION OF THE ELEMENTS

5.2 MENDELEEV'S PERIODIC CLASSIFICATION

5.3 MODERN PERIODIC TABLE

5.4 IMPORTANCE OF MODERN PERIODIC TABLE

⇨ *Unit Review*

UNIT OUTCOMES

After completing this unit, you will be able to:

- ✓ narrate the historical development of periodic classification of elements;
- ✓ state Mendeleev's periodic law, discuss the contributions and shortcomings of his periodic classification of elements;
- ✓ state the modern periodic law;
- ✓ explain the relationship between the electronic configuration of the atoms and arrangement of the elements in the periodic table;
- ✓ explain the structure of the modern periodic table;
- ✓ describe the trends in nuclear charge, atomic size, metallic and non metallic character of elements across the period and down a group of the modern periodic table;
- ✓ appreciate the importance of periodic classification of elements; and
- ✓ demonstrate scientific inquiry skills along this unit: observing, classifying, communicating, asking questions, interpreting data, applying concepts and making generalizations.

START-UP ACTIVITY

Discuss the following in your group and present to the class.

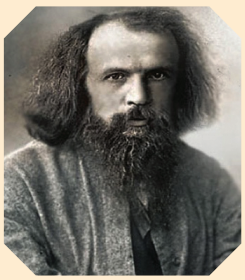
Consider days, months and seasons of a year.

1 How many days are there in a week according to the tradition in your locality?

2 How many days are there in a month?

3 Do you know seasons like summer, spring, autumn and winter. What similarity do you observe among months in a season?

HISTORICAL NOTE



Dmitri Mendeleev
(1834-1907)

Mendeleev was born in a small Siberean town of Russia. He showed early talent for mathematics and science. So, his mother took him to St. Petersburg, where he made much of his study and research. Early research interests centered on the physical properties of gases and liquids. In developing his periodic table, he prepared a note card on the properties of each element and arranged and rearranged them until he realized that properties repeated when the elements were placed in order of increasing atomic mass.

5.1 HISTORICAL DEVELOPMENT OF THE PERIODIC CLASSIFICATION OF THE ELEMENTS

By the end of this section, you will be able to:

- ✓ narrate the historical development of periodic classification of elements.

In this unit, you will study classification of elements in a systematic way. Sunrise, sunset as well as seasons like "*kiremt*" and "*bega*" are examples that show repetition in nature. Similarly there is a repetition of properties of the elements.

There were several attempts to classify the elements on the basis of similarities in properties. Scientists tried to classify the known elements to make their study easy.

Law of Triads – Group of Three

The first serious attempt to classify elements was made by the German scientist *J.W. Dobereiner* in 1817. Dobereiner arranged similar elements in a group of three or triads in increasing order of their atomic masses. Then, he observed that the atomic mass of the middle element is nearly equal to the average atomic mass of the other two elements. Some examples of triads are given in *Table 5.1*.

Table 5.1 **Debereiner's triads**

Elements	Atomic Mass	Average Atomic Mass of Middle Element
Lithium	7	
Sodium	23	$\left(\frac{7+39}{2}\right) = 23$
Potassium	39	

Elements	Atomic Mass	Average Atomic Mass of Middle Element
Calcium	40	
Strontium	88	$\left(\frac{40+137}{2}\right) = 88.5$
Barium	137	

But, the law of triads was not satisfactory for all the elements known at that time.

Law of Octaves – Groups of Eight

The next attempt came from the English chemist *John Newlands* in 1863. He reported the law of octaves (law of eight). It states that when elements are arranged in increasing order of their atomic masses the eighth element after a given element has similar properties to the first one. He called this the *law of octaves*. *Table 5.2* illustrates Newlands classification of elements.

Table 5.2 **Newlands classification of elements**

Number	1	2	3	4	5	6	7
Element	H	Li	Be	B	C	N	O
Atomic mass	1	7	9	11	12	14	16
Number	8	9	10	11	12	13	14
Element	F	Na	Mg	Al	Si	P	S
Atomic mass	19	23	24	27	28	31	32
Number	15	16	17	18	19	20	21
Element	Cl	K	Ca				
Atomic mass	35.5	39	40				

But the law of octaves could be applied only for elements known at that time and failed for elements beyond calcium.

Exercise 5.1

1 Based on the law of triads, predict the atomic mass of the middle element.

Element	Atomic mass
Cl	35.5
Br	–
I	127

2 According to the above Newlands classification (*Table 5.2*) which elements do you think have similar properties with:

i Berylium (Be)? ii Carbon (C)? iii Sodium (Na)?

5.2 MENDELEEV'S PERIODIC CLASSIFICATION

By the end of this section, you will be able to:

- ✓ describe periodicity;
- ✓ state Mendeleev's periodic law; and
- ✓ discuss the contribution and short-comings of Mendeleev's periodic classification of elements.

ACTIVITY 5.1

1 What do we mean by the term "periodic".

2 How do you describe the periodicity of days?

3 What other periodicities do you know?

The most successful attempt to classify elements was put forward by a Russian chemist Dimitri Mendeleev in 1869. When he arranged the known 65 elements in order of increasing atomic masses, he observed that elements with similar properties appeared at regular (periodic) intervals. This is known as *periodicity*. An occurrence that is repeated in a regular way is said to be periodic. The very reactive metals lithium, sodium and potassium occur at regular intervals. They have similar properties and can be described as a 'family'.

Mendeleev described the periodic repetition of the properties of the elements as the *periodic law*.

Mendeleev's periodic law state that "*the properties of elements are periodic functions of their atomic masses*". According to his table when the elements are arranged in increasing order of their atomic masses, there is a regular repetition in chemical and physical properties. Therefore, elements with similar properties fall in the same group.

Mendeleev had the idea of arranging 'families' of elements that have similar properties in vertical columns or groups. Mendeleeve's periodic table is given in *Table 5.3* below.

