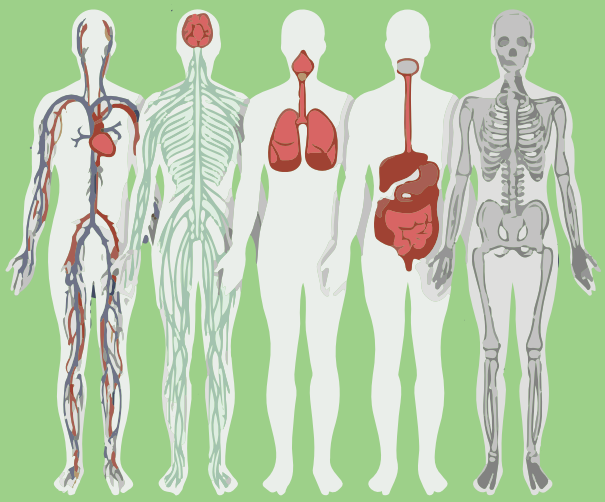
General Science

Student Textbook



Grade 8

General Science

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Table of Contents

UNIT FIVE

UNIT SIX

UNIT SEVEN

UNIT ONE

BASICS OF SCIENTIFIC INVESTIGATION

Learning Outcomes:

At the end of this unit, You will be able to:

- identify the basic and derived units of measurements;
- explain the concept of measuring physical quantities;
- describe the components of a scientific investigation;
- demonstrate ability to work effectively and respectfully with others in performing fair testing.

Main contents

Introduction

This unit contains two sub units: scientific measurement and doing scientific investigation. Under scientific measurement the indigenous and modern methods of measurement, the classification of physical quantities into fundamental and derived quantity and the difference between accuracy and precision will be discussed. Under doing scientific investigation, the importance, procedures and ethical issues of a scientific investigation will be discussed. Finally using locally available materials, a simple investigation will be conducted.

1.1 Scientific Measurements

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

- explain the concept of measuring physical quantities;
- describe the various indigenous methods of measurement;
- distinguish between the basic and derived physical quantities;
- categorize the basic and derived units of measurements (length, mass, time, temperature, volume, area, density, force);
- identify prefixes and perform conversions among units of measurements;
- distinguish between accuracy and precision in measurements.

Introduction

Making observation is common experience in science. Similarly, it is usual asking the basic questions like how big an object is? How tall are you? To answer these questions, measurements have to be made. Measurement is the process of obtaining the magnitude of a quantity relative to an agreed standard.

In this section both the indigenous and modern methods of measurement will be discussed. The indigenous method of measurement refers to a measurement practiced locally while the modern method refers to a measurement applied by the scientific community.

Indigenous Methods of Measurements

An indigenous method of measurement refers to measurement methods that are practiced locally for a long period of time and are passed from generations to generation. In this section, we will pay attention to the measurement of length, mass, and time.

A. Length

Length is a measure of the distance between two points. In Ethiopia we use different indigenous units of length measurement. The commonly used ones are:

1. **Hand-span:** The hand-span is the measure from the tip of your little finger to the tip of your thumb when your hand is stretched out, Fig 1.1 (a).
2. **Digit:** A digit is the width of an adult human male fingertip, Fig 1.1 (b).
3. **Cubit:** A measure of distance from the tip of one's elbow to the tip of the middle finger when your arm is extended, Fig 1.1 (c).
4. **Foot:** A measure of distance from the back of the heel to the tip of the big toe, Fig 1.1 (d).
5. **Pace:** A linear distance measure of a person's extended walk. A pace is a unit of length consisting either of one normal walking step. The pace is the distance measured from the heel of one foot to the heel of the same foot when it next touched the ground, Fig 1.1 (e).
6. **Arm span:** Arm span also known as fathom is the distance from the middle fingertip of the left hand to that of the right hand when you stretch your arms out as far as they can reach, Fig 1.1 (f).

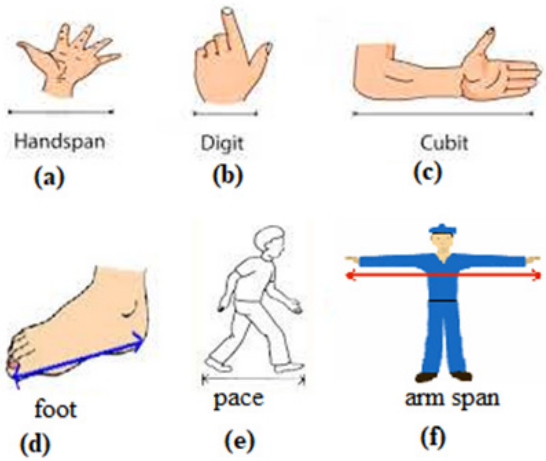


Figure 1.1 Indigenous Measurement Length

Activity 1.1: Make a group containing 5 students. Using your hand span, cubit and digit measure the width of a table or a desk in your classroom. Record your measurement in the table below.

No	*Name of the student making measurement*	*Measurement result*
1		
2		
3		
4		

Question: Did each of you obtain the same measure for that table or desk? Justify the difference of students' measurement.

Exercise1.1: Compare the size of your hand-span,digit,cubit,foot,pace and arm-span and write them in order of increasing value.

B. Mass

The amount of matter present in a substance is called mass. Like length, there is also an indigenous method of measuring mass. The following are some examples of the indigenous unit of mass measurement used in Ethiopia.

1. **Weqet-** Weqet is a mass measuring unit usually used to measure the mass of powder of gold in local markets.
2. **Quntal –** Quntal (may be taken from the English word quintal) is a bag used to measure the mass of grains. It is equal to a hundred kilogram.
3. **Feresula:-** is used to measure the mass of pepper and coffee. It is equal to 17 kilogram.

Figure 1.2 Indigenous mass measurements

Exercise 1.2:

Discuss about the reliability of the above three indigenous mass measuring methods.

C. Time

Time is the measure of the duration for an interval.There is also an indigenous method of measuring time. Our elders were used the shadow of a tree to measure time. As the position of the Sun changes from morning to evening the length of the shadow of a tree varies. In the morning and late in the afternoon, the length of the shadow is high. At noon when the Sun is overhead no shadow will be seen.

Using this fact they could tell the approximate time of the day by just looking at the position of the shadow of a tree found at or near their home.

Activity 1.2:

Using a long tree found in your school, mark the time at different height of the shadow of the tree. Use this shadow clock for some time. Discuss your observation.

Project 1.1: In ancient time three commonly known time measuring devices were used: They are known as sundial, sand clock and water clock. Using internet and other sources explore how these devices were used to measure time and report your finding to the class.

D. Volume

Volume is the measure of the space occupied by an object. In the local markets of Addis Ababa the following tools are used for different size volume measurements.

1. **Jog:** A plastic cup used for measuring the volume of liquids.
2. **Tassa:** A can used to measure cereals, pulses ,liquids and solids.
3. **Sini:** A small ceramic cup often used for measuring coffee, pulses and spices.
4. **Birchiko:** A glass often for measuring pulses and liquids.
5. **Kubaya:** A mug, often used for measuring cereals, pulses and liquids.

Figure 1.3 Some examples of Indigenous volume measurements

Exercise 1.3:

1. Discuss about the problems there could be in using the above indigenous volume measuring devices.

2. Discuss in group about the pros and cons of indigenous measurements used in your locality

Project 1.2: With the help of your teacher go to the local market found near to your school. Gather information about the indigenous measuring devices used for different measurements in the market. You can also ask your elder family members and present a report to your classmates.

Physical Quantities and Scientific Methods of Measurement

In our day to day life, we measure many things such as the mass of vegetables, the volume of liquids, the speed of a car, the temperature of the day etc. Such quantities which could be measured are called **physical quantities.** A physical quantity is a property of an object that can be measured or calculated from other physical quantity. Examples of physical quantities are: length, mass, time, temperature, area, volume, density, force etc.

Generally, physical quantities are classified into two types, namely: fundamental quantities and derived quantities

1.Fundamental Physical quantities and their units

Fundamental quantities, also known as base quantities, are quantities which cannot be expressed in terms of any other quantity. They are the bases for other quantities. There are seven fundamental (basic) physical quantities: length, mass, time, temperature, electric current, luminous intensity and amount of a substance.

In this section we will discuss only about the first four commonly measured fundamental quantities: length, mass, time and temperature. The names and symbols of the units of the fundamental quantities in the International System of units (SI) are shown in table 1.1.The International System of Units (SI, abbreviated from the French Système international (d'unités)) is a system of measurement based on base units. An International System of units (SI) is currently used all over the world.

Measurement is the comparison of an unknown quantity with some known quantity. This known fixed quantity is called a **unit.** Thus, the result of a measurement is expressed in two parts. One part is a number and the other part is the unit of the measurement. For example, if a student has a mass of 32 kg:

the quantity being measured is mass, the value of the measurement is 32 and the unit of measure is kilograms (kg).

This tells us that any measurement consists of two parts. The first is the number which indicates the magnitude of the quantity and the second indicates the unit (standard) of that quantity.

Units can be classified into two groups: fundamental units and derived units. The units used to measure fundamental quantities are called fundamental units. It does not depend on any other unit.

Table 1. 1 Fundamental quantities and their SI units

Quantity	**Name of Unit**	**Symbol of the unit**
Length	Meter	m
Mass	kilogram	kg
Time	Second	S
Temperature	Kelvin	K

2.Derived Physical Quantities and their Units

Physical quantities which depend on one or more fundamental quantities for their measurements are called **derived quantities.** Speed, area, volume, density and force are examples of derived quantities. The units used to measure derived quantities are called **derived units.** It depends on fundamental units for their measurement. SI derived units are described by mathematically combining (dividing, multiplying or powering) the base units. Some of the derived quantities and their units are given in table 1.2.

Table 1. 2 Derived quantities and their SI units

No.	Derived quantity	Symbol	Unit
1	Area	A	$m \times m = m^2$
2	Volume	V	$m \times m \times m = m^3$
3	Speed	V	m/s
4	Density	ρ	Kg/m^3

Example 1.1: Show how the unit of (a) area and (b) speed is derived from the fundamental units.

Solution:

(a) The equation for the area of rectangular surface is

Area = length x width.

Both length and width are length measurements. Hence they are measured in meter.

Unit of area = unit of length x unit of width

Unit of area = m x m = m^2

(b) The equation for speed is

Speed = distance/time

Thus the unit of speed is the unit of distance (m) over the unit of time (s) = m/s

Activity 1.3: Discuss in group about the importance of scientific measurement to the study of science. Let the representative of your group present what you have agreed to your classmate.

Exercise 1.4: Show how the units of the following derived quantities are derived from the unit of base quantities. (a) volume, (b) density and (c) force.

