PROTOTYPE

NCDC
NATIONAL CURRICULUM DEVELOPMENT CENTRE

# CHEMISTRY
## TEACHER'S GUIDE
## SENIOR ONE

LOWER SECONDARY CURRICULUM

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This material has been developed as a prototype for implementation of the revised Lower Secondary Curriculum and as a support for other textbook development interests.

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# Preface

This Teacher's Guide has been designed to enable you the teacher interpret the revised curriculum and use the accompanying Learner Book effectively. The Teacher's Guide provides guidance on what is required before, during and after the teaching and learning experiences.

To ease the work of the teacher, all the activities and instructions in the Learner's Book have been incorporated in this guide, but with additional information and possible responses to the activities. The guide has been designed bearing in mind the major aim of the revised curriculum which is to build in the learners the key competences that are required in the 21st century, while promoting values and attitudes and effective learning and acquisition of skills to prepare the learners for higher education and eventually the world of work.

This book has been written in line with the Revised Lower Secondary School Curriculum. The book has incorporated knowledge, skills required to produce a learner who has the competences that are needed in the 21st century; promoting values and attitudes; effective learning and acquisition of skills in order to reduce unemployment among school graduates.

**Associate Professor Betty Ezati**
Chairperson, NCDC Governing Council

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NCDC is committed to uphold the ethics and values of publishing. In developing this material, several sources have been referred to which we might not fully acknowledge.

We welcome any suggestions for improvement to continue making our service delivery better. Please get to us through P. O. Box 7002 Kampala or email us through admin@ncdc.go.ug.

**Grace K. Baguma**
Director, National Curriculum Development Centre

# CHAPTER 1

# Chemistry and Society

| Key Words | *By the end of this chapter, the learner will have learnt to:* |
|---|---|
| • chemistry<br>• careers<br>• science<br>• technology<br>• society | *a) explain the discrete nature of Chemistry.*<br>*b) explain why Chemistry is studied and its relationship with other subjects.*<br>*c) explain the importance of Chemistry in everyday life and the careers linked to the study of chemistry.*<br>***d)** talk about the contribution of Chemistry to the economy of Ugandan.* |

**COMPETENCY: By the end of this topic, the learners will be able to assess the application of Chemistry in our everyday life and its contribution to our economy.**

### Introduction

***Explain what competency the learners are expected to acquire at the end of the topic, how this will be acquired and measured as the lesson starts.***

***Explain that, the learner is able to assess the application of Chemistry in our everyday life and its contribution to our economy. Chemistry is a laboratory science. Its subject materials and theories are based on experimental observation. However, its scope reaches out beyond the laboratory and into every aspect of our lives—to our understanding of the nature of our planet, the environment we live in, the resources available to us and the factors that affect our health.***

***Therefore, in this topic, you should be able to guide the learners to find out about the application of Chemistry in their everyday life and its contribution to our economy.***

## 1.1: What is the Nature of Chemistry?

***Guidance to the Teacher***

- ***Organise the learners in groups of 5 – 7 depending on the size of the class.***
- ***Ask the learners to discuss what they already know about Chemistry and common chemicals in pharmaceutics and cosmetics, plastics, food and beverages, soaps and detergents, water treatment, and indigenous chemistry in local environments.***
- ***Ask them to produce a mind-map to show their conclusions.***
- ***Let them present in a plenary***

You have previously learnt that science is a study of living and non-living things. All living and non-living things occupy space and are

known as matter. We now look at science as made of separate branches namely: Chemistry, Biology and Physics.

Each of the branches of science deals with matter in a different way. Physics deals with the relationship between energy and matter, Biology deals with living things. In the following activity, you will find out what Chemistry deals with.

- ***Let the learners now give their own explanations of the relationship between chemistry and society.***
- ***Then summarise their discussions to bring out how chemistry is important in everyday life.***

**Activity 1.1: Finding out about substances in everyday life that are related to Chemistry**

1 In groups of 5 – 6, discuss what common things in everyday life you think are made up of chemicals.
2 In your groups, produce a mind-map to show your conclusions.
3 Present your responses in a plenary.

- ***Organise the learners in groups of 5 – 7.***
- ***Then ass the learners to discuss the common things in everyday life that are made up of chemicals. Guide them to find out the things related to chemistry.***
- ***Let them understand that common chemicals in pharmaceutics and cosmetics, plastics, food and beverages, soaps and detergents, water treatment, and indigenous chemistry in your local environment are related to Chemistry.***

## Activity 1.2: Finding out products in everyday life made with knowledge of chemistry

- ***Organises the learners to work in groups of 5 – 7.***
- ***Guide the learners to look at the pictures critically and answer the following questions.***
- ***Let the learners write down their findings and share with the rest of the class in a plenary.***

**Fig 1.1: Showing some common products used in everyday life**

The pictures above show some common products used in everyday life. The products are obtained using the knowledge of Chemistry.

1. Give the uses of the products in the pictures above.
   - ***Accept responses the learners give regarding the uses of the products in the pictures as long as it relates to the everyday use of the product.***
2. Suggest other items produced using the knowledge of Chemistry?
   - ***Also accept any other product they mention whose use applies knowledge of Chemistry***
3. What careers require the study and knowledge of Chemistry?

- ***Accept all responses referring to careers related to Chemistry, e.g. doctor, pharmacist, agriculturalist, chemical engineer, etc.***

***The Meaning of Chemistry***

Chemistry deals with the study of materials. In the following activity we shall explore the meaning of Chemistry further.

**Activity 1.2: Finding out what changes take place to substances in everyday life**

- ***Tell the learners that in this activity they will find out what changes take place to substances in everyday life.***

1. Burn a piece of paper using a candle or a lighted match. What changes take place to the paper during the burning?
2. Now consider the following processes which take place in everyday life:
   i) The rusting of a kitchen knife.
   ii) The boiling of water.
   iii) The rotting of fruits.
3. Describe the changes that take place in each of the processes (i – iii) above.
   iv) What are the necessary conditions for each of the above changes to take place?
4. Name any other processes in which materials change from one form to another?