Table 5.3 **Part of Mendeleev's periodic table**

	1	2	3	4	5	6	7
1	H 1						
2	Li 7	Be 9.4	B 11	C 12	N 14	O 16	F 19
3	Na 23	Mg 24	Al 27.3	Si 28	P 31	S 32	Cl 35.5
4	K 39	Ca 40	__ 44	Ti 48	V 51	Cr 52	Mn 55
5	Cu 63	Zn 65	__ 68	__ 72	As 75	Se 78	Br 80
6	Rb 85	Sr 87	Yt 88	Zr 90	Nb 94	Mo 96	__ 100
7	Ag 108	Cd 112	In 113	Sn 118	Sb 122	Tc 128	I 127

Contributions of Mendeleev's Classification of Elements

Mendeleev's classification was a great improvement over Newland's for two reasons. First, he grouped the elements more accurately based on their properties. Second, he was able to predict the existence and the properties of some elements that had not yet been discovered at that time. Therefore he left gaps for these elements.

Shortcomings of Mendeleev's Classification

Mendeleev's classification of the elements was of a great help in the study of the elements. But the following shortcomings were observed.

A *Wrong order of the Atomic Masses of Some Elements*

When certain elements are arranged according to their increasing atomic masses, similarity in the chemical properties of the elements in a group is violated. For example, Ar with atomic mass of 39.9 comes first and K with atomic mass of 39.1 comes after it so that similarity of elements in a group is realized.

B *The Position of Isotopes in the Periodic Table*

Isotopes could not be given separate places in Mendeleev's periodic table. This observation led to the conclusion that atomic mass cannot be the basis of the classification of elements.

Exercise 5.2

1 State Mendeleev's periodic law.

2 How does Mendeleev's periodic table differ from that of Newlands'?

3 What were the advantages of Mendeleev's periodic table?

4 What were the shortcoming of Mendeleev's periodic table?

5.3 MODERN PERIODIC TABLE

By the end of this section, you will be able to:

- ✓ state the modern periodic law;
- ✓ define period and group;
- ✓ tell the total number of periods and groups in the modern Periodic Table;
- ✓ determine the period and group numbers of some elements based on their atomic numbers;
- ✓ describe the relationship between the number of periods and the number of main shells of the atom;
- ✓ tell the total number of elements in each periods of the Periodic Table;

- ✓ describe the relationship between the number of groups and the valence electrons of the atoms;
- ✓ write the names of each main group of the elements in the Periodic Table;
- ✓ describe the variation of atomic size, nuclear charge, metallic and non metallic character of elements across the period; and
- ✓ describe the variation of atomic size, nuclear charge, metallic and non metallic character of elements down the group.

In the years after Mendeleev, chemists made many discoveries that brought about changes in the periodic table. Consequently in 1913, an English physicist, Henry Mosley performed experiments that led to the discovery of a new property of elements. This fundamental property of the elements is known as atomic number. No two elements can have the same atomic number. Therefore, atomic number of an element is a better basis for the classification of elements than atomic mass.

The Modern periodic law states that "*the properties of the elements are periodic functions of their atomic numbers*". In other words, if elements are arranged in the order of increasing atomic numbers, elements having similar properties will fall in the same column.

Structure of the Modern Periodic Table

In the modern periodic table, the elements are classified in periods and groups.

Periods: The horizontal rows of elements in the periodic table are called periods. There are seven periods in the modern periodic table. Each period contains a certain numbers of elements.

Period numbers are represented by Arabic numerals, 1 to 7.

- ⇨ *Period 1 contains 2 elements, H and He*
- ⇨ *Period 2 contains 8 elements, Li to Ne*
- ⇨ *Period 3 contains 8 elements, Na to Ar*
- ⇨ *Period 4 contains 18 elements, K to Kr*
- ⇨ *Period 5 contains 18 elements, Rb to Xe*
- ⇨ *Period 6 contains 32 elements, Cs to Rn*
- ⇨ *Period 7 is incomplete, it starts with Fr.*

In all the elements in a given period, electrons are filled in the same valence shell. For example, the first period consists of hydrogen and helium, in which the K-shell (1st shell) is occupied, in the second period from lithium to neon, the L shell (2nd shell) is occupied, in the third period from sodium to argon the M-shell (3rd shell) is occupied by the valence electrons. For the electronic configurations of the first 18 elements, you may refer Unit 4.

Each period ends with elements whose valence shell is completely filled. Hence, the last element in a period contains the maximum number of electrons the valence shell can accommodate.

Key: Relative Atomic Mass (1.0079) / Symbol (H) / Atomic Number (1); Group → ; Period ↓

Legend

- Alkali Metals
- Alkaline Earth Metals
- Transition Metals
- Rare Earth Metals
- Nonmetals
- Noble Gases
- Other Metals
- Metalloids

Period	IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIIIB	VIIIB	VIIIB	IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
1	1.0079 H 1																	4.003 He 2
2	6.941 Li 3	9.01 Be 4											10.81 B 5	12.01 C 6	14.01 N 7	15.999 O 8	18.998 F 9	20.18 Ne 10
3	22.990 Na 11	24.31 Mg 12											26.98 Al 13	28.09 Si 14	30.97 P 15	32.06 S 16	35.45 Cl 17	39.95 Ar 18
4	39.098 K 19	40.08 Ca 20	44.96 Sc 21	47.90 Ti 22	50.94 V 23	51.996 Cr 24	54.94 Mn 25	55.85 Fe 26	58.93 Co 27	58.70 Ni 28	63.55 Cu 29	65.37 Zn 30	69.72 Ga 31	72.59 Ge 32	74.92 As 33	78.96 Se 34	79.90 Br 35	83.80 Kr 36
5	85.458 Rb 37	87.62 Sr 38	88.91 Y 39	91.22 Zr 40	92.91 Nb 41	95.94 Mo 42	(98) Tc 43	(101.07) Ru 44	102.91 Rh 45	106.40 Pd 46	107.87 Ag 47	112.47 Cd 48	114.82 In 49	118.69 Sn 50	121.75 Sb 51	127.60 Te 52	126.90 I 53	131.30 Xe 54
6	132.91 Cs 55	137.33 Ba 56	136.91 La* 57	178.49 Hf 72	180.95 Ta 73	183.85 W 74	186.21 Re 75	190.20 Os 76	192.22 Ir 77	195.09 Pt 78	196.97 Au 79	200.59 Hg 80	204.37 Tl 81	207.19 Pb 82	208.98 Bi 83	(209) Po 84	(210) At 85	(222) Rn 86
7	(223) Fr 87	226.03 Ra 88	227.03 Ac* 89	(261) Rf 104	(262) Ha 105	(266) Sg 106	(262) Bh 107	(277) Hs 108	(268) Mt 109	(281) Uun 110	(272) Uun 111	(285) Uub 112	(284) Uut 113	(289) Uuq 114	(288) Uup 115			