Prefixes and Conversion of Base Units

Prefix

In science we deal with quantities which are both very large and very small. A short hand form of writing very large and very small numbers is known as a **prefix.** A few of the prefixes used in the SI system of units are shown in Table 1.3.

Table 1.3. prefixes

Prefix	Symbol	Name	Decimal representation
Mega	M	million	1 000 000
Kilo	k	thousand	1 000
Centi	c	hundredth	0.01
milli	m	thousandth	0.001
micro	**μ**	**millionth**	0.000001

Conversion of base units

It is often necessary to convert between units of measurement. For example, a mass measured in grams may be required to convert into kilogram.

To convert from one unit to another within the SI, usually means moving a decimal point. If you can remember what the prefixes mean, you can convert within the SI system relatively easily by simply multiplying or dividing the number by the value of the prefix.

Example 1.2: Convert 6.5 kilogram (kg) to gram (g).

Solution: Since killo (k) is a prefix representing 1000, so:

6.5 kg = 6.5 × (1000) g = 6500 g

Example 1.3: Convert 200 meters to kilometers.

We know that 1 km = 1000m. Then we will ask if 1000m is 1km then what will be 200m in km?

Solution: 1 km = 1000 m

? = 200m ⟹ $200\,m = \frac{1\,km \times 200\,m}{1000\,m} = \frac{200\,km}{1000} = 0.2\,km$

Exercise 1.5

1. Convert the following:
   a) 0.6 km to cm b) 500 g to kg c) 30 min to hour
   d) 50 m to mm e) 0.25 kg to g f) 0.5 hour to second
2. Write the following quantities in units with the appropriate prefixes:
   a) 3500 m b) 0.0012 sec c) 0.01 g

Measuring Physical Quantities

The measurement of a physical quantity is done by using measuring instruments. In this section we will discuss how to measure mass, length, time, and temperature using their appropriate devices.

Measuring the mass of objects

Instruments which are used to measure mass are known as ***balances.*** The balance compares the mass of an object with a known mass. Different types of balances are there, see Fig 1.4.

Figure 1.4 Instruments Used to Measure Mass

Note that, before taking measurement check that the balance is on a level surface, and reads zero when no load is placed on it.

The SI unit of mass is **kilogram** (kg). For small mass we use gram (g). To measure the mass of objects less than 1 gram, we can use milligram. To measure the mass of big objects we use quintal and tone.

The relationship between different units of Length.
1 kg = 1000 g.
1 g = 1000 mg
1 quintal = 100 kg
1 tone = 1000 kg

Example 1.4: How much is 1200 gram in kilogram?

Solution: $1200\,g = 1200 \times \frac{1}{1000} kg = 1.2\,kg$

Exercise 1.6: Convert the following measurement:
(a) 2.5 kg to gram, (b) 200 gram to milligram.

Measuring Length

Length is a measure of how long an object is. Depending on the size of the length of the object, we are going to use different types of length measuring instrument, see Fig 1.5.

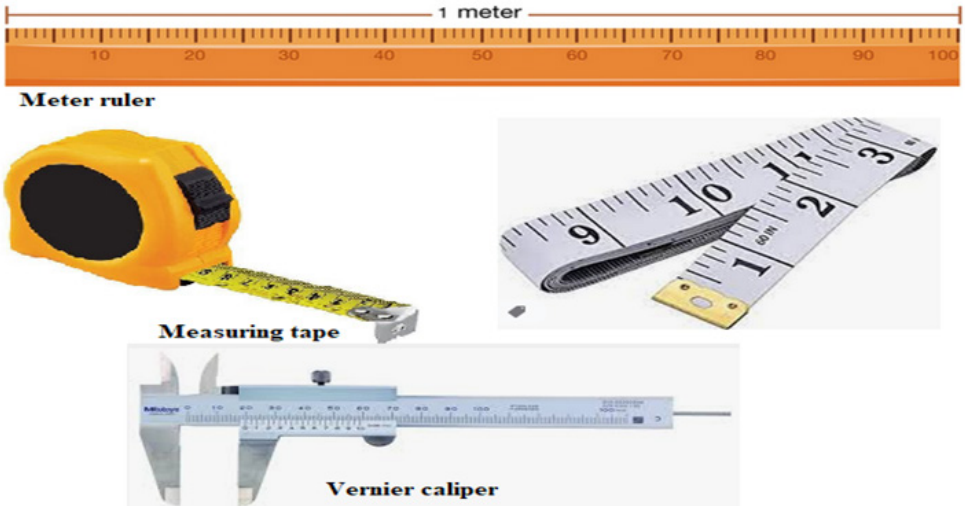


Figure 1.5 Instruments used to Measure Length

The SI unit of length is meter (m). When we want to measure larger lengths, we can use kilometers. If we want to measure small lengths, we can use centimeters or millimeters.

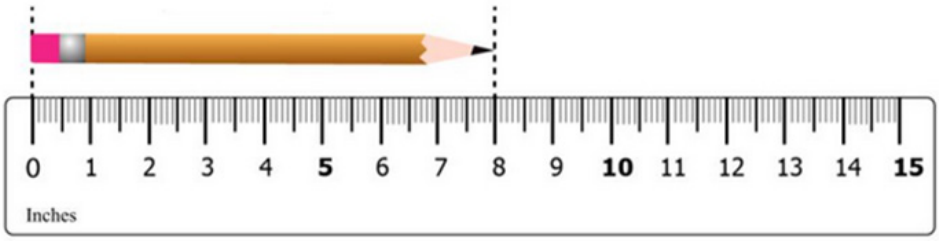
The relationship between different units of Length.

1km = 1000 m

1 m = 100 cm

1cm = 10mm

Note that when we are measuring length using these device do not forget to place the zero mark exactly at one end of the thing you are measuring and read the scale at the other end.



Example 1.5: How many millimeters are there in a meter?

Solution: 1m = 100 cm = 100 x 10 mm = 1000 mm

Exercise 1.7: Convert the following into the required measures:

(a) 8 meters to millimeter. (b) 5500 meters to kilometer.

Measuring time

Time is used to quantify the duration of events. Time is measured with a stop watch or clock.

Figure 1.6 Time measuring Instruments

The SI unit of time is second (s). For longer intervals of time we use: day, month , year, decades, century and millennium.

The relationship between different units of time

1 hour = 60 minutes
1 minute = 60 seconds
1 day = 24 hours
1 week = 7 days
1 year = 365 or 366 days

Example 1.6: Convert one hour into seconds.
Solution: 1 hour = 60 minutes = 60 × 60 second = 3600 seconds.

Exercise 1.8:
How many (a) minutes, and (b) seconds are there in one day?

Measuring Temperature
Thermometer is the device used to measure the temperature of an object or place. The SI unit of temperature is Kelvin. Degree Celsius (°C) and degree Fahrenheit (0F) are other units of temperature Thermometers could be analogue or digital, see Figure 1.7

Figure 1.7 Temperature Measuring Devices

Activity 1.4: Measuring body temperature.
- measure the body temperature of two students by using thermometer.
- Compare the two temperatures with the standard temperature of a body which is 37°C
- Discuss about your observations.

In using thermometer, hold the thermometer at the top, do not hold the bulb of a thermometer and do not let the bulb touch the glass.

Activity 1.5: Measuring the temperature of water.

- Using a laboratory thermometer, measure the temperature of a warm water.
- Record your observations

Safety!! Never put a laboratory thermometer into your mouth.

Accuracy and Precision in Measurement

Accuracy refers to how close a measurement is to its accepted or known value.

Example 1.7: If in a laboratory you obtain a mass measurement of 8.2 kg for a given substance, but the actual or known mass is 10 kg, is your measurement accurate?

Answer: This measurement is not accurate, because your measurement (8.2 kg) is not close to the known value (10kg).

Precision refers to how close two or more measurements are to each other, regardless of whether those measurements are accurate or not.

Example 1.8: In the above example 1.4, if you measure the mass of the given substance five times, and get 3.2 kg, 3.1 kg, 3.25 kg, 3.3 kg and 3.2 kg. Is your measurement precise?

Answer: This measurement is precise, because the values are close to each other but not accurate because it is far from the known value (10 kg). This shows that precision is independent of accuracy. You can be very precise but inaccurate. You can also be accurate but not precise.

Exercise 1.9: The figure below shows 3 results of a student playing a dart game. In the space provided below each figure, write whether the result is

(a) accurate but not precise
(b) accurate and precise
(c) precise but not accurate
(d) neither precise noraccurate

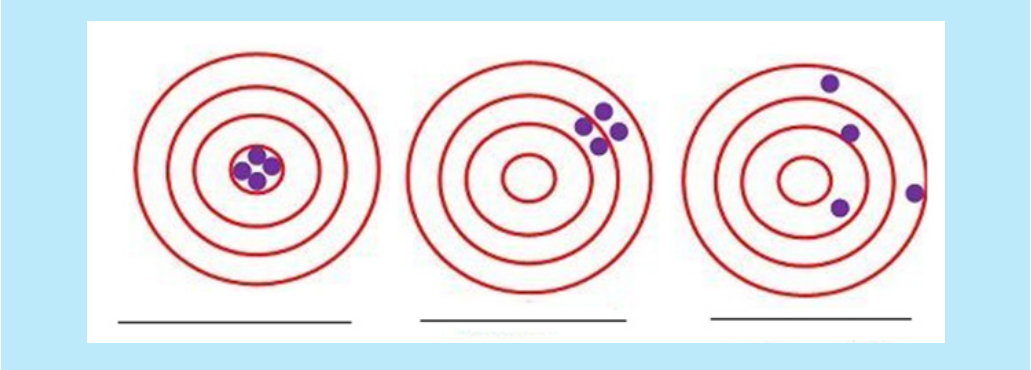


Figure 1.8 Dart game

Exercise 1.10:

1. Define the following terms: physical quantity, fundamental quantity, derived quantity.
2. State the various indigenous methods of measurement used in Addis Ababa.
3. What are prefixes?
4. What is the difference between accuracy and precision in measurements?

1.2 Doing Scientific Investigation

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

- describe the components of a scientific investigation;
- demonstrate ability to work effectively and respectfully with others in performing fair testing;
- practice scientific investigation procedures using appropriate contents to their age levels.

Introduction to Scientific Investigation

Science is a process of learning about the world through observation, inquiry, formulating and testing hypotheses, gathering and analyzing data, and reporting and evaluating findings.This process is referred as the scientific investigation or scientific method.

1.2 Scientific Method

Activity 1.6
What are the applications of scientific method?

All sciences, including the social sciences, employ variations of what is called the **scientific method.** Scientific method is the process by which scientists approach their work.