- ***Let the learner understand that the changes they have observed and many others show what the study of Chemistry is about.***
- ***Tell the learners that these changes you have observed and many others show what the study of Chemistry is about.***
- ***Ask some learners to explain what Chemistry is in their own words.***
- ***Then harmonise their definition for emphasis.***

***Hence Chemistry is the study of the matter and the changes that occur to substances under different conditions.***

## 1.2: Why Chemistry is studied and how it overlaps with other subjects

- ***Let the learners understand that in this section they find out why Chemistry is studied and how it relates to other subjects like biology, physics, agriculture, mathematics, earth and space etc.***
- ***Allow them to form groups of 5 – 7 and proceed to do activity 1.2.***

### Activity 1.3: Discussing reasons for studying Chemistry

- ***In this activity the learners discuss the reasons why Chemistry is studied and how it overlaps with other subjects.***
- ***Organise the learners in groups of 5 – 7 depending on the size of the class.***
- ***Ask the learners to find out which subjects are related to Chemistry. Accept answers which show some reasonable relationships.***
- ***Let the learners present their reports in a plenary.***

## 1.3: The importance of Chemistry and relationship of knowledge of Chemistry to relevant careers

- ***Now briefly explain the importance of Chemistry and the careers related to Chemistry (medicine, agriculture, environment, health, etc.)***

Everything is made of chemicals. Many of the changes we observe in the world around us are caused by chemical reactions. Chemistry is very important because it helps us to know the composition, structure and changes of matter. All the matters are made up of chemistry. In our everyday life various chemicals are being used in various forms; some of those are being used as food, and some of those used clanging etc.

**What are some examples of chemistry in daily life?**

You encounter chemistry every day, yet might have trouble recognising it, especially if you are asked as part of an assignment! What are some examples of chemistry in daily life?

**Activity 1.3: Finding out examples of Chemistry in everyday life.**

In groups, using the explanation of what Chemistry is, brainstorm examples of chemistry in daily life. Hint: consider areas such as human and animal medicine, pharmacy, chemical engineering, teaching, etc. and produce a table to present their ideas.

**Table 1.1: Examples of chemistry in everyday life**

| ***Example*** | ***Nature of action*** |
|---|---|
| ***Digestion*** | ***Digestion relies on chemical reactions between food and acids and enzymes to break down molecules into nutrients that the body can absorb and use.*** |
| | |
| | |
| | |
| | |

- ***Accept any relevant example mentioned by the learners, e.g. food industry, chemical industry, climate change etc.***

## Examples of Chemistry in the Real World

There are many examples of Chemistry in daily life, which show how prevalent and important it is.

1. *Digestion relies on chemical reactions between food and acids and enzymes to break down molecules into nutrients that the body can absorb and use.*

2. *Soaps and detergents act as emulsifiers to surround dirt and grime so it can be washed away from clothing, dishes, and our bodies.*
3. *Drugs work because of Chemistry. The chemical compounds may fit into the binding site for natural chemicals in our body (e.g., block pain receptors) or may attack chemicals found in pathogens but not human cells (e.g., antibiotics).*
4. *Cooking is a chemical change that alters food to make it more palatable, killing dangerous micro-organisms, and making it more digestible. The heat used for cooking may denature proteins; promote chemical reactions between ingredients, sugars, etc.*
5. *Ask the learners to summarise these given examples in their own notebooks.*

## 1.4: Contribution of Chemistry to the Economy of Uganda

**Activity 1.4: Research the contribution of Chemistry to economy**

1. In groups of 5 – 7, you research how chemistry contributes to the economy of Uganda.
2. Base your research in the fields of medicines, industries, transport and agriculture.
3. Write a short report, showing the areas in Chemistry which contribute to the economy of Uganda.
4. If possible, organise the learners in groups to have a field visit and carry out research to explore the common industrial products in our country and relate their uses to the importance of Chemistry. Groups write a report on their research and give a presentation in class.
5. Let the different groups present their discussions and report in a plenary.
6. Observe them as they carry out the discussions. Make a checklist of their participation and responses.
7. Then harmonise how Chemistry contributes to the economy of Uganda from their research and discussions.
8. Let the individual learners write reports of the visit to show knowledge of the importance of Chemistry to the Ugandan society.

Industry is very limited in Uganda. The most important sectors are the processing of **agricultural** products (such as coffee curing), the manufacture of light consumer goods and textiles, and the production of beverages, electricity and cement.

Chemistry plays a vital role in feeding the growing world population. There are a number of chemicals which help in increasing food production to keep pace with the growing world population. These chemicals have both negative and positive impacts.

**Activity of Integration**

As a young Chemistry student, organise a half-day workshop for people in your community to sensitise them on the application of Chemistry in everyday life and its economic contribution to the country.

**Fig. 1.2: Materials used on a house**

**Fig. 1.3: Common things we eat and drink**

**Task:**

1 Develop short messages which you will deliver to the people in this community about application of Chemistry in everyday life.