* Lanthanides	40.12 Ce 58	140.91 Pr 59	144.24 Nd 60	(145) Pm 61	(145) Sm 62	151.96 Eu 63	157.25 Gd 64	158.93 Tb 65	162.50 Dy 66	164.93 Ho 67	167.26 Er 68	168.93 Tm 69	168.93 Yb 70	174.97 Lu 71
* Actinides	232.04 Th 90	231.04 Pa 91	238.03 U 92	237.05 Np 93	(244) Pu 94	(243) Am 95	(247) Cm 96	(247) Bk 97	(251) Cf 98	(252) Es 99	(257) Fm 100	(260) Md 101	(259) No 102	(262) Lr 103

Figuer 5.1 **Periodic Table**

The number of elements in a period corresponds with the maximum number of electrons that can be placed in the valence shells of an atom. For example, the first period contains only 2 elements because the first shell can accommodate only 2 electrons. Period 2 contains 8 elements because the 2nd shell can have a maximum of 8 electrons, and so on.

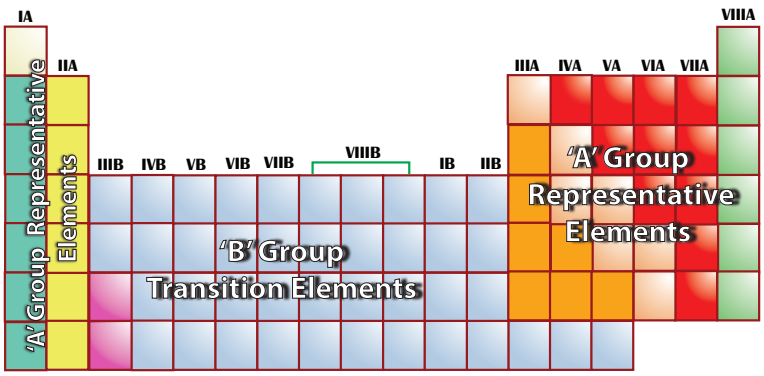
Groups: The vertical column of the elements in the periodic table are known as *Groups* or *Families*. In the modern periodic table, there are 18 vertical columns or groups. Each group is usually represented by the Roman numerals, I to VIII followed by the letters A or B as shown in *Figure 5.2*.

- *The "A" groups are designated with IA to VIIIA and referred to as the main groups or representative elements.*

  "A" group elements /main groups/: IA, IIA, IIIA ... VIIIA

- *The "B" groups that are designated with IB to VIIIB, are known as transition elements. They are placed between group IIA and group IIIA. All transition elements are metals. Iron, copper, gold and zinc are some examples of transition elements.*

  "B" group elements /subgroups/: IB, IIB, IIIB ... VIIIB.



Figuer 5.2 **Classification of the elements**

Note that the groups of elements can also be named using Arabic numerals from 1 to 18. This is a more recent numbering system of groups.

Some of the main groups of elements have common names or family names as given in *Table 5.4*.

Table 5.4 Common names of group 'A' elements

Groups	Common names
Group IA	Alkali metals
Group IIA	Alkaline earth metals
Group IIIA	Boron family
Group IVA	Carbon family
Group VA	Nitrogen family
Group VIA	Oxygen family (Chalcogens)
Group VIIA	Halogens
Group VIIIA	Noble gases (Inert gases)

Exercise 5.3

1 Identify A group elements in *Figure 5.1*.

2 Identify B group elements in *Figure 5.1*.

3 How many elements are there in each of the columns in A group elements?

4 How many elements are there in period 4?

Electronic Configuration and Arrangement of Elements

ACTIVITY 5.2

Consider elements X, Y and Z. Element X is in the same group as element Y and in the same period as element Z. Which two of these elements are likely to have similar properties? Explain your answer.

Electronic configuration of the elements helps us to explain the repetition of properties. The position of elements in the periodic table can also be predicted from their electronic configurations.

➪ *The period number of an element corresponds to the number of shells in its atom. For example, if an element has 3 shells (K, L and M) then it belongs to the third period.*

The number of shells is equal to the period number to which the element belongs. For example, if an element has two shells, it is found in period 2, an element with three shells belongs to the third period, and so on.

Table 5.5 Relationship between atomic number, electron configuration and number of shells of period 2 elements

Elements	Li	Be	B	C	N	O	F	Ne
Atomic numbers	3	4	5	6	7	8	9	10
Electron Configuration	2, 1	2, 2	2, 3	2, 4	2, 5	2, 6	2, 7	2, 8
Number of Shells /Period number/	2	2	2	2	2	2	2	2

What is the relationship between the number of shells and period number?

➪ *The group number of an element is equal to the number of its valence electrons. For example, if the valence electron of an element is 1, it belongs to groups IA, if it has 2 valence electrons, the element is found in group IIA, and so on.*

➪ *All elements in the same group have the same number of valence electrons. For example, Group IA elements, have 1 valence electron, Group IIA elements have 2 valence electrons, etc.*

All the elements in a group have similar properties due to the same outer electronic configuration. As you have learnt in Unit 4, valence electrons are the electrons that are involved in chemical combination. For example, all Group IA elements have one valence electron as shown in *Table 5.6* and thus have similar chemical properties.

Table 5.6 Electronic configuration of Group IA elements

Group 1A Elements	Atomic Number	Electronic Configuration					No of Valence Electron(s)
		K	L	M	N	O	
H	1	1					1
Li	3	2	1				1
Na	11	2	8	1			1
K	19	2	8	8	1		1
Rb	37	2	8	18	8	1	1

Example:

To which period and group does an element with atomic number 16 belong?