The Steps of the Scientific Method

Based on the type of question being asked, the type of science being applied and the laws that apply to that particular branch of science, you may need to modify the method and alter or remove one or several of the steps.

1. Ask Questions

A scientific investigation typically begins with observations. Observations often lead to questions. This question will include one of the key starters, which are, how, what, when, why, where, who or which. The question you ask should also be measurable and answerable through experimentation. It is often something that can be measured with a numerical result, although behavioral results are part of the scientific method as well.

2. Perform Background Research

With your question formulated, conduct preliminary background research to prepare yourself for the experiment. You can find information through online searches or in your local library, depending on the question you are asking and the nature of the background data. You may also find previous studies and experiments that can help with your process and conclusions.

3. Establish your Hypothesis

Based on the data that were gathered, the researcher formulated a hypothesis. A hypothesis is a tentative explanation for a set of observations. Your hypothes should also include your predictions that you can measure through experimentation and research.A hypothesis must be based on scientific knowledge, and it must be logical.

4. Test your Hypothesis

Next, test your hypothesis by conducting an experiment. Your experiment is a way to quantifiably test your predictions and should be able to be repeated by another scientist. Assess your scientific process and make sure that the conditions remain the same throughout all testing measures. If you change any factors in your experiment, keep all others the same to maintain fairness. After you complete the experiment, repeat it a few more times to make sure the results are accurate.

5. Analyze the Results and Draw a Conclusion

You can now take your experiment findings and analyze them to determine if they support your hypothesis or not. Drawing a conclusion means determining whether what you believed would happen actually happened. If it did not happen, you can create a new hypothesis and return to step three, then conduct a new experiment to prove your new theory. If what you hypothesized happened during the experimentation phase, the final step is putting together your findings and presenting them to others.

6. Communicating Results

The last step in a scientific investigation is communicating what you have learned with others. This is a very important step because it allows others to verify your methods and results. If other researchers get the same results as yours, the hypothesis becomes stronger. However, if they get different results, they may not support the hypothesis. When scientists share their results, they should describe their methods and point out any possible problems with the investigation. Finally, communicating results can be done in a variety of ways including scientific papers, blogs, news, articles, conferences, etc.

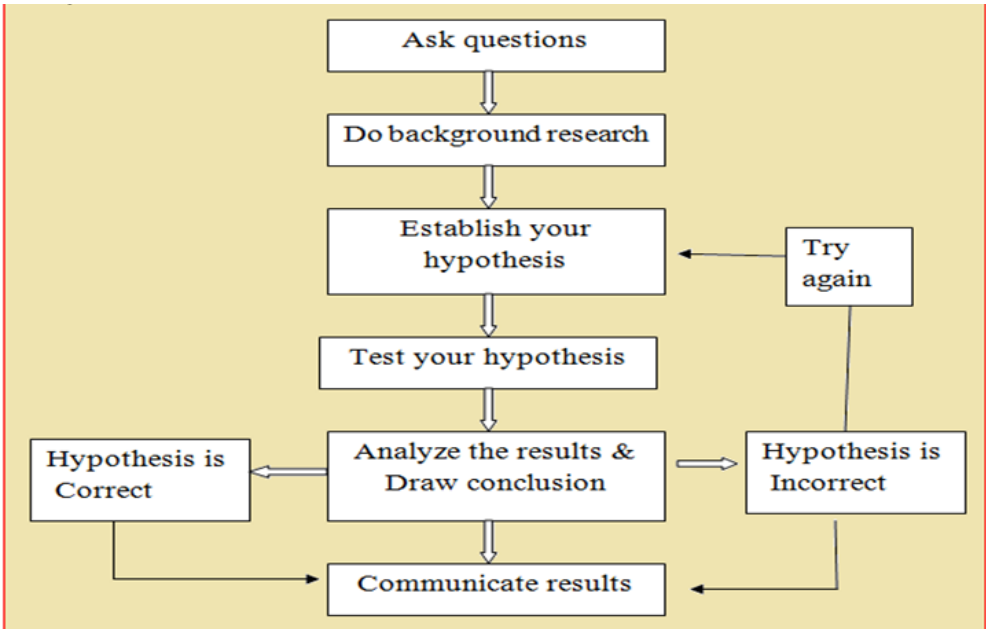


Figure 1.9 Steps in Scientific Method

Example1.9: Simple experiment with candle that shows the necessary of air for burning. Consider how the scientific method applies in this simple experiment with air necessary for burning under two different conditions.

1. **Ask Question:** Is air necessary for burning?
2. **Do back ground Research:** From different literatures "air is necessary for burning."
3. **Formulate Hypothesis:** The null hypothesis is that there wil be no air needs for burning. The alternative hypothesis is that there will be air needs for burning.
4. **Test Hypothesis by Experiment and Collect Data:** Take a candle and fix it on a table. Light the candle. The candle will continue to burn due to continuously available fresh air providing the required oxygen for combustion.Now cover the burning candle by putting an inverted gas jar over it. After a short time, the candle stops burning and gets extinguished.
5. **Analyze the Results and Draw Conclusion:**
   When the burning candle is covered with gas jar, then the candle takes away the oxygen necessary for burning from

the air enclosed in the gas jar. After some time, when all the oxygen of air inside the gas jar is used up, then the burning candle gets extinguished. This proves that air is necessary for combustion or burning of substances.

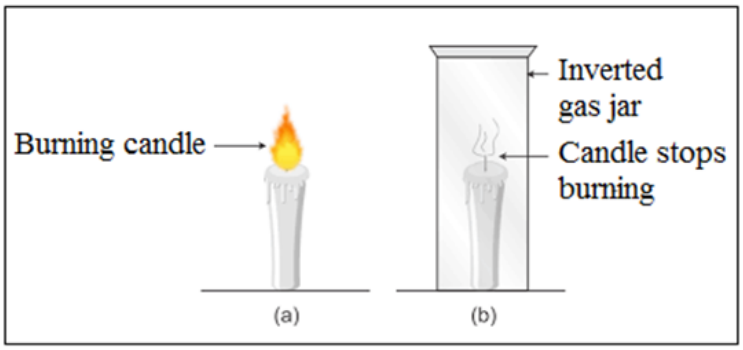


Figure 1.10 a) Burning of candle b) Candle stops burning

6. Communicate Results: Report your findings in the form of a written report as an oral presentation. Air is necessary for burning.

Activity 1.7

Form groups and conduct investigations on activities listed below. After investigation present your findings to the class.

a. What is the effect of sunlight on the growth of bean plant?
b. Does a coiled nail act like a magnet?
c. How do plants store their food in their leaf?

Exercise 1.13

Describe the components of a scientific investigation.

Project 1.3

Conduct some investigations (for example, making injera) using local materials and methods (procedures) in groups by reading different reference books or asking a person who is knowledgeable and experienced in the area.

Figure 1.11Injera

Figure 1.12 Injera being cooked on a griddle

Key Terms: -Fundamental quantity,
-Derived quantity,
-Fundamental unit,
-Derived unit,
-Prefix, Accuracy
-Precision, and
-Scientific method.

Summary

- Measurement is the process of obtaining the magnitude of a quantity relative to an agreed standard.
- Indigenous units of measurement for length: cubit, span, digit, foot and pace, for mass weqet and quntal, for time length of a shadow are used.
- Fundamental quantities are a set of physical quantities which cannot be expressed in terms of any other quantities. Their corresponding units are called "Fundamental units".
- The physical quantities which can be obtained by mathematically combining (i.e., multiplying and dividing) the fundamental quantities are known as "Derived quantities". Their corresponding units are called "Derived units".
- Prefixes are a short hand form of writing very large or very small numbers.
- Accuracy refers to how close a measurement is to the accepted value while precision refers to how close measurements are to each other.
- Scientific method is the process by which scientists approach their work.

Review Exercise

I. Choose the correct answer from the given alternative

1. Which of the following quantities is a fundamental quantity?
   a) Area b) volume
   c) temperature d) force
2. The difference between fundamental and derived unit is
   a) Fundamental units are big in value but derived units are small in value.
   b) Fundamental units are derived from derived units.
   c) Derived units are derived from fundamental units.
   d) There is no difference between them.
3. Which of the following is a derived quantity?
   a) mass b) area
   c) time d) length
4. The SI unit of density is
   a) kg/m^2 b) kg/m^3
   c) kg/m d) g/m^3
5. The prefix that represents $\frac{1}{1000}$ is_____.
   a) kilo b) mega
   c) centi d) milli

II. Fill in the blank spaces with an appropriate word.

1. Length, mass, time and temperature are _____quantities.
2. Area, volume, density and force are _____ quantities
3. One million centimeter is equal to _____ meter.
4. The prefix for a number 0.01 is _____.
5. The SI unit of volume is _____.

III. Match the quantities in column-I to their units in column-II:

	Column I	Column II
1	Area	(a) K
2	Temperature	(b)m^3
3	Density	(c) m2
4	Volume	(d)kg
5	Mass	(e) kg/m3

IV. Give short answer

1. Write four fundamental quantities with their units.
2. Write four derived quantities with their units.
3. Write the measurement 0.005 m using prefix.
4. Convert 1000 cm to kilometer.
5. The value of acceleration due to gravity on the surface of Earth is known to be 9.81 m/s^2. In an experiment students have found the following results. 12.2 m/s^2, 12.3 m/s^2, 12.1 m/s^2 and 12.08 m/s^2. Is this measurement accurate or precise?
6. List the steps used in scientific method.

UNIT TWO
COMPOSITION OF MATTER

Learning Outcomes:

At the end of this unit, you will be able to:

- narrate the historical development of the atomic nature of substances;
- appreciate that atoms are the building blocks which make up all substances;
- demonstrate understanding of the idea that the identity of a substance is determined by its atomic structure;
- differentiate molecules of elements from molecules of compounds;
- demonstrate scientific inquiry skills along this unit: communicating, asking questions, drawing conclusions, applying concepts.

Main contents

2.1 Early Thinking about the Composition of Matter

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

- Give a short history of the concept of the atom;
- Compare and contrast the continuity and discreteness (discontinuity) theory of matter;
- Compare earlier conceptions of the structure of matter with their conceptions.

Activity 2.1

Form groups and discuss the following and present your opinion to the class.

1. What is matter?
2. What do you think matters made up of?

The earliest recorded discussion of the basic structure of matter comes from ancient Greek philosophers, the scientists of their day. Some of them argued that matter is continuous i.e., it could be divided endlessly into smaller pieces. Others believed that matter is discrete; i.e., it cannot be infinitely divided.