2 Develop some messages to illustrate the contribution of Chemistry to the economy of the society.

3 How would you ensure that members of the community appreciate the use of Chemistry in everyday life?

**Hint:** Use resources in **Fig. 1.2** and **1.3** to develop your message.

## Sample Assessment Grid

| Grades | Relevance | Coherence | Accuracy of the History tools | Originality of the product. |
|---|---|---|---|---|
| Task 1 | A learner will earn a mark if she/he makes an attempt to develop a short message which he/she will deliver to the people in this community about application of chemistry in everyday life. /1 | The learner will earn a mark If the message is coherent and logical. /1 | If the learner gives an accurate message to the community about the application of Chemistry in everyday life, he/she will get a mark /1 | An excellent learner who can add additional information (such as anecdotes, external information, drawings, schemas) on the tasks asked. /1 |
| Task 2 | If the learner can develop some messages to illustrate the contribution of Chemistry to the economy of the society /1 | If the learner attempts to show some explanations to support his/her facts. /1 | The learner gets a mark if the right arguments in the message accurately illustrate the contribution of Chemistry to the economy of the society /1 | |

| | | | | |
|---|---|---|---|---|
| Task 3 | Any attempts by a learner to explain how the community can appreciate the use of Chemistry in everyday life./1 | When there is fair knowledge expressed about how the community can appreciate the use of chemistry in everyday life, the learner will earn a mark./1 | The learner gets a mark if accurate explanation of how the community can appreciate the use of Chemistry in everyday life. /1 | |
| Total 10 | /3 | /3 | /3 | /1 |

## Summary

In this chapter, the learners have learnt that:

- Chemistry is a laboratory science: its subject materials and theories are based on experimental observation.
- common chemicals in pharmaceutics and cosmetics, plastics, food and beverages, soaps and detergents, water treatment, and indigenous chemistry in your local environments are related to Chemistry.
- Chemistry is the study of the matter and the changes that occur to substances under different conditions.
- the importance of Chemistry in everyday life and the careers linked to the study of Chemistry.
- Chemistry plays a vital role in feeding the growing world population, and contributes greatly to Uganda's economy.

### End-of-Chapter Questions

1. Why, is Chemistry called a laboratory science?
2. Physics deals with the relationship between energy and matter, Biology deals with living things. What does Chemistry deal with?
3. The following are changes that take place in everyday life:
   i) Rusting of a kitchen knife
   ii) Boiling of water
   Describe the changes that take place in each of the processes i) and ii) in 3 above.
4. Why is Chemistry important in our everyday life?
5. Identify the areas in Chemistry which contribute to the economy of Uganda.

# Chapter 2

# Experimental Chemistry

| Key Words | *By the end of this chapter, the learner will have learnt to:* |
|---|---|
| ◆ laboratory<br>◆ apparatus<br>◆ experiment<br>◆ purity<br>◆ scientific method | *a) explain the importance of the laboratory rules and regulations in ensuring safety in the laboratory.*<br>*b) demonstrate appropriate choice and use of laboratory equipment/apparatus for different experiments.*<br>*c) explain the scientific procedure/method of carrying out investigations and its importance.*<br>*d) describe how mixture can be purified, given the composition of its components.*<br>*e) apply the knowledge of melting point and boiling point in identifying purity of a substance compressing.* |

## Introducing Chemistry

- *Briefly remind the learners about what Chemistry is through questions and then explain how sciences are generally studied.*
- *Let the learners know that because Chemistry is one of the sciences, it has to be learnt in the same way like the others.*
- *Explain to the learners that the method of learning is through investigation and we refer to it as the science process skill (scientific method).*

In the preceding chapter you learnt about what Chemistry is, its importance to you as an individual and the world in which you live. The study of Chemistry involves the process of finding facts or investigating evidence of facts about the knowledge of Chemistry. This is done through systematic steps of collecting information or facts in order to find out the truth about a given or required knowledge in Chemistry.

This systematic step used in collecting information or facts is known as the scientific method. Scientific method requires the use of appropriate tools to gather or collect particular information. These tools are collectively known as apparatus. There are several different forms of apparatus depending on the kind of information required and the degree of accuracy needed.

In this section you will explore the importance of the scientific method and use of some of the apparatus. You will also learn how to apply the scientific method and make suitable choice of apparatus for different experiments.

For the sake simplicity at this level, the examples of experiments have mainly been limited to methods of separation of mixtures and testing purity, but you will study the topic on mixtures and pure substances in greater detail later in chapter 6.

## 2.1: Laboratory Rules and Regulations and Scientific Methods

### Activity 2.1: Preparation of a fruit juice

In groups of five, prepare a glass of juice using a named fruit.

1. State the aim of the activity.
2. List the materials required for the activity.
3. Identify the steps followed in making the juice.
4. Describe the process involved in the making of the juice.
5. The safety measures required to prepare safe juice.

What you have just carried out is called the scientific method. It involves

i) observing a particular behaviour.
ii) making immediate conclusions about the behaviour.
iii) identifying a problem to be acted upon.
iv) making a hypothesis.
v) determining and controlling variables.
vi) planning method of the investigations.
vii) analysing and interpreting data.
viii) making conclusions.
ix) writing a report.

***Project work***
*Identify a suitable activity of interest where the scientific process will be applied or used.*

- *Ask the learners to make small manageable groups of 5 – 7.*
- *Let them follow the steps given in Activity 2.2 to carry out the experiment.*
- *Let them know after the activity that, they have just carried out a scientific method by following the steps given.*
- *Then ask the different groups to make a presentation in a plenary and the rest critique.*
- *Harmonise the lesson by giving a summary of the science process skills in Chemistry.*

## 2.2: Laboratory and Laboratory Rules/Regulations

Referring to **Activity 2.1** above, which place would be the most suitable for preparing the fruit juice and why?

- ***Accept any answer, such as a kitchen, laboratory or factory.***
- ***Then explain that laboratories are the special rooms required for carrying out experiments in the school.***

You will discover that different experiments require different special places for carrying them out. These places are called ***laboratories***. In many instances, a special room is required although some experiments may be done outside the room.

What special safety measures were required in the preparation of the juice?

- ***Accept any safety precautions that make sense, e.g. caution when using a knife for cutting the fruits, keeping the containers clean and covered, etc.***

### Activity 2.2: Reading passage about rules in the laboratory

In groups, learners a) examine a list of laboratory rules and produce a table or diagram showing the reasons for each rule. b) Observe a demonstration of how to deal with a fire outbreak and how a fire extinguisher is used, and produce a set of guidelines.