Solution:

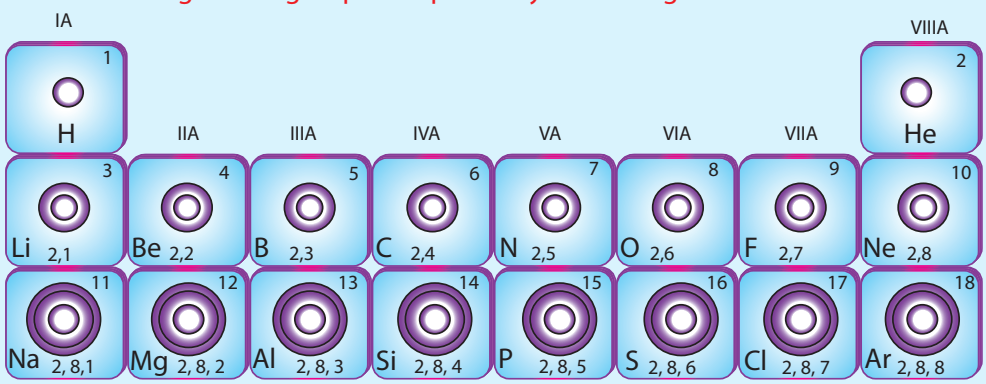
First write the electronic configuration of the element.

Atomic number: 16 $\Rightarrow$ 2, 8, 6

The element belongs to the third period because it has three shells (K, L and M) and it belongs to group VIA because it has 6 valence electrons.

ACTIVITY 5.3

Perform the following task in groups and present your findings to the class.



i Which elements have the same number of valence electrons?

ii Which elements have the same number of shells?

iii List the elements that are found in Group IA, VA, VIIA and VIIIA?

iv List all the elements that are found in periods 1, 2 and 3.

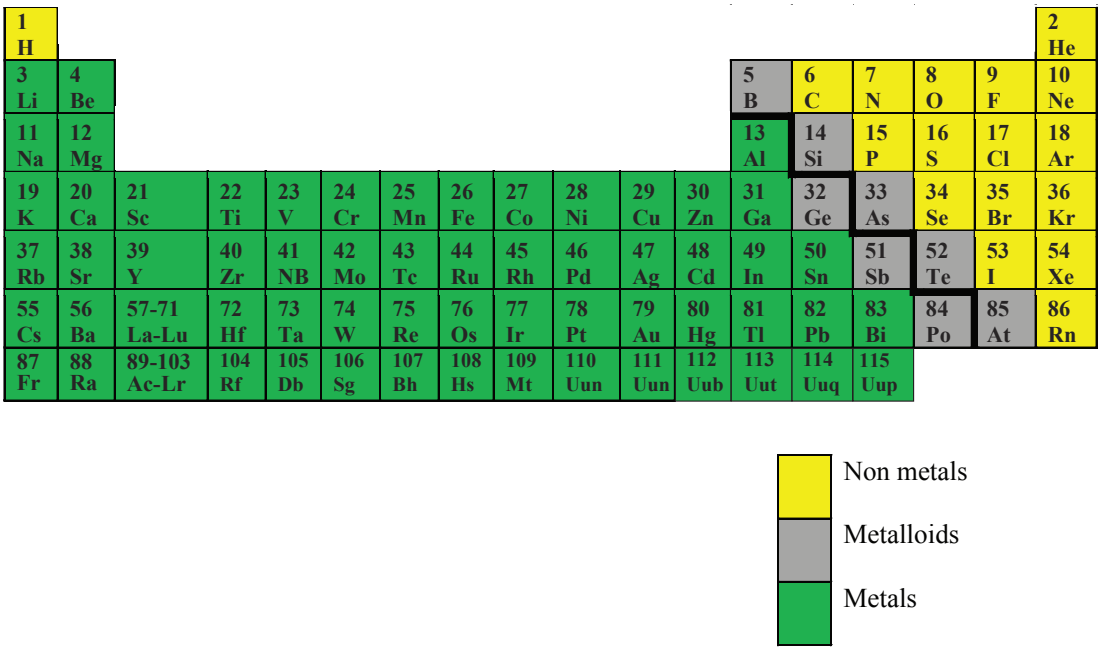
v Which element belongs to Group IVA and period 3?

vi Which element belongs to Group VIIA and period 2?

Elements are classified as metals, non metals and metalloids.

- *Metallic elements are found to the left and centre of the periodic table.*
- *Non metallic elements are found to the right of the periodic table.*

All Group IA and IIA elements except hydrogen are metals. All transition elements are also metals. There are a few number of elements that show both metallic and non metallic properties. These are called *semi-metals* or *metalloids*. On the right hand side of the periodic table, there is a stair step line that separates metals and non metals. Elements that are found near the border line are metalloids. Silicon, Boron and Germanium are some examples of metalloids.



Figuer 5.3 **Metals, non metals and metalloids in the periodic table**

Exercise 5.4

1 Using the periodic table given in *Figure 5.3*, name the metals, nonmetals and metalloids in Group IVA.

2 Name at least five common examples of transition metals.

3 Element Z has an electronic configuration of 2, 8, 4. To which group and period does it belong?

4 Determine the period and group for the elements with atomic numbers:

a 4 c 12

b 9 d 18

Some Periodic Properties in the Periodic Table

As you have learnt earlier the properties of the elements show periodicity. A periodic property is a physical or chemical property which changes periodically with increasing atomic number.

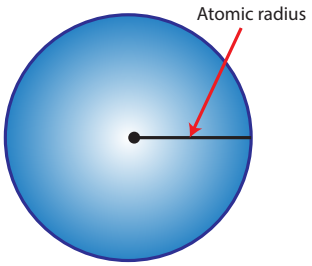
Some of the periodic properties of the elements are:

- Nuclear charge
- Atomic size and
- Metallic and non metallic characters.

Trends Across a Period

1 *Nuclear Charge:* The total charge of protons in the nucleus of an atom is called nuclear charge. The nucleus of an atom is positively charged due to protons. Generally, nuclear charge increases as more protons are added to an atom. Since the elements are arranged in the periodic table according to increasing atomic numbers nuclear charge increases from left to right across a period.

2 *Atomic Size:* The size of an atom is defined in terms of its atomic radius. The atomic size is the distance from the nucleus to the outermost shell of an atom.



Figuer 5.4 **Representation of atomic radius in an atom**

ACTIVITY 5.4

Discuss the following phenomenon in groups and present your findings to the class.

Consider the illustration given below. Three students pull two students with a rope. Other five students pull two students with a rope.