Democritus (460 - 370 B.C) expressed the belief that all matter consists of very small, indivisible particles, which he named atomos (meaning uncuttable or indivisible). He thought of atoms as moving particles that differed in shape and size which could join together. *According to Democritus matter is discrete.*

Aristotle (384 – 322 B.C) argued that matter is divided into smaller and smaller parts, the division continuous forever without any limit. He did not believe in microscopic building particles of matter. Therefore, according to Aristotle, matter is continuous and he believed that matter consisted of the combinations of fire, earth, air, and water.

Activity 2.2

Form two groups and debate on one of the following ideas assigned to your group. After discussion present your reasons to the class.

1. If matter is divided and subdivided again and again, what would ultimately be obtained?
   a. Group 1: According to Aristotle's believe
   b. Group 2: According to Democritus's believe

Table 2.1 Comparison between the discrete and continuous theory of matter

Discreteness Theory	Continuous Theory
➢ Proposed by Democritus	Proposed by Aristotle
➢ There is a limit to which matter is broken	Matter is infinitely divisible
➢ Believed in the existence of atoms	Rejected the idea of atoms

Exercise 2.1

1. Compare and contrast the continuity and discreteness theory of matter.

2.2 Inside of an Atom

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

- describe the structure of an atom as a nucleus containing protons and neutrons, surrounded by electrons in shells (energy levels);
- state the relative charge and approximate relative mass of a proton, a neutron and an electron;
- draw hydrogen atoms, including the location of the protons and electrons, with respect to the nucleus;
- differentiate between mass number and atomic number;
- determine the number of protons, neutrons, and electrons in an atom.

What are the two parts of atom?

An atom consists of a tiny dense **nucleus** surrounded by **electrons**. The nucleus contains positively charged protons and neutral neutrons, so it is positively charged. The electrons are negatively charged. Protons and neutrons have approximately the same mass and are about 1800 times more massive than an electron. This means that most of the mass of an atom is in its nucleus. However, most of the volume of an atom is occupied by its electrons.

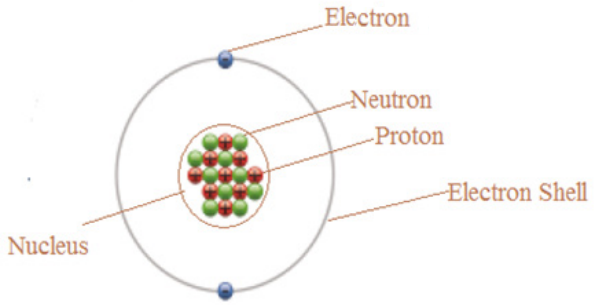


Figure 2.1 Diagrammatic representation of the atom

The subatomic particles

Activity 2.3

Draw a simple sketch of hydrogen atom model on your exercise book by using coloured pen following the instructions listed below.

i. Draw a small circle labeled "nucleus".
ii. Add a smaller circle labeled "proton" inside the nucleus.
iii. Add another circle around the nucleus and add a symbol such as a dot for the electron

Atoms possess internal structure; that is, they are made up of even smaller particles, which are called subatomic particles. A subatomic particle is a very small particle that is a building block for atoms.

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.

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 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 because it is ≈ 2000 times less heavier than both the proton and neutron.

Table 2.2Nature and location of sub-atomic particles

Particle' Name	Location	Actual Mass (g)	Relative Mass (amu)	Actual Charge (C)	Relative charge (C)
Proton	Nucleus	1.673×10^{-24}	1.00728 ≈1	$+1.60218\times10^{-19}$	+1
Electron	Outside nucleus (shell)	9.109×10^{-28}	0.00055 ≈ 0	-1.60218×10^{-19}	-1
Neutron	Nucleus	1.675×10^{-24}	1.00866 ≈ 1	0	0

Project Work 2.1

Prepare hydrogen model by using locally available materials in groups and present your model to the rest of class.

Atomic Number and Mass Number

Activity 2.4

Form groups and discuss the following activity. Share your opinion with your group members and present your group opinion's to the class. Determine atomic numbers and mass numbers of common elements by using periodic table.

All atoms can be identified by the number of protons and neutrons they contain. The atomic number (Z) of an atom equals the number of protons in its nucleus. The atomic number is also the number of electrons that surround the nucleus of a neutral atom.

Atomic number (Z) = Number of protons= number of electrons

Mass number (A) is the sum of the number of protons and the number of neutrons in the nucleus of an atom.Except for the most common form of hydrogen, which has one proton and no neutrons, all atomic nuclei contain both protons and neutrons.

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

The mass and atomic numbers of a given atom are often specified using the notation:

Example: ${}^{12}_{6}C$, mass number = 12, atomic number = 6, and C is the symbol of carbon.

Determination of the electrons, protons and neutrons

Activity 2.5

Form groups and discuss the following activity. Share your opinion with your group members.

1. Use a periodic table to tell the atomic number, mass number, proton numbers, neutron numbers and electron numbers of the first 10 elements.

Proton is equal to the atomic number of atoms.

Number of protons = atomic number (Z)

Electron: The atom is neutral therefore the number of electrons is equal to the number of protons.

Number of electrons = atomic number (Z) = number of protons

The number of neutrons in an atom is equal to the difference between the mass number and the atomic number or proton number.

Number of neutrons = Mass number (A) - Number of protons

Exercise 2.2

Give the appropriate answers for the following questions.

1. Complete the following table.

Particle	Location	Actual Mass (g)	Relative Mass (amu)	Relative Charge
Proton				
Electron				
Neutron				

2. A nucleus consists of 9 protons and 10 neutrons. Determine:
   i. The element by referring periodic table
   ii. Mass number
3. How many neutrons, protons and electrons are there in an atom of the element $^{14}_{7}N$?

2.3 Molecules

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

- define molecules;
- give examples of monatomic, diatomic and polyatomic molecules;
- use models or particles model diagram to represent molecules of elements and compounds.

Activity 2.6

Form groups and discuss the following activiy. Share your opinion with your group members. After discussion present your findings to the class.

1. What is molecule?
2. Mention some examples of monoatomic, diatomic and poly atomic molecules.

Molecules of Elements

A molecule of an element consists of only one type of an atom. Molecules of elements can be classified as monoatomic, diatomic and polyatomic.

1. **Monoatomic molecules are** molecules that contain one atom of the element. Examples: He, Ne, Ar, Kr, Xe and Rn are monoatomic molecules
2. **Diatomic molecules are** molecules that contain two atoms of the element. Examples: O2, H2, F2, Cl2, I2 are diatomic molecules.

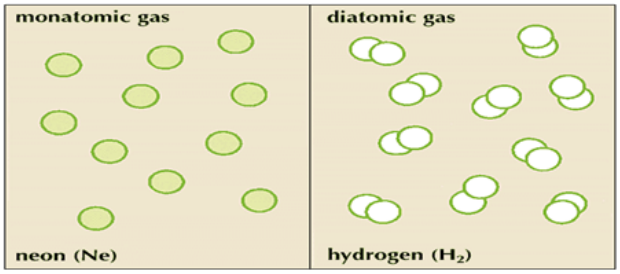


Figure 2.2 Diagrammatical representations of Ne and H_2.

3. **Polyatomic molecules** are molecules that contain more than three atoms of the element. Examples: O_3, P_4, S_8 are polyatomic molecules.

Molecules of compounds

A molecule of a compound always contains two or more atoms of different elements combined chemically. Water (H2O), ammonia (NH3), carbon dioxide (CO2), etc. are some examples of molecules of compounds.

Exercise 2.3

Give the appropriate answers for the following questions.

1. What is a molecule?
2. Classify the following molecules as monoatomic, diatomic or polyatomic?
   a. Ar
   b. N_2
   c. S_8
   d. O_3
   e. He
   f. Br_2

3. Draw the diagram representation of ozone (O_3) molecule.
4. Which of the following molecules are molecules of elements? Which of them are molecules of compounds?

a. Ne	d. Br2
b. H2O	e. NH3
c. HCl	f. P4

Key Terms

- Atom
- Atomic nucleus
- Atomic number
- Continuous theory
- Diatomic molecule
- Discreteness theory
- Electron
- Electron shell
- Mass number
- Molecule
- Monoatomic molecule
- Neutron
- Polyatomic molecule
- Proton

Summary

- Democritus (460-370 BC) introduced the idea that matter consists of very small indivisible particles called “atoms”.
- The three fundamental subatomic particles are protons, neutrons and electrons.
- Protons are positively charged.
- Neutrons are chargeless.
- 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.
- An atom is electrically neutral because the amount of positive charge on a proton equals the amount of negative charge on an electron.
- The mass number is the sum of the number of protons and the number of neutrons in the nucleus of an atom.
- The number of neutrons in an atom is equal to the difference between the mass number and the atomic number or proton number.
- 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.
- 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 can be classified as monoatomic, diatomic or polyatomic.
- Molecules of compounds consist of two or more different type of atoms.

Review Exercise

I. Write "True" if the statement is correct and write "False" if the statement is incorrect.

1. Nucleus consists of protons and neutrons.
2. Atomic number is the number of protons in the nucleus.
3. Molecules of elements consist of two or more different type of atoms.
4. Proton and electron have approximately the same mass.
5. Different elements have the same number of protons.

II. Choose the correct answer from the given alternatives.

6. The idea that matter is 'continuous' was proposed by
   A. Democritus
   B. Aristotle
   C. Dalton
   D. None
7. The idea of 'atoms' first proposed by the Greek philosopher----
   A. Aristotle
   B. Plato
   C. Dalton
   D. Democritus
8. Which of the following particles located in the nucleus of an atom?
   A. Proton and electron
   B. Neutron and proton
   C. Electron and neutron
   D. Proton, electron and neutron
9. 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

10. The number of neutrons in $^{24}_{12}Mg$ are

A. 12 B. 11

C. 24 D. 13

11. Which of the following statements concerning the nucleus of an atom is correct?

A. Contains only neutrons

B. Contains all protons and all electrons

C. Is always positively charged

D. Accounts for most of the total volume of an atom

12. Which of the following molecule is diatomic molecule?

A. O_2

B. O_3

C. P_4

D. S_8

13. Which of the following statement is false?

A. Molecules of elements consist of only one type of atoms.

B. Nucleus is positively charged.

C. Molecules of compounds consist of only one type of atoms.

D. Neutrons have no charge.

14. Which of the following molecule is molecule of elements?

A. H_2O

B. NH_3

C. H_2

D. HCl

III. Give short answers for the following questions.

15. What are the two main parts of an atom?
16. What are the fundamental sub-atomic particles?
17. Determine the atomic number, number of protons, number of neutrons, number of electrons and mass number for $^{16}_{8}O$.