- ***Ask the learners to read the passage and discuss among themselves the correct responses.***
- ***Let them present their findings in a plenary.***

**Read the passage below:**

***Mukisa**, an S1 student was required to prepare a salt solution in the laboratory. He wrapped his sweater around his waist, picked on his books and run to the laboratory. On entering, he knocked a table with glassware, spilling a colourless liquid. His books fell down into the pool of the colourless liquid while the glass fell on the floor and broke. Mukisa tried to collect the broken pieces of glass. The pieces cut his fingers while the books were burnt by the liquid. In pain he rushed to wash his fingers using water and in the process the sweater around his waist pulled down a beaker of hot water from another table that poured on his leg. Mukisa was rushed to a clinic and never carried out his experiment.*

a) From the above passage, what errors were committed by Mukisa?

- ***Running to the laboratory, knocking a table with glassware, spilling a colourless liquid, collecting the broken pieces of glass with bear hands, washing his fingers using water without reporting to the teacher, wrapping the sweater around his waist.***

b) How could Mukisa have avoided the accident?

- ***Wearing the sweater properly,***
- ***Not running in the laboratory***
- ***By following the laboratory rules***

c) Using the above story, what rules should be enforced to ensure safety in the laboratory?

- ***Do not run in the laboratory***
- ***Do not wear loose attire in the laboratory***
- ***Always wear protective gloves***
- ***Report any accidents to the teacher or the laboratory assistant***

Further reading about safety in laboratory

## 2.3: Laboratory Apparatus

- ***Ask the learners which equipment they use when they are cooking, digging, cleaning the compound, repairing cars, etc.***
- ***Ask them to give a general term to the set of equipment used to do a particular activity. Expect answers like: tools, kitchenware, etc.***
- ***Then let them know that in this section they will learn about equipment used in the Chemistry laboratory.***

Every workplace has its own tools or equipment; for example, equipment used in the kitchen is called kitchenware. In the same way, hoes, machetes, rakes, slashers are known as garden tools. Equipment used in the laboratory for different experiments are called **apparatus.**

### Activity 2.3: Identification and use of common laboratory apparatus

Some apparatus used in the Chemistry laboratory are shown below. With the help of your teacher

i) observe those that are present in your laboratory.
ii) suggest the name and use of each piece of apparatus.

- ***You can take the learners to the Chemistry laboratory or collect the common pieces of equipment and take them to the classroom for the learners to interact with.***
- ***Allow the learners to observe and familiarise themselves with the apparatus.***
- ***Ask the learners what they use to measure mass, volume, temperature and time in their homes.***
- ***Then, show the various items of equipment to the learners and let them predict or guess the uses of the different items of equipment in Chemistry.***
- ***Harmonise their answers by giving the correct uses.***
- ***Then, let them carry out experiments on how to use the equipment for measuring volumes accurately and roughly; temperature and mass.***

**Fig. 2.1: Common laboratory apparatus**

### Activity 2.4: To compare the accuracy of different volume measuring apparatus

***What you need***

- graduated beaker ($250cm^3$)
- measuring cylinder (100 $cm^3$)
- burette
- water
- retort stand

- ***Ask the learners to form groups of 5 – 7.***
- ***Let them plan and carry out an investigation using measuring cylinders, separating funnel, a thermometer, Bunsen burner and balance to mix 5 g of sand and 200 cm³ water, separating them and recording detailed observations and measurements.***

***The learners should:***

*i)* ***plan by selecting techniques, apparatus and materials.***
*ii)* ***make predictions based on prior knowledge and propose a hypothesis.***
*iii)* ***record observations and measurements in a table.***
*iv)* ***interpret observations and report results.***
*v)* ***compare observations and results with other groups.***
*vi)* ***discuss and develop explanations.***

### What to do

1. Clamp the empty burette into a retort stand.
2. Measure 50 $cm^3$ of water using a measuring cylinder provided.
3. Transfer the water into an empty burette and note the volume.
4. Repeat the same procedure using a beaker and record the new volume reading on the burette.

### *Results and discussion*

1. Which of the volumes measured using the two instruments is closest to the volume on the burette scale?

   - ***The one in the measuring cylinder has the closest value as that measured by a burette.***

2. Which of the two pieces of apparatus is more accurate?

   - ***A burette is more accurate***

## 2.4: Scientific Procedure and Experiment

Chemistry is a practical subject. To get knowledge, chemists carry out experiments during which they make careful observations and measurements. In order to do this, they use a variety of measuring

instruments and containers which are collectively called **apparatus** or **pieces of apparatus.**

The success of an experiment is often dependent on the accuracy with which the measurements are taken. The measuring devices which are used in everyday life, like the locally made weighing balance in some butcheries and measuring jug, are not sufficiently accurate for the needs of a chemist.

**Volume**

The volume of a substance is the amount of space that it occupies. The units of volume are the cubic meter or decimetre ($dm^{-3}$) for large volumes, and the cubic centimetre ($cm^3$) for smaller volumes. For very large volumes the cubic metre ($m^3$) may also be used.

$1\ m^3 = 1000\ dm^3$ $\quad$ $1\ dm^3 = 1000\ cm^3$

The use of units in litre (l) and millilitre (ml) for volumes are sometimes not commonly used in many measurements of simple laboratory experiments, but their equivalent in cubic decimetre ($dm^{-3}$) and cubic centimetre ($cm^{-3}$) respectively may instead be more frequently used in laboratory practice.

All these units are useful and can appear in any scientific texts. They are also commonly used in everyday life. You therefore must endeavour to understand their inter-conversion or relationship.

$1\ dm^3 = 1000\ cm^3$

$1\ L = 1\ dm^3$ $\quad$ $1\ ml = 1\ cm^3$

The apparatus used in Uganda laboratories often show volume in l or ml. These values

**measuring cylinder**
**beaker**

**syringe** **conical flask**

**Fig. 2.2: Apparatus that shows approximate volume**

| | |
|---|---|
| must be converted into $dm^3$ and $cm^3$ as appropriate for use in calculations. Chemical apparatus for measuring volume can conveniently be divided into two groups. **Apparatus which shows approximate volume (Fig. 2.2) and apparatus which show accurate volumes (Fig. 2.3)** | |

volumetric flask

burette

Pipette

**Fig. 2.3: Apparatus that show accurate volume**

Apparatus like the beaker provides only a rough guide to the volume of the liquid it contains, but the accuracy is not sufficient to be used in calculations. Apparatus like the burette can be read to a high degree of accuracy. Table 1.1 shows the degree of accuracy to which some of the pieces of apparatus can be read. Readings from such pieces of apparatus can be used in calculations.