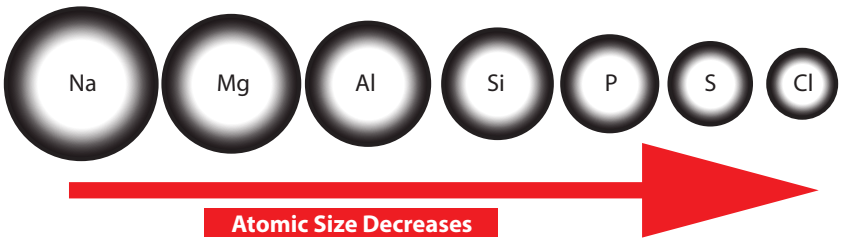
Figuer 5.5 Students pulling each other with a rope

i Which students attract the two students more?

ii Compare this with the attraction of the nuclei of lithium and boron for their inner electrons.

Atomic size decreases in going from left to right across a period. This is because across a period the number of protons in the nucleus increases. But the electrons are being added to the same shell of the atom. These electrons are more strongly attracted towards the nucleus by a progressively higher positive nuclear charge. As a result of this, atomic size decreases.

Generally, in the periodic table, elements on the left side have larger atomic size, while elements on the right side have smaller atomic size. *Figure 5.5* illustrates the decrease in size of period 3 elements across a period.



Figuer 5.6 The trend in atomic size across Period 3 elements

3 *Metallic and non metallic characters:* From left to right across a period, metallic character decreases while nonmetallic character increases. In any period metals are found on the left side and non metals on the right side of the periodic table.

Generally, a period starts with a metal, passes through a metalloid and a non metal and ends with a noble gas. *Table 5.7* shows this trend across a period.

Table 5.7 Metallic and non metallic character of period 2 elements

Elements	Li	Be	B	C	N	O	F	Ne
Character	Metals		Metalloid	Nonmetals				

Metallic Character Decreases

Non-Metallic Character Increases

Exercise 5.5

1 Compare the sizes of lithium (*atomic number = 3*) and boron (*atomic number = 5*). which is one larger and which one is smaller?

2 Identify the most metallic and the most non metallic elements in period 3.

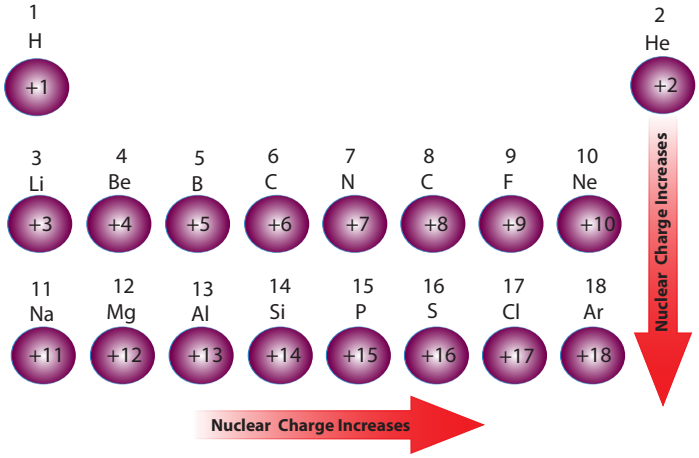
3 Look at period 3 elements. Classify them as metals, metalloids and non metals.

Trends Down a Group

I *Nuclear charge:*

In going down a given group in the periodic table, nuclear charge increases due to increase in the number of protons in the nucleus.

Figure 5.7 shows the variation of nuclear charge for some main group elements.



Figuer 5.7 Periodic trend in nuclear charge

II *Atomic Size:*

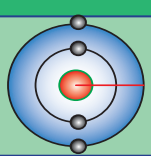
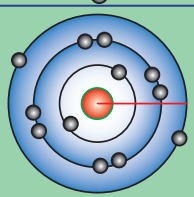
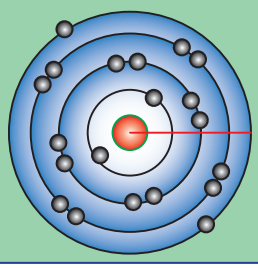
ACTIVITY 5.5

Discuss the following activity in your group and present your ideas to the class.

Compare the sizes of lithium (atomic number = 3) and sodium (atomic number =11). Which one is larger in size? Why?

In moving down a group, atomic size of the elements increases. This is due to the addition of new shells in steps down a group. Table 5.8 shows the relationship between the number of shells and atomic size for some Group IIA elements.

Table 5.8 Atomic radius and number of shells of some Group IIA elements

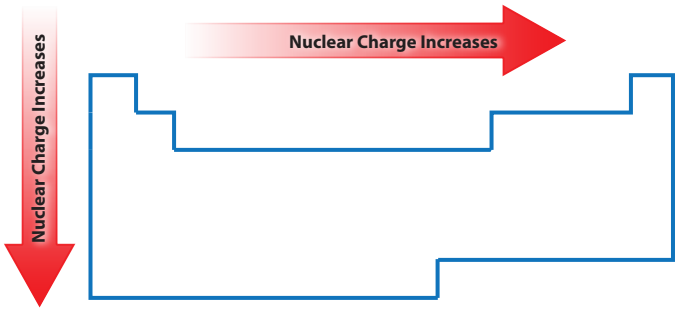
Group IIA Elements	Atomic Number	Number of Shells	Diagrammatic representation
Be	4	2	
Mg	12	3	
Ca	20	4	

III *Metallic and Non Metallic Characters:*

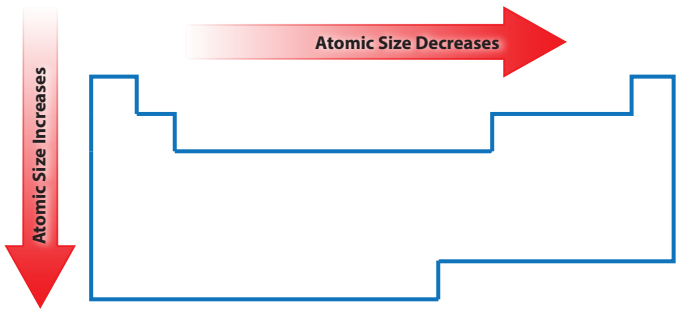
In going down a group, metallic character of the elements for Group IA, IIA and IIIA increases due to increase in atomic size. On the other hand, non metallic character of the elements for Group IVA, VA, VIA and VIIA elements decrease down a group.