UNIT THREE

CLASSIFICATION OF COMPOUNDS

Learning Outcomes:

At the end of this unit, you will able to:

- explain the classification of compounds into organic and inorganic;
- write the formulas and names the first ten alkanes, alkenes alkynes and list the uses some important common organic compounds;
- classify oxides into different groups and give examples of each group;
- develop skills in identifying acidic, basic and neutral solutions;
- define, and apply the concept of neutralization;
- explain the safety precautions while working with acids and bases;
- demonstrate scientific inquiry skills along this unit: observing, classifying, comparing and contrasting, communicating, asking questions, designing experiment, drawing conclusion, applying concepts and problem solving.

Main contents

3.1 Introduction

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

- define organic compounds as carbon containing compounds and give examples;
- define inorganic compounds as compounds of elements other than carbon.

Activity 3.1

Form groups and discuss the following activity. After the group discussion, choose a group representative to present the group's opinion to the class.

1. State earlier definitions of organic and inorganic compounds.
2. Do you agree with the notion that says: "organic compounds can be synthesized only from animals and plants"?
3. State modern definitions of organic and inorganic compounds.

During the latter part of the eighteenth century and the early part of the nineteenth century, chemists began to categorize compounds into two types: organic and inorganic. Compounds obtained from living organisms were called organic compounds, and compounds obtained from mineral constituents of the earth were called inorganic compounds. During this early period, chemists believed that a special "vital force" supplied by a living organism was necessary for the formation of an organic compound. This concept was disproved in 1828 by the German chemist Friedrich Wöhler. Wohler prepared urea, an organic compound, from the reaction between solutions of inorganic compounds ammonium chloride and silver cyanate.

$$\underset{\text{Ammonium chloride}}{NH_4Cl\,(aq)} + \underset{\text{Silver cyanate}}{AgCNO\,(aq)} \longrightarrow \underset{\text{Ammonium cyanate}}{NH_4CNO\,(aq)} + \underset{\text{Silver chloride}}{AgCl\,(s)}$$

$$NH_4CNO\,(aq) \xrightarrow{\text{Heat}} \underset{\text{Urea}}{(NH_2)_2CO\,(s)} \quad \text{Or} \quad H_2N-\overset{\overset{O}{\|}}{C}-NH_2$$

Soon other chemists had successfully synthesized organic compounds from inorganic starting materials. As a result, the vital-force theory was completely abandoned.

The terms organic and inorganic continue to be used in classifying compounds, but the definitions of these terms no longer reflect their historical origins.

All organic compounds contain carbon and hydrogen, along with other possible elements such as oxygen, nitrogen, sulphur, halogens and phosphorus except the oxides of carbon, carbonates, hydrogen carbonates, cyanides and cyanates.

Inorganic compounds are the compounds consisting of mineral constituents of the earth or generally found in non-living things. The term inorganic compound refers to all compounds that do not contain carbon. Although, carbon dioxide, carbon monoxide, carbonates and hydrogen carbonates are carbon-containing compounds, which are classified as inorganic compounds.

Exercise 3.1

Classify each of the following compounds as organic or inorganic.

a. $C_{12}H_{22}O_{11}$
b. NaCl
c. CaO
d. C_2H_5OH
e. CH3Cl
f. C_2H_4

3. 2 Organic Compounds

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

- Define hydrocarbons and mention at least one source of hydrocarbons;
- Write the general formula of alkanes, alkenes and alkynes;
- Write the specific chemical formulas of the first ten members of alkanes, alkenes and alkynes;
- Describe a homologous series and its general characteristics;
- Name the first eight members of alkanes, alkenes and alkynes;
- Identify some common uses of organic compounds.

Hydrocarbons

Activity 3.2

Form a group and perform the following activity. Share your opinion with your group members.

1. What is hydrocarbon?
2. List the sources of hydrocarbons and indicate their location in Ethiopia.

A hydrocarbon is a compound that contains only carbon atoms and hydrogenatoms.Hydrocarbons divided into three large classes:***alkanes, alkenes*** and ***alkynes.***

Alkanes

Alkanes are hydrocarbons that have the general formula $C_nH_{2n+2,}$ where, n is the number of carbon atoms present, n = 1, 2, 3…..

For example, the molecular formulas of the first four alkanes are $C_1H_{2\times1+2} = CH_4$, $C_2H_{2\times2+2} = C_2H_6$, $C_3H_{2\times3+2} = C_3H_8$, and $C_4H_{2\times4+2} = C_4H_{10}$, respectively.

When we compare the formulas of CH4 and C2H6 or C2H6 and C3H8, they differ by one carbon and two hydrogen atoms or **– CH2 –** group called the **methylene group.** A family of compounds in which each member differs from the next by one methylene ($-CH_2-$) groupis called **homologous series** (homo is Greek for "the same as). The members of a homologous series are called **homologues.**

Exercise 3.2

1. Write the formulas of alkanes that contain 5, 7 and 9 carbon atoms.

Alkenes

Alkenes are hydrocarbons that have the general formula C_nH_{2n}, where, n is the number of carbon atoms present, n = 2, 3….. For example, the molecular formulas of the first three alkenes are $C_2H_{2\times2} = C_2H_4$, $C_3H_{2\times3} = C_3H_6$, and $C_4H_{2\times4} = C_4H_8$, respectively.

Exercise 3.3

1. Write the formulas of the alkenes that contain 6, 8 and 10 carbon atoms.

Alkynes

Alkynes are hydrocarbons that have the general formula C_nH_{2n-2}, where n = 2, 3, 4, etc. For example, the formulas of the first three alkynes are $C_2H_{2\times2-2} = C_2H_2$, $C_3H_{2\times3-2} = C_3H_4$, and $C_4H_{2\times4-2} = C_4H_6$, respectively.

Exercise 3.4

1. Write the formulas of the alkynes that contain five-eight carbon atoms.

Nomenclature (Naming) of Hydrocarbons

Activity 3.3

Form a group and perform the following activity. Share your opinion with your group members.

1. How do we give specific name to a hydrocarbon?
2. Are hydrocarbons named based on certain rules or randomly?

The name of hydrocarbons is derived from the number of carbon atoms present (prefix) and the ending it contains (suffix).The names of alkanes, alkenes and alkynes end with the suffixes '-ane', '-ene' and '-yne', respectively.

i. a ***prefix***- indicating the number of carbon atoms (listed in Table 3.1) and
ii. a **suffix** indicating the type of the functional group present in the molecule or the type of hydrocarbon.

Table 3.1 Prefixes commonly used to indicate one to ten carbon atoms.

Number of carbon atoms	Prefix	Number of carbon atoms	Prefix
1	Meth-	6	Hex-
2	Eth-	7	Hept-
3	Prop-	8	Oct-
4	But-	9	Non-
5	Pent-	10	Dec-

Example 1: Write the names of alkanes; CH_4 and C_3H_8.
Solution:

- CH_4 contains one carbon atom. So, we use the prefix 'meth-' and adding the suffix '-ane' i.e. meth + ane. Thus the name of CH_4 becomes **methane.**
- C_3H_8 contains three carbon atoms. So, we use the prefix 'prop-'and adding the suffix '-ane' i.e. prop + ane. Thus the name of C_3H_8 becomes **propane.**

Example 2: Write the names of alkenes; C_2H_4 and C_4H.
Solution:

- C2H4 contains two carbon atoms. So, we use the prefix 'eth-' and adding the suffix '-ene' i.e. eth + ene. Thus the name of C_2H_4 becomes **ethene.**
- C_4H_8 contains four carbon atoms. So, we use the prefix 'but-' and adding the suffix '-ene' i.e. but + ene. Thus the name of C_4H_8 becomes **butene.**

Example 3: Write the names of alkynes; C_3H_4 and C_4H_6.
Solution:

- C_3H_4 contains three carbon atoms. So, we use the prefix 'prop-'and adding the suffix '-yne' i.e. prop + yne. Thus the name of C_3H_4 becomes **propyne.**
- C_4H_8 contains four carbon atoms. So, we use the prefix 'but-' and adding the suffix '-yne' i.e. but + yne. Thus the name of C_4H_6 becomes **butyne.**

Exercise 3.5

1. Write the formulas and names of alkanes, alkenes and alkynes containing five to ten carbon atoms.

Uses of Common Organic Compounds

Many organic compounds are very useful in our daily life. Some important organic compounds and their uses are described in the following section.

Methane, CH_4

Methane is used primarily as fuel for cooking, heating and generating electricity. Methane is the main constituents of biogas that is used as a domestic fuel.

Propane (C_3H_6) and Butane (C_4H_{10})

The mixture of propane and butane is compressed at a moderate pressure and stored in steel cylinders. It is marked as bottled gas and commonly known as "butagas". It is mainly used for cooking and heating.

Ethyne (C_2H_2)

One of the main uses of ethyne is to produce oxyacetylene flame, which is used in the cutting and welding of steel and iron.

Figure 3.1 Oxyacetylene torch

Ethanol (Ethyl alcohol)

Ethanol is used in the intoxication ingredient of many alcoholic beverages such as beer, wine, tella, ouzo, teji, etc. Nowadays ethanol mixed with petrol is used as a fuel. It is also used in the production of acetic acid, and in hospitals and clinics for cleaning wounds.

Ethanoic Acid (Acetic acid)

Activity 3.4

Form a group and perform the following activity. Share your opinion with your group members.

Why we add 'acheto' or 'vinegar' when we eat uncooked vegetables such as salad?

Table vinegar contains 4% to 8% acetic acid. Vinegar is used as food flavoring agent. It is also used as a disinfectant. For use in preserving vegetables (pickling) it typically ranges up to 18%.

Figure 3.2Adding vinegar

Formalin

When formaldehyde is dissolved in water it is called formalin. Formalin contains 40%, by volume, of formaldehyde. Formalin is used for the preservation of biological specimens, because it makes proteins hard and insoluble.

Exercise 3.6

Give the appropriate answers for the following questions.

1. Classify each of the following hydrocarbons as alkane, alkene or alkyne.
   a. C_5H_{10}
   b. $C_{10}H_{22}$
   c. C_8H_{14}
   d. C_8H_{18}
   e. $C_{10}H_{18}$
   f. C_9H_{18}
2. Write the uses of methane, ethyne, formalin, acetic acid and ethanol.

3.3 Inorganic Compounds

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

- state that inorganic compounds are classified into oxides, acids, base and salts;
- classify oxides into metallic and nonmetallic;
- describe the properties of acidic oxides and basic oxides;
- predict the nature of common oxides;
- prepare sulphur dioxide in the laboratory by burning sulphur in air and use moist blue litmus paper to test its acidic nature;
- prepare magnesium oxide in the laboratory by burning magnesium ribbon in air and use red litmus paper to test its basicity in water solution;
- define acid and base;
- describe properties a of acids and bases;
- relate acidic properties to the presence of hydrogen ions and basic properties to the presence of hydroxide ions.
- name and write formulas for some common acids (HCl, HNO_3, H_2SO_4) and bases (NaOH, KOH, NH_4OH), using the periodic table, a list of ions, and rules for naming acids;
- describe how indicators can be used to classify solutions as acidic or basic;
- investigate properties of bases/alkalis experimentally;

- in group, with guidance, prepare their own indicator by extracting the colour from a vegetable, such as beetroot, or flowers and evaluate the indicator;
- investigate household chemicals using locally prepared indicators;
- explain the safety precautions while working with acids and bases;
- create a safety booklet dealing with the handling of acids and alkali.