**Table 1.1: Accuracy of some Apparatus Used to Measure Volume**

| Apparatus | Degree of accuracy |
|---|---|
| | |
| burette | to the nearest 0.05 $cm^3$ |
| pipette | marked value $\pm$ 0.05 $cm^3$ |
| volumetric flask | marked value $\pm$0.01 $cm^3$ |

Care must be taken when measuring the level of a liquid in a tube.

**Fig. 2.5a: Meniscus of aqueous solution**

**Fig. 2.5b: Meniscus of mercury**

When the liquid is an aqueous solution, the volume is read from the bottom of the meniscus. If the liquid is mercury, the volume is read from the top of the meniscus. For coloured liquids which are opaque i.e. the bottom of the meniscus cannot be seen, the upper level is read.

The volume of the gas produced during a chemical reaction can be conveniently and accurately measured using a gas syringe.

An alternative but less accurate method is to collect the gas in an inverted burette filled with water (Fig. 2.4.). This method is limited to gases, which are effectively insoluble in water. For those gases which are soluble in water, mercury can be used in place of water.

**Assessment Exercise**

Using a 100 ml measuring cylinder, 100 ml beaker and a 50 ml burette, design a scientific method to carry out an experiment to find out which one of the three pieces of apparatus is:

a) most accurate in measuring volume.

b) least accurate in measuring volume.

- ***Ask the students to do the activity in groups of 5 – 7.***
- ***The design of the experiment should have the following headings: Title (Problem to be investigated), tentative solution, prediction, variables, investigation (data collection), reporting (data analysis) and conclusion.***

**Situation of Integration**

**Fig. 2.6: Support resources**

a) As a student who now understands what Chemistry is and how it is studied, prepare a brief message to deliver to the new students on why
   i) laboratory is important in the study of Chemistry.
   ii) you should not enter the laboratory and carry your own experiments without instruction from the teacher or laboratory worker.
   iii) it is important to consider safety precautions while in the laboratory and to discuss how you can ensure safety in the laboratory.

iv) it is important to understand the essential steps that you would follow to carry out an experiment in a Chemistry laboratory.

b) Make a list four different pieces of apparatus that can be used to measure volume of a liquid in the laboratory and discuss condition under which each of them would be most appropriate to choose for measurement of volume.

## Summary

In this chapter, learners have learnt

- that finding facts or investigating evidence of facts about the knowledge of Chemistry is done through systematic steps.
- that the different steps, data/information is collected in order to find out the truth about a given or required knowledge in Chemistry, and the systematic steps used in collecting information or facts is known as the scientific method.
- that the special places for conducting experiments is called laboratory.
- about laboratory regulations for the safety of yourself and others in the class.
- about equipment used in the laboratory for different experiments are called **apparatus.**
- that scientific procedures require one to make careful observations and measurements.

## End-of-Chapter Questions

1 Why, is Chemistry called a laboratory science?

- ***Because study of Chemistry follows the same science process skills like the other sciences.***

2 Physics deals with the relationship between energy and matter, Biology deals with living things. What does Chemistry deal with?

- ***Chemistry deals with what matter is made of and how it behaves when treated in certain ways.***

3 Using a 100 ml measuring cylinder, 100 ml beaker and a 50 ml burette, design a scientific method to carry out an experiment to find out which one of the three pieces of apparatus is

a) most accurate in measuring volume.

b) least accurate in measuring volume.

- ***The answers given, should have the following headings: Title (problem to be investigated), tentative solution, prediction, variables, investigation (data collection), reporting (data analysis), and conclusion.***

# CHAPTER 3

# States and Changes of States of Matter

| Key Words | *By the end of this chapter, the learners will have learnt to:* |
|---|---|
| ◆ matter<br>◆ states of matter<br>◆ particle theory<br>◆ diffusion<br>◆ kinetic theory | *a) explain what matter is.*<br>*b) recognize that different states of matter have different properties.*<br>*c) use the kinetic theory of matter to explain particle arrangement, inter-particle forces, movement of particles and the properties of solids, liquids and gases.*<br>*d) explain the changes in states of matter when heat is gained or lost.*<br>**e)** *appreciate the cooling effect of evaporation and how it contributes to maintaining constant body temperature.* |

**Competency:** The learner uses knowledge of the arrangement and motion of particles to explain the properties of solids, liquids and gases.

## Introduction

- ***Give a brief introduction on the topic.***
- ***Let the learners know that in this topic they will discuss the particulate nature of matter. They are going to distinguish between a physical and a chemical change. They will look at atoms as the building blocks of all matter and how atoms can combine to form different molecules. The atom is made up of sub-atomic particles, called protons, electrons and neutrons. The electrons are arranged in a specific way around the nucleus of an atom. They will also look at the meaning of atomic number, mass number and isotopes, and how all these relate to sub-atomic particles.***

Our natural surrounding is made up very many different objects that occur in different forms. You can detect or feel the presence of these objects around you when you see, hear, smell, touch and taste them. For example, when you are at the lake or river shores or the beach, you see many grains of sand, plants, water and anything else.

**Fig 3.1: Heaps of sand at the lake shores**

What do you think is the scientific term/name given to the grains of sand and anything else around you?

In this chapter you will find out about the scientific terms used to describe the general composition of objects or material around you, the forms in which they occur and the properties of each of these forms.