Summary of Periodic Trends

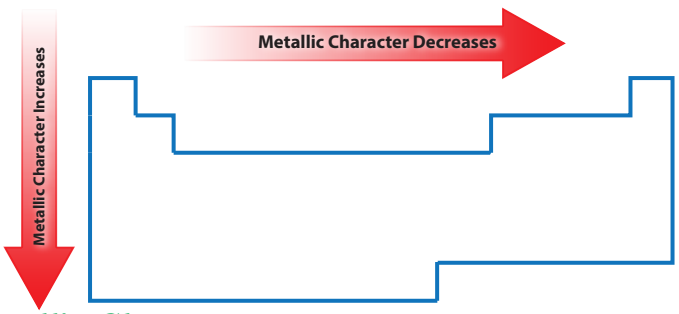
Nuclear Charge



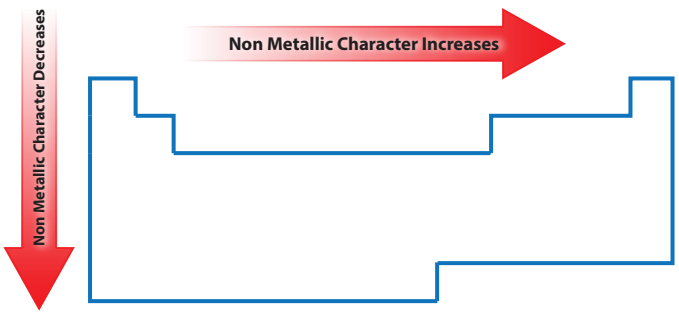
Atomic Size



Metallic Characters



Non-metallic Characters



Project Work

Form a group and prepare a periodic table on chart paper. Make it as attractive and informative as possible. Include the following in your chart.

1 Atomic symbol.
2 Atomic number.
3 Atomic mass.
4 Group (Using Roman numerals).
5 Period (Using Arabic numerals).

5.4 IMPORTANCE OF THE MODERN PERIODIC TABLE

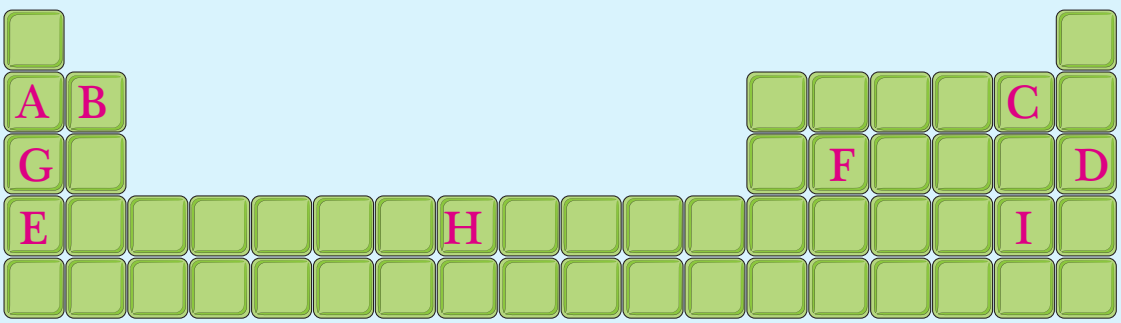
By the end of this section, you will be able to:

- ✓ prepare a periodic table chart; and
- ✓ tell the importance (advantages) of Periodic Table as a quick reference of atomic number, atomic mass and properties of elements.

ACTIVITY 5.6

Perform the following activities in groups. Present your finding to the class.

Some elements in the periodic table represented by the letters A to I and are contained in the table below.



i Which element is an alkaline earth metal?
ii Which element is a noble gas?
iii Which metallic element is more reactive than G? Why?
iv Indicate the most reactive non-metallic element.
v Which elements are found in period 4?
vi Name the element that is found in Group IVA and period 3.
vii Which element is a transition metal?

The periodic table helps us to organize and systematize the study of elements. It provides

a useful information for studying the characteristics of the elements. The properties of an element is related with its position in the periodic table and also with its electronic configuration.

The advantages of the periodic table can be summarized as follows:

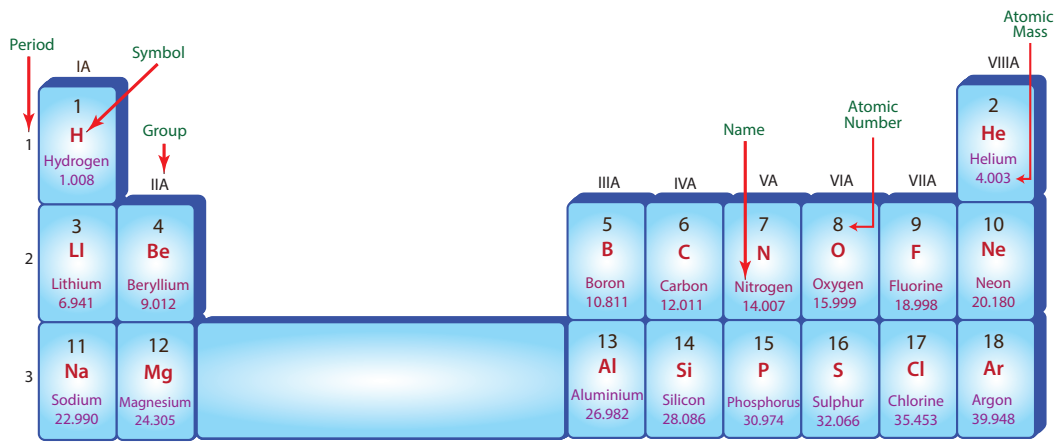
1 The periodic table is useful in predicting the properties of elements. For instance, if an element is known to be in a certain group of which the group properties are known, its properties can be predicted from group properties. For example Francium, an extremely unstable element, is found in Group IA. Thus, the chemical properties of Francium would be similar to the properties of Group IA elements.