Inorganic compounds can be classified into four groups according to their composition and their properties. These include ***oxides, acids, bases*** and ***salts.***

Oxides

Activity 3.5

Form groups and discuss the following activity. After the group discussion,choose a group representative to present the group's opinion to the class.

1. Define oxides and give some examples that are not listed below.
2. Are all compounds containing oxygen oxides? Why?

Oxides are binary compounds containing oxygen and any other element.

Element + Oxygen → Oxide

Some common examples of oxides are water (hydrogen oxide, H_2O), carbon dioxide (CO_2), lime (calcium oxide, CaO), rust (iron (III) oxide), etc.

Exercise 3.7

Give the appropriate answers for the following questions.

1. Define oxides.
2. Which of the following compounds are oxides?

a. $CaCO_3$	d. rust	g. SO_3
b. KOH	e. H_2CO_3	h. CO_2
c. H_2O	f. CaO	

Types of Oxides

Most oxides are classified as metallic oxides and non-metallic oxides.

i. Metallic oxides are binary compounds containing only metals and oxygen.

Metal + Oxygen → Metallic Oxide

Examples: CaO, Na_2O, Al_2O_3, MgO, etc.

ii. Non-Metallic Oxides are binary compounds containing only non-metals and oxygen.

Non-metal + Oxygen → Non-metallic Oxide

NO2, H2O, CO_2, SO_2, SO_3, etc are common example of non-metallic oxides.

Oxides are also classified as acidic and basic oxides depending on their properties or behaviours.

Acidic oxides are oxides that react with water to form acids or acidic solutions. They are mostly non-metallic oxides. Some examples of acidic oxides are SO_2, $P4O_6$, CO_2, etc.

Basic oxides are oxides that react with water to form bases or basic solutions. They are mostly metallic oxides. Some examples of basic oxides are Na_2O, Li_2O, CaO, MgO, etc.

Exercise 3.8

Give appropriate answers for the following questions.

1. Predict whether or not the oxide formed from each of the following elements is a basic oxide and an acidic oxide.
   a. Calcium
   b. Carbon
   c. Sodium
   d. Magnesium
   e. Sulphur
   f. Phosphorus
2. Classify the following oxides as metallic or non-metallic oxides.
   a. CO_2
   b. MgO
   c. SO_3
   d. CaO
   e. NO_2
   f. K_2O

Properties of Oxides

Properties of Acidic Oxides

Activity 3.6

Form groups and discuss the following activity. After the group discussion, choose a group representative to present the group's opinion to the class.Predict the nature of the oxides formed by some non-metals such as arbon and phosphorus.

An *acidic oxide* or acid anhydride dissolves in water, to form acidic solution or an acid.

Acidic oxide + Water → Acid

Examples:

$SO_3 + H_2O \rightarrow H_2SO_4$ $CO_2 + H_2O \rightarrow H_2CO_3$

Acidic oxides react with bases to form salts and water.

Acidic oxide + Base → Salt + Water

Examples:

$SO_3 + Ca(OH)_2 \rightarrow CaSO_4 + H_2O$

$CO_2 + 2NaOH \rightarrow Na_2CO_3 + H_2O$

Acidic oxides react with basic or metallic oxides to form salt.

Acidic oxide + Basic oxide → Salt

Examples:

$CO_2 + Na_2O \rightarrow Na_2CO_3$ $SO_3 + CaO \rightarrow CaSO_4$

Properties of Basic Oxides

Activity 3.7

Form groups and discuss the following activity. After the group discussion, choose a group representative to present the group's opinion to the class. Predict the nature of the oxides formed by somemetals such as sodium, potassium and calcium.

A basic oxide or basic anhydride reacts with water to produce a base or alkali.

Basic oxide + Water → Base (alkali)

Examples:

$CaO + H_2O \rightarrow Ca(OH)_2$ $K_2O + H_2O \rightarrow 2KOH$

Basic oxides react with acidic oxides to form salts.

Basic oxide + acidic oxide → salt

Examples:

$CaO + CO_2 \rightarrow CaCO_3$ $Na_2O + SO_3 \rightarrow Na_2SO_4$

Basic oxides react with acids to form a salt and water.

Basic oxide + Acid → salt + water

Examples:

$CaO + 2HCl \rightarrow CaCl_2 + H_2O$ $Na_2O + H_2SO_4 \rightarrow Na_2SO_4 + H_2O$

Exercise 3.9

1. What are the missing products 'X', 'Y' and 'Z' in the following equations?
   a. $CO_2 + H_2O \rightarrow X$
   b. $CaO + H_2O \rightarrow Y$
   c. $CaO + CO_2 \rightarrow Z$

Laboratory Preparation of Sulphur dioxide and Magnesium Oxide

Sulphur dioxide and magnesium oxide can be prepared in the laboratory by using direct synthesis method.

Direct synthesis involves the combination of oxygen with active metals and non-metals.

Non-metal + Oxygen → Non-metallic oxide

Example: $S + O_2 \rightarrow SO_2$

Metal + Oxygen → Metallic oxide

Example: $2Mg + O_2 \rightarrow 2MgO$

Experiment 3.1

Title: Preparation of Sulphur Dioxide

Objective: To prepare sulphur dioxide and test whether it is an acidic oxide or a basic oxide.

Materials required: Sulphur, litmus paper (blue and red), gas jar, Bunsen burner, deflagrating spoon.

Procedure:

1. Place a small amount of powdered sulphur in a deflagrating spoon and heat it as shown in Figure 3.3.
2. When it starts burning, put it into a gas jar.
3. When the burning stops, add 5 mL of water to the gas jar and shake it.
4. Put blue and red litmus paper, one after the other, in the jar.
5. Record your observations

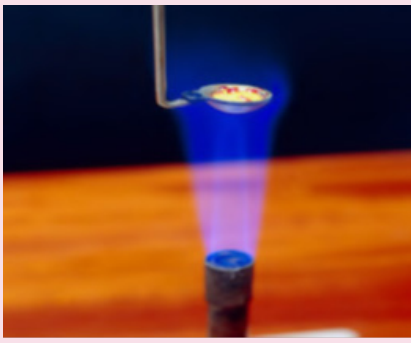


Figure 3.3 Burning of sulphur in air

Observation and Analysis:

a. What is the color of the flame when sulphur burns in air?
b. What happens to the color of blue and red litmus papers in step 4?
c. Write the chemical equation for this combustion reaction.
d. Classify the oxide formed by the combustion of sulphur as acidic or basic.

Experiment 3.2

Title: Preparation of Magnesium Oxide

Objective: To prepare magnesium oxide and test whether it is an acidic oxide or a basic oxide.

***Materials required*:** Magnesium ribbon, red and blue litmus papers, Bunsen burner, tongs, crucible, sand paper, and goggle.

Procedure:

1. Cut about 2-4 cm of magnesium ribbon.
2. Clean the surface of it properly with sand paper.
3. Hold the magnesium ribbon with the help of a pair of tong and burn it over a flame from the Bunsen burner as shown in ***Figure 3.4.*** The moment it starts burning, put the burning metal into a crucible and collect the product.

Figure 3.4 Burning of magnesium in air

4. Add a small amount of water to the resulting powder in the crucible and shake it.
5. Take red and blue litmus paper and bring them turn by turn in contact with the solution.
6. Record your observations.

Observation and Analysis:

a. Why you were cleaned the magnesium ribbon with sand paper?
b. What is the color of the flame produced when magnesium burns in air?
c. Write the chemical equation for the reaction.
d. What happens to the color of the red and blue litmus papers?
e. Is the resulting solution basic or acidic?

Exercise 3.10

1. Describe how you could prepare each of the following oxides.

a. MgO b. SO_2

Acids and Bases

Acids

Activity 3.8

Form a group and perform the following activities.

Imagine a taste experiment using orange and lemon. After tasting, present your feeling to the class.

1. What do you feel during tasting lemon?
2. What do you feel during tasting orange?
3. Are they having the same taste?
4. Are they acidic in nature? Why?

Acids are a group of substances that release hydrogen ions (H^+) when they are in aqueous solution. Acids have sour taste.

Examples: lemon juice, vinegar, sour tella and milk are some acidic substances in our daily life. HCl, H_2 SO_4 and HNO3 are common laboratory acids. They are also called mineral acids.

Bases

A base is an oxide or hydroxide of a metal which neutralizes acid to form salt and water. Bases which are soluble in water are called alkalis. An alkali is a substance that releases hydroxide ion (OH^-) when dissolved in water. Bases have bitter taste.

Examples: NaOH, $Ca(OH)_2$

Naming and Writing Formula of Acids and Bases

Activity 3.9

Form groups and discuss the following activities. After the group discussion, choose a group representative to present the group's opinion to the rest of the class.

1. Write the formulas of hydrochloric acid, sulphuric acid and nitric acid.

2. Write the formulas of sodium hydroxide, calcium hydroxide, potassium hydroxide and ammonium hydroxide.

When naming an acid, you can consider the acid to consist of an anion combined with as many hydrogen ions are needed to make the molecule electrically neutral. Therefore, the chemical formulas of acids are in the general form $\boldsymbol{H_nX}$, where $\boldsymbol{X}$ is a monoatomic or polyatomic anion and n is a subscript indicating the number of hydrogen ions that are combined with the anion.

The rules that used to named an acid with the general formula H_nX.

1. When the name of the anion (X) ends in –ide, the acid name begins with the prefix hydro-. The stem of anion has the suffix –ic and is followed by the word acid.
2. When the anion name ends in –ite, the acid name is the stem of the anion with the suffix –ous, followed by the word acid.
3. When the anion name ends in –ate, the acid name is the stem of the anion with the suffix –ic followed by the word acid.

Table 3.2 Naming of common acids

Anion ending	Example	Acid name	Example
-ide	Chloride, Cl^-	Hydro-(stem)-ic acid	HCl (Hydrochloric acid)
-ite	Sulfite, SO_3^{2-}	(Stem)-ous acid	H_2SO_3 (Sulfurous acid)
-ate	Nitrate, NO_3^- Sulphate, SO_4^{2-}	(stem)-ic acid (stem)-ic acid	HNO_3 (Nitric acid) H_2SO_4 (Sulphuric acid)

Bases are named in the same way as other ionic compounds: the name of the cation is followed by the name of the anion i.e. ***hydroxide.***

Examples:

NaOH (sodium hydroxide), Ca(OH)2 (calcium hydroxide), NH4OH (ammonium hydroxide)

Exercise 3.11

Give the appropriate answers for the following questions.