## 3.1: What is Matter?

- ***Guide the learners in a discussion on what matter is. They should be able to explain in their own words what matter is.***
- ***In groups of two to three, ask them to read the text about what matter is.***
- ***Let them summarise the information in their own words in their notebooks.***
- ***Then, let them present to each other what they understand.***
- ***Everything you see, hear, smell, touch, and taste is matter. Matter is anything that has mass and takes up space. Matter exists in many shapes, colours, textures and forms. Water, rocks, living things, and stars are all made of matter.***

By studying matter, we learn to understand how and why some things work. After that we can manage and control those things to make new things that improve our lives. The study of matter is important because it guides us in classifying substances.

To understand matter, you need to take a closer look at it. As you observe or examine matter more closely, more of its parts are revealed. Now that the term 'matter' has been introduced, we can use it to say there are three states of matter: solids, liquids and gases.

**Look at the picture. Make a table with three columns labelled 'solid', 'liquid' and 'gas'. Write all the solid things you can see in the picture in the column labelled 'solids'. Do the same with the other two columns named `liquids' and `gases. Get physical substances you have listed as solids or liquids from your class or outside class and observe them critically.**

**Fig.3.2: Group of assorted items**

- ***Ask the learners to do assignment 3.1 individually.***
- ***Let them make a table of all the things they see in the picture and classify them as solid, liquid and gas.***
- ***Accept answers where the classification is accurately done.***

## 3.2: What are the Properties of Different States of Matter?

- ***Lead a discussion on the properties of different states of matter.***
- ***Together with the learners, create anchor charts and observe properties of various objects.***
- ***You will be creating language which allows the learners to describe materials by their observable properties.***

To understand the properties of matter, you need to look at the composition or particle nature of matter. Describing the composition of matter is not easy since the actual composition can only be inferred rather than observed. Suppose you take a piece of charcoal and break it up into tiny pieces and then crash these tiny pieces into dust. It is still charcoal. Then take the charcoal dust and further divide it until it is no longer visible. These invisible dust particles is still charcoal.

As early as 400 B.C., the Greek philosopher Democritus thought that matter could be broken down until it can no longer be subdivided. He called these invisible particles **atoms** (from the Greek word meaning not divisible).

By observing how particles behave in water and smoke, scientists developed a model (**the particle theory of matter**) to identify the composition of matter.

### 3.2.1: The Particle Theory of Matter

- *Ask the learners to read about the points of the particle theory and give explanations of what they understand by the different points.*

1. All matter is made up of extremely tiny particles. There are spaces between the particles.
2. Each pure substance has its own kind of particles different from the particles of other pure substances.
3. Particles attract each other.
4. Particles are always moving.
5. Particles at a higher temperature move faster on average than particles at a lower temperature.

There are things we experience in our daily life situations which can also explain that solids, liquids and gases are made of small particle which we cannot see with our naked eyes. For example, when your clothes are drying or when sugar mixes (dissolves) in water, we cannot see what is happening. Scientists use the idea of **particles** to explain what is happening. The particles are so small that we cannot see them.

What do you think happens to the water particles when clothes dry and to the sugar particles when they dissolve in the water?

- The water particles on your clothes escape into the air.
- The sugar particles that the sugar crystals are made of move away from the sugar crystals into the water.

**Fig. 3.3: Dust rising on gravel road**

If rock breaks, it can form a fine powder which we call dust. When you travel on a dusty road, you may have noticed that very fine dust stays in the air for a long time and can easily get inside the car or bus. You can even see very fine dust with your naked eye. But each grain of dust is made up of even smaller particles which you cannot see. It takes millions of small particles to make the grain of dust which you can see.

### Think about Air

We cannot see air particles because they are very much smaller than grains of dust.

We know that they exist because we breathe in air particles. We also feel the wind when many air particles are moving and hitting us.

### 3.2.2: Investigating Properties of Solids, Liquids and Gas

**Fig. 3.4: Arrangement of particles in gas, liquid and solid**

The properties of substances depend on how the particles in these substances are arranged, and how they are held together. To investigate the properties of solids, liquids and gases including shape, pouring and compressing, it is important to study the arrangement, the forces between the particles and movement of the particles.

### Forces between Particles

When you swim, you have to use more force to break the water particles apart. The diagram on the left shows how particles are held together in solids, liquids and gases.

### Particles in solids

The particles in solids are very close to one another and are in fixed positions. The forces of attraction between particles are strong. The particles can vibrate but cannot move past each other. They are close together and touching each other.

### Particles in liquids

The particles in liquids vibrate but can also move past each other. They are close together and touching each other as in a solid. However, the forces of attraction between the particles are not as strong as in solids. The weak attraction between them cannot support particles in one position, so liquids take up the shape of the container.

### Particles in Gases

The particles in gases are very far apart from each other. They move quickly in all directions, so they spread out. If squeezed in a closed container, they move closer together.

- ***Allow the learners to read the text above on the properties of matter in pairs.***
- ***Ask the learners to draw a table to make a comparison of properties of matter.***
- ***Check on the summaries of the different groups and then wrap up the results.***

The next activity compares a liquid with a gas. It provides *evidence* for the idea that particles are close together in a liquid and far apart in a gas.

### Activity 3.1: Find out if gas or liquid can be compressed

Which is easiest to compress: a gas or a liquid?

#### What you need

- a syringe
- water

**Fig. 3.5: Compressing as or liquid**

#### What to do

1. Draw some air into a syringe.
2. Close the opening with your finger so that the air cannot get out.
3. Press down on the plunger (piston) as shown in the picture. Observe what happens.

- ***On pressing the piston, the air inside gets compressed.***

4 Do the same with a syringe containing water.
Observe what happens.

- ***On pressing the piston, the water is not easily compressed.***

By doing the above activities, you will have found out that it was easy to compress (squeeze) the syringe full of air, but impossible to compress the water.

This tells us that the water particles are already close together and cannot be pushed closer together. In the gas, the particles are far apart and can easily be pushed closer together.