2 The periodic table is useful to predict new elements.

3 From the periodic table you can read, deduce and state basic information about a given element:

Thus the periodic table helps to:

- *Read the name, symbol, atomic number and atomic mass of the element.*
- *Deduce the number of protons and electrons, electronic configuration (number of shells and valence electrons) and metallic and non-metallic character of the element.*
- *State the period and group number of a given element.*



Figuer 5.8 **Illustration of the importance of the periodic table**

Unit Review

CHECK LIST

Competencies given below are expected to be achieved in this unit by students. You are required to respond by saying Yes or No. Put a tick (✓) mark under "Yes" column if you are able to perform the competency or under "No" column if you are unable to perform the competency.

This would help to evaluate yourself and you can revise the parts of topics for which the competencies are not met

№	Can I	Yes	No
1	Narrate the historical development of periodic classification of elements?		
2	Describe periodicity?		
3	State Mendeleev's periodic law?		
4	Discuss the contribution and short-comings of Mendeleev's periodic classification of elements?		
5	State the modern periodic law?		
6	Tell the total number of elements in each periods of the Periodic Table?		
7	Define period and group?		
8	Tell the total number of periods and groups in the modern Periodic Table?		
9	Determine the period and group numbers of some elements based on their atomic numbers?		
10	Describe the relationship between the number of periods and the number of main shells of the atom?		
11	Describe the relationship between the number of groups and the valence electrons of the atoms?		
12	Write the names of each main group of the elements in the Periodic Table?		
13	Describe the variation of atomic size, nuclear charge, metallic and non-metallic character of elements across the period?		
14	Describe the maximum number of electrons each energy level (atomic shell) can accommodate?		
15	Describe the variation of atomic size, nuclear charge, metallic and non-metallic character of elements down the group?		
16	Prepare a periodic table chart?		
17	Tell the importance (advantages) of Periodic Table as a quick reference of atomic number, atomic mass and properties of elements?		

Key Terms

- "A" group elements
- "B" group elements
- Alkali metals
- Alkaline earth metals
- Atomic size
- Chalcogens
- Dobereiner's triads
- Electron configuration
- Family
- Group
- Halogens
- Law of octaves
- Mendeleev's periodic law
- Metallic character
- Modern periodic law
- Noble gases
- Nonmetallic character
- Nuclear charge
- Period
- Periodic law
- Periodic table
- Periodicity
- Shells (Energy levels)
- Transition elements
- Valence electrons

Unit Summary

- ✓ Doberenier and Newlands classifications of the elements were the early attempt in classifying the elements.
- ✓ Mendeleev's periodic law states that the properties of elements are periodic functions of their atomic masses.
- ✓ Group is the vertical column of elements.
- ✓ Period is the horizontal row of elements.
- ✓ The modern periodic law states that the properties of elements are periodic functions of their atomic numbers.
- ✓ The periodic table is the arrangement of the elements into periods and groups.
- ✓ The periodic table consists of 8 main groups and 7 periods.
- ✓ The electronic configurations of elements helps to determine the group and period number of an element.
- ✓ All elements in the same group have the same number of valence electrons.
- ✓ The number of valence electrons determines the group number of an element in main group elements.
- ✓ The number of shells of an atom equals the period number to which the element belongs.
- ✓ Elements in the same group have similar chemical properties because they have the same valence electronic configuration (valence electrons).
- ✓ Elements are classified as metals, non metals and metalloids.
- ✓ Metals are found on the left side while nonmetals are found on the right side of the periodic table.

- ✓ Metals and nonmetals are separated by a stair step line and elements near to this border line are known as metalloids.
- ✓ Periodic properties of elements such as atomic size, nuclear charge and metallic and nonmetallic character vary across a period and down a group.
- ✓ The periodic table is a source of information on the properties of elements.

REVIEW EXERCISE ON UNIT 5

I *Write true for correct statement and false for wrong statement.*

1 The first attempt to classify the elements was made by Newlands.

2 Mendeleev classified elements in the order of increasing atomic number.

3 Elements in the same family have the same number of shells.

4 The atomic numbers of elements were assigned by Mosley.

5 Elements in a given period have different properties because they have different valence electrons.

6 In the periodic table, most elements are metals.

7 An element with atomic number 15 is found in group IVA and period 5.

II *Choose the best answer.*

8 The first periodic law was proposed by _____.

A Mendeleev C Newlands

B Dobereiner D Mosely

9 Which one of the following scientist arranged the elements based on their atomic masses?

A Dobereiner C Mendeleev

B Newlands D All

10 An element with atomic number 8 is found in _____.

A Group IIA and period 8 C Group IIA and period 3

B Group VIA and period 2 D Group VIIIA and period 1

11 All elements in the same period have the same _____.

A atomic number C number of shells

B physical properties D number of valence electrons

12 How many elements are there in the fourth period of the periodic table?

A 8 B 18 C 4 D 32

13 Across a period, atomic size of the elements _____.

A decreases C increases and decreases

B increases D remains the same

14 Which one of the following increases both down a group and across a period in the periodic table?

A Valence electrons
C Atomic radius
B Nuclear charge
D Metallic character

15 If the electronic configuration of element 'X' is 2,8,8,1, the element is

A a non metal
C found in group IVA and period 1
B an alkali metal
D an alkaline earth metal

16 The common name of Group VIIA elements is _____.

A noble gases
C halogens
B chalcogens
D alkaline earth metals

Answer questions 17 and 18 based on the following table.

Period 3 elements	Na	Mg	Al	Si	P	S	Cl
atomic number	11	12	13	14	15	16	17

17 Which of the elements has the largest atomic size?

A Na B Al C P D Cl

18 _____ is the most metallic and _____ is the most nonmetallic element in the period.

A Cl and Na
C Mg and S
B Na and Cl
D Si and P

III *Fill in the blank spaces.*

19 An occurrence that is repeated in a regular way is said to be _____.

20 The horizontal rows of the elements are called _____.

21 The distance between the centre of the atom and the outer most shell is known as _____.

22 Argon is found in the third period. Hence it has _____ energy levels.

IV *Give short answers to the following questions.*

23 Why is argon (atomic mass 40) placed before potassium (atomic mass 39) in the modern periodic table?

24 An element has mass number of 23 and its nucleus has 12 neutrons. To which group of the periodic table does it belong? Explain.