1. Define the following terms and give some examples for each.
   a. Acid b. Base
2. Which ion is a characteristic of all acids in water solution?
3. Copy and complete the following table in your exercise book.

Name	Formula	Name	Formula
Hydrochloric acid		Calcium hydroxide	
	HNO_3		KOH
Sulfuric acid			NaOH

Acid – Base Indicators

Acid-base indicators are dyes extracted from plants that show the presence of an acid or a base by undergoing specific color changes when placed in a solution. Litmus, methyl orange and phenolphthalein are common indicators.

Properties of acids and bases

Properties of Acids

Acids generally have the following properties:

1. ***Acids have a sour taste***
2. ***Acids change the colour of indicators***

Experiment 3.3

Title: Effect of acids on acid-base indicators

Objective: To investigate the effect of dilute hydrochloric acid and sulphuric acid on the colors of litmus paper, phenolphthalein and methyl orange.

Materials required: Blue and red litmus papers, phenolphthalein, methyl orange, test tubes, test tube rack, dilute solutions of hydrochloric acid and sulphuric acid.

Procedure:

1. Label three clean test tubes.
2. Pour about 5 mL of dilute H_2SO_4 into three test tubes.
3. Hold the first test tube in inclined position and put blue and red litmus papers turn by turn into it and see if there is any colour change.
4. Add few drops of phenolphthalein in the second and few drops of methyl orange in the third and observe if there is colour change.
5. Repeat the above procedure using dilute HCl and HNO_3 solution.

Observation and analysis:

Record your findings in the following table.

Acid	Color of the indicator in the acid solution		
	Litmus	**Phenolphthalein**	**Methyl orange**
Dilute H_2SO_4			
Dilute HCl			
Diluted HNO_3			

Write a laboratory report in groups and submit it to your teacher.

3. Reaction of Acids with metals

Dilute acids react with active metals like zinc, magnesium, iron and aluminum to form salts and liberate hydrogen gas.

Active Metal + Dilute Acid →Salt + Hydrogen

Example

$Ca + 2HCl \rightarrow CaCl_2 + H_2$

$Mg + H_2SO_4 \rightarrow MgSO_4 + H_2$

Experiment 3.4

Title: Reaction of an acid with a metal
Objective: To investigate the reaction of zinc metal with hydrochloric acid.
Materials required: Test tube, narrow jet test tube, candle, cork, zinc metal, dilute HCl, lighter or match, steel wool, and stand and clamp.
Procedure:

1. Set up the apparatus as shown in **Figure 3.5.**
2. Pour about 5 mL of dilute HCl into a test tube.
3. Clean a piece of zinc with the steel wool until it is shiny.
4. Add zinc to the test tube containing dilute HCl, close the test tube with a cork, deep narrow jet tube through cork and record your observations.
5. Light a candle using lighter or match and bring near the lighted candle in to the mouth of the narrow jet tube.
6. Repeat the above procedure using dilute sulphuric acid solution.

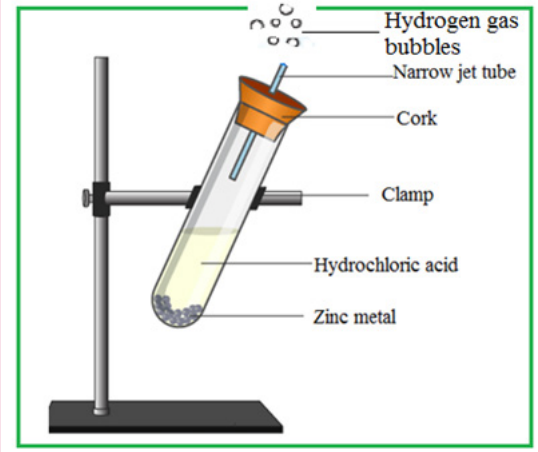


Figure 3.5 Reaction of Zn with HCl

Observation and analysis:

a. Why was the piece of zinc cleaned with steel wool?
b. What happens when you drop zinc metal into the test tube containing dilute HCl?
c. How do you know that a gas is produced in the reaction?

d. What is the colour of the gas?
e. What happens when the lighted candle is brought near the mouth of the narrow jet tube?
f. Write the chemical equation for the reaction between:
i. Zinc and hydrochloric acid.
ii. Zinc and sulphuric acid.

Write a laboratory report in groups and present to the rest of the class.

4. Reaction of Acids with Carbonates and Hydrogen Carbonates

Acids react with carbonates and hydrogen carbonates to form salts, water and carbon dioxide gas.

Acid + Carbonate → Salt + Water + Carbon dioxide

Example

$2HCl\ (aq) + CaCO_3\ (s) \rightarrow CaCl_2\ (aq) + H2O\ (l) + CO_2\ (g)$

Example

Acid + Hydrogen carbonate →Salt + Water + Carbon dioxide

$H_2SO_4\ (aq) + Ca(HCO_3)_2\ (aq) \rightarrow CaSO_4\ (aq) + 2H_2O\ (l) + 2CO_2\ (g)$

Experiment 3.5

Title:Reactions of acids with carbonates and hydrogen carbonates

Objective: To investigate the reactions of carbonates and hydrogen carbonates with dilute hydrochloric acid and sulphuric acid.

Materials required: Dilute hydrochloric acid, dilute sulphuric acid, calcium carbonate, sodium hydrogen carbonate, test tubes, test tube rack, lime water (calcium hydroxide solution), spatula, and rubber stopper.

Procedure:

1. Using a spatula, add calcium carbonate powder or a lump of calcium carbonate into the first test tube and 5 mL of lime water into the second test tube.
2. Add 5 mL of dilute hydrochloric acid into a test tube containing calcium carbonate cover its mouth with rubber stopper immediately and hold it in inclined position.
3. Bring the mouth of the test tube containing lime water with your other hand holding it in an inclined position closer to that of the test tube which you covered with rubber stopper.

4. Remove the stopper so that the gas produced can escape into the test tube containing lime water. Shake the test tube and see if there is any colour change.
5. Repeat the above procedure using sodium hydrogen carbonate and dilute sulphuric acid.

Observation and analysis:

a. Is there formation of bubbles in step 2?
b. If yes, what does the formation of bubbles indicate?
c. What happens to the lime water used in step 4? Why is that so?
d. Write the equation for the reaction:
   1. between hydrochloric acid and calcium carbonate.
   2. between sodium hydrogen carbonate and sulphuric acid.
   3. that occurs in step 4.

5.Acids neutralize bases.

Acids react with bases and basic oxides to form salts and water.

Acid + Base →Salt + Water.

Examples:

$2HCl + Ca(OH)_2 \rightarrow CaCl_2 + 2H_2O$

$H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$

The reaction of an acid with a base is called neutralization reaction.

Experiment 3.6

Title: Neutralizing effect of an acid on a base.

Objective: To investigate the neutralizing effect of sulphuric acid on sodium hydroxide.

Materials required: Dilute hydrochloric acid, sodium hydroxide solution, conical flask, phenolphthalein, burette, stand, clamp, measuring cylinder, blue and red litmus papers.

Procedure:

1. Set up the apparatus as shown in Figure 3.6
2. Fill the burette with dilute hydrochloric acid.
3. Measure 20 mL of sodium hydroxide solution, pour it into a conical flask and add about five drops of phenolphthalein.

4. Open the stop cock of the burette; add hydrochloric acid to the sodium hydroxide solution with your one hand, while shaking the conical flask with your other hand.
5. When the colour begins to disappear, add the acid drop by drop shaking the flask continuously.
6. When the colour disappears, completely, close the stop cock of the burette immediately and check the solution in the conical flask using blue and red litmus papers

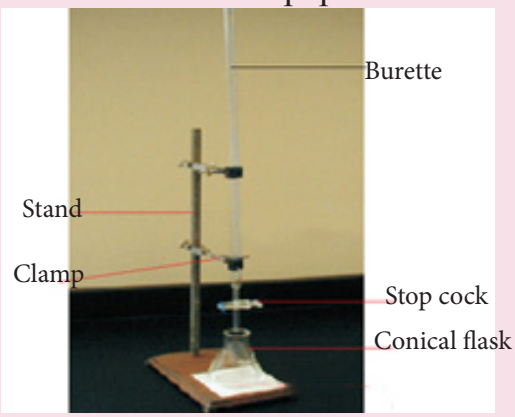


Figure 3.6 Neutralization reaction of hydrochloric acid with sodium hydroxide

Observation and analysis

a. What colour appeared when phenolphthalein is added to the solution in the conical flask in step 3.
b. Why does the colour disappear in step 6?
c. Does the solution obtained in step 6 affect the colour of either blue or red litmus paper?
d. Write the balanced chemical equation for the reaction that takes place in this experiment.

Write a laboratory report in groups and present your findings to the rest of the class.

Properties of Bases

1. Bases have bitter taste.
2. Effect on acid-base indicators

Alkalis change the colour of indicators.

Experiment 3.7

Title: The effect of a base on indicators

Objective: To study the effect of a base on indicators

Materials required: Red and blue litmus papers; phenolphthalein solution, methyl orange, diluted sodium hydroxide (NaOH) solution, test tubes, test tube holder and test tube rack.

Procedure:

1. Take four clean test tubes.
2. Add about 5 mL NaOH solution in each of the test tubes and label the test tubes as 1, 2, 3, and 4 as shown in Figure 3.7.
3. Put red litmus paper, blue litmus paper, 2 drops of phenolphthalein solution and 2 drops of methyl orange solution in test tubes 1, 2, 3 and 4, respectively.
4. Observe the colour change and record your observation.
5. Repeat the above procedure using ammonia solution.

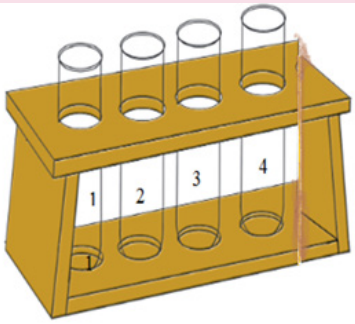


Figure 3.7 Testing the effect of a base on indicators

Observation and analysis:

a. Record your findings in the following table.

a. Record your findings in the following table.

Base	Color of the indicator in the base solution			
	Red litmus	Blue litmus	Phenolphthalein	Methyl orange
Dilute NaOH				
NH_4OH solution				

b. What do you conclude from this experiment?

Write a laboratory report in groups and present your findings to the rest of the class.