### 3.2.3: What Evidence is there for Particles?

We cannot see particles because they are too small. However, scientists believe they exist. This is a **scientific theory**. Scientists think up theories to explain their observations. Then they look for **evidence** to confirm that their theory is correct. Evidence is something that you can see or hear or touch that can be explained by the theory.

The next activity provides some *evidence* for particles. You will make an observation that can be explained by the *theory of particles*.

### Activity3.2: Investigate evidence of particles using balloon filled with air

How can we explain what happens to a balloon full of air?

#### What you need

- a balloon
- string

#### What to do

1 Blow up a balloon.
2 Tie the string tightly around the neck of the balloon many times.
3 Look at the balloon every day to see if it has changed size.

## Results

Did you see that the balloon gets smaller and smaller? This is because the air is escaping.

How is it escaping? Can you think of an explanation why the balloon goes down?

Here is an explanation that uses the theory of particles. The balloon going down is evidence for the theory of particles. Look at the picture below. It shows the rubber skin of the balloon. The skin is made of rubber particles packed closely together. But there are places where the air particles can get out through holes between the rubber particles. The air particles inside the balloon are constantly moving around and hitting the skin of the balloon.

**Fig. 3.6: Balloon filled with air**

Solids and liquids are also made of particles. When we mix a cool drink powder (a solid) in water (a liquid), we notice that the powder seems to disappear into the water. The water takes the colour of the powder and tastes different.

- ***Ask the learners to read about this section and discuss the questions:***
- ***Did you see that the balloon gets smaller and smaller?***
- ***If so, why did it become smaller?***

- ***How is it escaping? Can you think of an explanation why the balloon goes down?***
- ***Allow 5 minutes of discussion and ask them to share their answers with the rest of the class.***

### Activity 3.3: Investigate evidence of particles using liquid

How do we know that solids and liquids are also made of particles and are in a state of motion?

#### What you need

- a crystal of potassium permanganate
- a drop of ink
- water
- two small containers (tops from jam jars are suitable)

#### What to do

1. Fill the containers with water.
2. Carefully place a crystal of potassium permanganate in the water on one side of one container.
3. At the same time a friend must carefully place a drop of ink in the water on one side of the other container.
4. Do not move the containers. Look at what happens to them during the rest of the lesson. Leave them overnight and observe again. What is the difference between them?

What happened to the crystal of potassium? permanganate? Did you see that the crystal of potassium permanganate changed the colour of the water? This can be explained by the idea of particles.

◆ ***Explain that:***
***Each particle that leaves the crystal moves in between the particles of water and spread.***

**Fig. 3.7: Showing difussion in liquids**

You cannot see each particle of water because the particles are very, very small. When particles of a substance spread from one region to another, the process is called **diffusion**. After some time, all the particles from the potassium permanganate crystal have spread evenly throughout the water to form a **solution**. This is why the crystal cannot be seen any more. It has **dissolved**.

Think of coloured liquid like ink. What would happen to the colour of water if a drop of the ink is put into the glass of water? The particles in the ink (which is a liquid) will also diffuse (spread) throughout the water until the colour becomes the same throughout the solution.

### Diffusion in Gases

If someone is cooking in the kitchen, it does not take long for the smell to travel around the house to other rooms. This is because of diffusion. Gas particles from car exhaust fumes, perfumes or flowers diffuse through the atmosphere. Our nose detects the small particles. This is how we smell things around us.

You do not have to mix the gases by waving your arms around—it mixes on its own.

You can easily show this with a gas that has a smell such as butane in a burner. One person should turn on the burner for a few seconds in the front of the classroom. Are you able to smell anything?

### Activity 3.4: Investigate particles in gases

How do we know that gases are also made of particles?

- ***You should carry out this demonstration activity:***
- ***Ask the learners to make their own observations and take notes as the experiment proceeds.***
- ***Ask the learners to give their observations about the particles in the two gas jars.***
- ***Let them attempt to explain what diffusion is in their own words before harmonizing their answers.***

#### What you need

- gas of bromine vapour
- two empty gas jars
- cover plate

#### What to do

1. Fill one of the gas jars with bromine gas and carefully cover it with cover plate.
2. Invert the gas jar and place it on top of jar full of bromine with its cover.
3. Carefully remove the cover plate and let the two open ends of the jars be in contact.
4. Do not move the jars. Look at what happens to the bromine gas.
5. What is the difference between two jars?

#### Results and Discussion

The difference between the two jars can be explained by the idea of particles. Each particle that leaves bromine vapour moves in between the particles of air in the jar on top. The bromine gas spreads (diffuses)

rapidly into the air to produce a uniform pale brown colour in both jars. You cannot see each particle because the particles are very, very small. But you see the brown colour spreading throughout the two jars.

Diffusion in gases is quick because the particles in a gas move quickly. Gas particles are further apart than liquid particles, and so other gases can diffuse between them easily. It happens even faster in hot gases.

**Fig. 3.8: Showing diffusion in gases**

**Exercise/Assessment**

**1** Using suitable examples, explain what the following terms mean:

a) Kinetic theory of matter

- ***The Kinetic theory of matter states that matter is composed of a large number of small particles—individual atoms or molecules—that are in constant motion.***
- ***It also assumes that particles are small and widely separated. They collide and exchange energy. The theory helps explain the flow or transfer of heat and the relationship between pressure, temperature and volume properties of gases.***

b) Brownian motion

- ***Brownian motion is the continuous random movement of small particles suspended in a fluid, which arise from collisions with the fluid molecules.***

c) Diffusion

- ***Diffusion is a result of the kinetic properties of particles of matter. The particles will mix until they are evenly distributed. Diffusion may also be thought of as the movement of particles down a concentration gradient.***

**2** a) Describe two ways in which properties of;

i) a liquid is similar to that of a solid

| Property | Solid | Liquid |
|---|---|---|
| Shape | Fixed shape | Shape same as part of container |
| Density | Very high density | Quite high density |
| Volume | Fixed volume | Fixed volume |
| Ease of flow | Doesn't flow | Flows easily |

ii) a gas is similar to that of a liquid

- ***Liquids and gases are similar in both shape and volume because they both have their shapes determined by their surroundings. Liquids and gases are different in the amount of space between particles. Particles in a liquid are close together, but still have a slight movement. Particles in a gas, are very free.***

b) Give reasons for each of the similarities you have stated in (a) above

- ***Liquids and gases flow easily because their particles can move or slide past one another. Liquids and solids are not easily compressible; meaning they have little space between the particles.***

c) Why is gas compressible while a liquid is incompressible, yet particles of the two states undergo Brownian motion in a similar pattern?