25 Why do atomic sizes of the elements increase from top to bottom in a given group?

26 If the atomic number of an element X is 17, deduce the following from the given information.

i Number of protons
ii Number of electrons
iii Electronic configuration
iv Number of valence electrons
v Number of shells
vi The period and group number

Glossary

- **A compound:** a substance composed of two or more elements chemically combined in a fixed proportion.
- **A mixture:** a substance which consists of two or more pure substances that are mixed together physically.
- **Alkali metals:** Family of elements in Group IA in the periodic table.
- **Alkaline earth metals:** Family of elements in Group IIA in the periodic table.
- **An element:** a substance that cannot be broken down into simpler form by chemical means.
- **Atom:** The smallest particle of an element that can take part in a chemical reaction.
- **Atomic mass:** The average mass of the isotopes of an element.
- **Atomic nucleus:** The dense central region of the atom that consists of protons and neutrons.
- **Atomic number (Z):** The number of protons in the nucleus of an atom of an element.
- **Atomic size:** The distance from the nucleus to the outermost shell of an atom.
- **Binary compounds:** Compounds that contain atoms of two different elements only.
- **Chalcogens:** Family of elements in Group VIA in the periodic table.
- **Chemical changes:** changes in the composition of substances
- **Chemical equation:** The method of representing a chemical reaction with the help of symbols and formulas of substances.
- **Chemical formula:** A symbolic representation of a molecule of an element or a compound.
- **Chemical industry:** a plant or a factory involved in the manufacturing of finished or semi-finished products.
- **Chemical properties:** Properties that describe the characteristics of a substance related to chemical changes.
- **Chemical industry:** A plant or a factory involved in the manufacturing of finished or semi-finished products.
- **Chemical reaction:** A process by which a substance(s) is/are changed into two or more new substances.
- **Chemistry:** A branch of natural science that studies the composition, properties, structure and transformation of substances.
- **Coefficient:** A number written in front of a symbol or a formula.
- **Continuous theory:** A theory that describes that matter is divided endlessly into small pieces.
- **Diatomic molecules:** Molecules that contain only two atoms.
- **Discreteness theory:** A theory that explains that matter cannot be endlessly divided into small pieces; matter contains a smallest indivisible piece (discrete).

Distillation: Distillation is a process by which mixtures are separated based on differences in their boiling points.

Electron Configuration: The distribution of electrons in the shells of atoms.

Electron shell: Definite path around a nucleus in which electrons move.

Electron: A subatomic particle with a negative charge that exits outside an atomic nucleus.

Energy Level: Another name of electron shell; it also represents a particular energy an electron can have in an atom.

Evaporation: Evaporation is a process in which liquids are changed to gases.

Fertilizer: Chemicals added to the soil to increase plant nutrients.

Gas: A state of matter that has no definite shape and volume.

Group: The vertical column of elements in the periodic table. It is also known as family.

Halogens: Family of elements in Group VIIA in the periodic table.

Herbicides: Chemicals used to kill weeds.

Heterogeneous Mixture: A mixture that does not have uniform composition.

Homogeneous mixture: A mixture that has uniform composition and only one phase.

Ion: An atom or group of atoms that is positively or negatively charged.

Isotope: Atoms of the same element with the same number of protons but different number of neutrons.

Law of Conservation of Mass: The law that states matter is neither created nor destroyed. Thus the total mass of reactants is equal to that of products in a chemical reaction.

Law of octaves: States that when elements are arranged in an increasing order of their atomic masses the eighth element after a given element has similar properties to the first one.

Law of triads: States that the atomic mass of the middle element is nearly equal to the average mass of the other two elements.

Liquid: A state of matter that has a definite volume but no definite shape.

Mass number: The sum of the number of protons and the number of neutrons in the nucleus of an atom.

Mendeleev's periodic law: States that the properties of the elements are periodic functions of their atomic mass.

Modern periodic law: States that the properties of the elements are periodic functions of their atomic numbers.

Molecule: The smallest particle of an element or a compound that exists in nature.

Monatomic molecule: Molecules that contain only one atom;

Natural science: A branch of science that studies natural laws governing living and non-living things.

- **Neutron:** A subatomic particle with a charge of zero that exists in the atomic nucleus.
- **Noble Gases:** Group VIIIA elements in the periodic table;
- **Nuclear charge:** The total charge of protons in the nucleus of an atom.
- **Oxide:** An Oxide is a binary compounds of Oxygen and another element
- **Oxide:** A binary compound of oxygen and another element.
- **Period:** The horizontal row of elements in the periodic table.
- **Periodic law:** Repetition of properties of the elements in a regular manner.
- **Periodic table:** The arrangement of the elements into periods and groups.
- **Periodicity:** The appearance of elements with similar properties at regular intervals.
- **Pesticides:** Chemicals used to control agricultural pests.
- **Physical changes:** changes that do not result in the formation of new substances with new properties.
- **Physical properties:** Properties that describe the characteristics of the substance that are related to physical changes.
- **Polyatomic Ion:** An ion composed of two or more atoms.
- **Polyatomic molecules:** Molecules that contain more than two atoms.
- **Prefix:** A letter or group of letters added to the beginning of a word.
- **Products:** The substances produced by a chemical reaction.
- **Proton:** A tiny positively charged particle found in atomic nucleus.
- **Qualitative meaning of a symbol:** represents the identity or kind of an element.
- **Quantitative meaning of a symbol:** represents the number of atoms of an element.
- **Raw material:** Substances used as starting materials in the production of useful substances.
- **Reactants:** Substances that take part in a chemical reaction.
- **Solid:** Solid is a state of matter that has definite shape and definite volume.
- **Subscript:** A number written in the bottom right hand side of a symbol to indicate the number of atoms in a formula.
- **Substance:** a form of matter possessing constant properties under specific conditions.
- **Symbol:** Short hand notation for the chemical name of an element.
- **The essence of chemistry:** Application of chemistry in the production of substances to satisfy social needs.
- **Valence electrons:** The electrons found in the outermost shell of an atom.
- **Valence number:** Combining power of an element or polyatomic ions.
- **Valence shell:** The outermost shell of an atom.

CHEMISTRY

STUDENT TEXTBOOK

Grade 7

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