3. Bases neutralize acids.

Bases react with acids (acidic oxides) to form salt and water.

Base + Acid →Salt + Water

Example

$Ca(OH)_2 + H_2SO_4 \rightarrow CaSO_4 + 2H2O$

Experiment 3.8

Title: Neutralizing effect of a base on an acid

Objective: To investigate the neutralizing effect of sodium hydroxide on hydrochloric acid.

Materials required: Sodium hydroxide solution, hydrochloric acid, conical flask, phenolphthalein, burette, stand, clamp, measuring cylinder, blue and red litmus papers.

Procedure:

1. Set-up the apparatus as shown in Figure 3.8.
2. Fill the burette with sodium hydroxide.
3. Measure 20 mL of hydrochloric acid solution, pour into a conical flask and add five drops of phenolphthalein.
4. Open the stop cock of the burette; add sodium hydroxide to the acid solution with your one hand, and shaking the conical flask with the other hand.
5. When the colour begins to appear, add the base drop by drop and shaking the flask continuously.
6. When the colour becomes intense, close the stop cock of the burette immediately and check the solution in the conical flask using blue and red litmus papers.

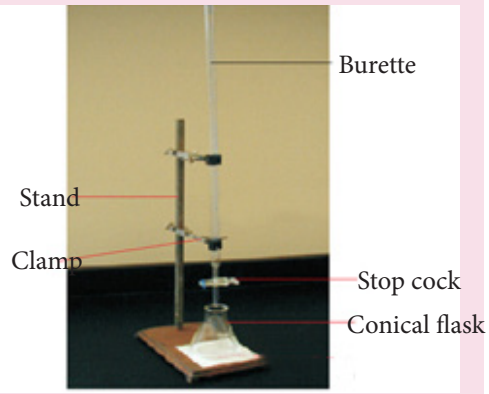


Figure 3.8 Neutralization reactions of hydrochloric acid and sodium hydroxide

Observation and analysis:

a. What colour appeared when phenolphthalein is added to the solution in the conical flask in step 3?
b. Why does the colour appear in step 6?
c. Does the solution obtained in step 6 affect the colour of blue or red litmus paper?
d. Write the balanced equation for the reaction that take place in this experiment.

Write a laboratory report in groups and present your findings to the rest of the class.

Project work

Preparation of natural indicator from beetroot

How do you prepare your own indicator using beetroot at home? Explain.

Hint:-

Materials you will need:

Beetroot 2-3, knife, water, spoon, boiler, lemon juice (citric acid)

Procedure:

1. Take some beetroots, wash them and peel them with the help of a knife.
2. Chop or cut the beetroot into pieces.
3. Put these pieces into a boiler and boil it 30-60 minutes.
4. Filter and collect only juice.
5. Add 5 to 6 drops of beetroot juice to lemon juice and mix it.

Observation and analysis

1. What colour is appear in step 5?
2. Why the colour of orange juice changed after the addition of beetroot juice?
3. Is your indicator effective?
4. What do you conclude from this project work?discuss the characteristics of a good indicator.

Write your report in groups and present your findings to the rest of the class.

Precautions while Working with Acids and Bases

Safety Precautions while Working with Acids

Acids can cause severe burns to exposed skin or severe eye injury or blindness if splashed in your eyes. If taken by mouth, they will cause severe internal irritation and damage. Especially hydrochloric acid, sulphuric acid and nitric acid are dangerous, poisonous and corrosive. Therefore, they must be handled with great care.

The following measures are immediately taken if a concentrated acid is spilled on your skin, enter your eyes or accidentally drink.

- If a concentrated acid is spilled or splashed on your skin, wash thoroughly the affected part with water, and then wash it with 10%

Na_2CO_3 solution.

- If an acid enters your eye, wash thoroughly with water for a long time and then seek medical treatment.
- If you accidentally drink corrosive acids, take a base such as $Mg(OH)_2$ which is available in the pharmacy to neutralize the acid.

Safety Precautions while Working with Bases

Just like acids, bases can cause severe burns to exposed skin or severe eye injury or blindness if enters in your eyes. For example, NaOH and KOH are corrosive and poisonous. Therefore, they must be handled with great care and you have to avoid contact with your skin and other parts of your body while working with bases.

The following measures are useful if a concentrated base is spilled on your skin or enters your eyes.

- If a base is spilled on your skin, wash the affected area with plenty of water and then treat the affected part with a weak acid such as dilute acetic acid to neutralize the base.
- If a base comes into contact with your eyes, wash the eyes with plenty of cold water and advice medical doctor.
- If you drink a base by accident, neutralize it by drinking 1 – 2% dilute solution of acetic acid or lemon juice and then seek medical treatment.
- If a base is spilled on your working table wipe the spillage immediately.
- Whenever bases are splashed on your cloth wash the affected part with running tap water.

Activity 3.10

In this activity you are expected to perform the following task in groups by reading different chemistry reference books. After the discussion, present the group's opinion to the class.

Write laboratory safety rules dealing with the handling of acids and alkalis.

Exercise 3.12

Give the appropriate answers for the following questions.

1. Define acid-base indicator.
2. Write the colour of each of the following indicators in acidic and basic solution.
   a. Litmus paper b. Methyl orange c. Phenolphthalein
3. Complete and balance the following reactions:
   a. $2HNO_3 + Na_2CO_3 \rightarrow$
   b. $2NaOH + H2SO_4 \rightarrow$
   c. $2HCl + Zn \rightarrow$
4. What measures should you take if:
   a. a base enters your eyes?
   b. you accidentally drink an acid?

3.4 Neutralization Reaction and Salts

After completing this section, you will be able to:

- identify some everyday uses of neutralization;
- define and give examples of salts;
- name and write formulas for some common salts using the periodic table, a list of ions, and rules for naming salts.

The reaction of acids with basic oxides or bases to form salt and water is called neutralization reaction.

Applications of Neutralization in Daily Life

Activity 3.11

Form a group and perform the following activity. After the discussion, present the group's opinion to the class.

1. What are the important uses of neutralization in daily life?
2. Why our hairs get rough after applying shampoo and again turn shiny after we add conditioner?

In our everyday life we come across many situations which involve neutralization reactions. The following examples will illustrate common neutralization reactions that occur around us.

Neutralization at Home

- Toothpaste contains bases that neutralize the acid produced by bacteria in our mouth.
- Baking powder is usually used to help the cake rise.
- Conditioner is used with shampoo to prevent small scales on hair which make your hair unmanageable.

Neutralization in Health

- Antiacids contains bases such as aluminum hydroxide ($Al(OH)_3$ and magnesium hydroxide (Mg(OH)2 to neutralize the excess acid in the stomach.
- Vinegar is acidic in nature which is used to cure wasp stings that are alkaline in nature.
- Baking powder is alkaline which is used to cure bee stings and ant bites that are acidic in nature.

Neutralization in Agriculture

- Acidic soil is treated with powdered lime, CaO, limestone, $CaCO_3$ or ashes of burnt wood.
- The acidic gas from the decomposition of compost neutralizes the alkalis in basic soil.

Project Work

Collect different soil samples from different locations and measure their PH values. Which soil sample is more acidic and how to prepare the soil to produce good yields of crops? Write your report in groups and present your findings to the rest of the class.

Salts

What are salts?

The term 'salt' does not refer only to the table salt which we use to make our food. Salts are group of chemicals that are obtained by the reactions of acids and bases. These reactions are called neutralization reactions.

Salt is defined as a compound consisting of the positive ion of a base and the negative ion of an acid. The positive ion in the salt can be that of a metal ion or ammonium ion. Sodium chloride (NaCl), calcium carbonate ($CaCO_3$), potassium nitrate (KNO_3), sodium bicarbonate ($NaHCO_3$), diammonium phosphate ($(NH_4)_2HPO_4$) are examples of salts.

Naming and Writing Formula of Salts

Activity 3.12

Form groups and discuss the following activity. After the group discussion, choose a group representative to present the group's opinion to the rest of class.Write names and formulas of some common salts.

The group names of salts are related to the names of the acids from which they are derived.

Table 3.5 Names of some acids and group names of their salts

Name of the acid	Group name of salt	Example of salt
Carbonic acid, H_2CO_3	Carbonates, CO_3^{2-}	Calcium carbonate, $CaCO_3$
Hydrochloric acid, HCl	Chlorides, Cl^-	Sodium chloride, NaCl
Sulphuric acid, H_2SO_4	Sulphates, SO_4^{2-}	Calcium sulphate, $CaSO_4$
Nitric acid, HNO_3	Nitrates, NO_3^-	Sodium nitrate, $NaNO_3$

The name of a salt is derived from the names of two parts. The first part comes from the base. The second part comes from the acid. You can always work out the name of the salt by looking at the reactants. As illustrative examples, see the following chemical equations:

Sodium hydroxide (base) + Hydrochloric acid (acid) → Sodium chloride (salt) + Water

The name of the salt sodium chloride is obtained by taking the word 'sodium' from the name of the base and 'chloride' from the name of the acid by dropping the word 'hydro' and changing the ending '-ic acid' to '-ide'.

Follow the following simple rules to write the formula of salts.

1. Break the name of the salt up into the name of the cation (positive ion) which is derived from base and the name of anion (negative ion) which is derived from acid.
2. Use the cation's name to determine the formula for the cation and anion's name determine the formula for anion.
3. Now criss cross the charges and put the numbers below the formulas.

Example:

a. Write the formula of Calcium carbonate.
   1. Name of cation is calcium and name of anion is carbonate.
   2. Formula or symbol of cation is Ca^{2+} and anion is CO_3^{2-}

   3. $Ca^{2+}\swarrow\!\!\!\nearrow Co_3^{2-} = Ca_2(CO_3)_2$, Simplify and write the simplest formula of the salt.Thus, the formula of calcium carbonate is $CaCO_3$

Exercise 3.13

Give the appropriate answers for the following questions.

1. What are the applications of neutralization in everyday life?
2. Write the formula of the following salts.
   A. Sodium chloride B. Potassium nitrate
   C. Calcium carbonate

Uses of Some Salts

Activity 3.13

In this activity you are expected to perform the following tasks in groups by reading different chemistry reference books.

1. Prepare a table as shown below and fill in with required information. Prepare five minutes presentation on the uses of the salts listed below.

Name of the salt	Formula of the salt	Uses
Sodium chloride		
Sodium bicarbonate		
Potassium nitrate		

Key Terms

- Acid
- Acidic oxide
- Alkali
- Alkane
- Alkene
- Alkyne
- Base
- Basic oxide
- Hydrocarbon
- Indicator
- Inorganic compound
- Metallic oxide
- Neutralization
- Non-metallic oxide
- Organic compound
- Oxide
- Salt