- ***In gas, the particles are further spaced and can move more freely than in liquids.***

## 3.3: The Kinetic Theory of Matter

Activities 2.3 (particles in liquids) and 2.4 (particle in gases) can be used to explain kinetic theory of matter.

These activities demonstrated that particles in liquid and gases are constantly moving freely and randomly in all directions, and colliding with each other. The particles in liquids and gases move freely because forces of attraction between particles in liquids are weak, while forces between particles in gases are negligible.

The particles in solid also do move but their movement differs from that in liquids and gases for they do not move freely: they vibrate about a certain average/mean position.

Therefore, the kinetic theory of matter states that all matter is made up of small particles that are in continuous state of motion.

## 3.4: Changes of State by Heat Gain or Heat Loss

Many of the uses of the different states of matter rely on their changing from one state matter to another. For example, purifying water relies on a change of state from liquid to gas and back to water as does the formation of rain. The burning of candle relies on the wax changing from a solid to a liquid and then to a gas.

Understanding that when things change from one state to another requires energy (heat) gain or loss is very important. Substances can move from one state to another when specific **physical conditions** change. For example, when the temperature of a substance goes up, the particles in the substance becomes more excited and active. If enough energy is placed in a substance, a change of state may occur as the matter moves to a more active state.

In this section, the particle model will help you to explain how substances change from one state to another. An example of this is the changing of ice (solid) to water (liquid) to water vapour (gas) during boiling.

Can you give examples of substances which are always in solid forms but you change them into liquid forms before use? How do you do it? What happens when you put drinking water in fridge? Why do you put other drinks in fridge?

What happens to particles of any warm liquid when put in fringe? Look at the diagram below and explain what happens to arrangement of particles, and forces holding the particles together when energy (heat) increases at every state. Do the same to explain when energy (heat) decreases at every state.

**Fig. 3.9: Showing changes of states**

This can be explained by the idea of the movement of particles due to increase or decrease of heat energy.

When matter is heated, the particles absorb heat energy and they move faster, thus an increase in the kinetic energy. When matter is cooled, the particles will release heat energy and move slower, thus a decrease in kinetic energy.

**Activity 3.5: Observe the changes of state when water is heated**

**What you need**

- source of heat
- ice cubes(100mL)
- Celsius thermometer
- stirring rod

- 250 ml beaker
- stopwatch or wall clock

**Safety Precautions**
To avoid burnings, do not touch the source of heat or beaker at any moment when you are performing this experiment.

**What to do**

1. Put 150 ml of water and 100 ml of ice into a beaker and place the beaker on the hot plate.
2. Put the thermometer into the ice/water mixture. Do not stir with the thermometer or allow it to rest on the bottom of the beaker.
3. Record the temperature of the ice/water mixture.
4. Put the ice/water on a source of heat and record the temperature every minute in the table below, including the physical state of the water.
5. Continue doing this until water begins to boil.

**NOTE:** Before making each temperature measurement, stir the ice/water mixture with the stirring rod.

Use your data to plot a graph of temperature ($^{O}C$) vs. time (sec).

**Data Table:**

| Time (min) | Temperature (°C) | Physical state |
|---|---|---|
| 0 | | |
| 1 | | |
| 2 | | |
| 3 | | |
| . | | |

- ***The learner should obtain a graph of the shape below.***
- ***Look at this graph. It shows how the temperature changes, as a block of ice is steadily heated. First the ice melts to water. Then the water gets warmer and warmer, and eventually turns to steam:***

- ***Let the learners know that a graph like this is called a heating curve.***
- ***Ask the learners to look at the step where the ice is melting to give their own explanation of this part of the graph.***
- ***Then harmonise their points by mentioning that once melting starts, the temperature stays at 0°C until all the ice has melted. When the water starts to boil, the temperature stays at about 100°C until all the water has turned to steam. So, the melting and boiling points are clear and sharp.***

## Energy Changes during Heating and Cooling

When you heated a beaker of ice, you noticed that the temperature stayed at °C until all the ice had melted. Only after this does the temperature rise. So, what happens to the heat energy that you put into the ice if it does not make the ice warmer? The answer is that energy is needed to pull apart the particles in the ice so that they are no longer in regular rows but are moving around. This energy is called the latent heat of melting of ice.

Try the opposite experiment. Put a beaker of water containing a thermometer in an icebox and look at the temperature as it cools. It will go down to zero and then it will stop going down any further as the water freezes. The temperature of the ice will not start falling again until all the water has frozen. This is because when the water particles stop moving around as ice is formed; their kinetic energy is given out as heat energy. This stops water from cooling further. In this case the latent heat is given out.

## 3.5: Cooling Effect of Evaporation

### Activity 3.5: Investigate effect of evaporation

**What you need**

- ether or acetone
- a spatula

**What to do**

1. With the help of spatula, get some ether or acetone.
2. Carefully put a drop of ether or acetone on the back of your hand.
3. Keep the drop on the back of your hand until it completely evaporates.
4. Pay attention to sensation or effect produced/felt on your skin as the drop evaporates.

**Results and Discussion**

1. What did you feel on your skin as the drop was evaporating?

   ◆ ***The skin felt very cold***

   - What conclusion can you draw about the effect of evaporation?

     ◆ ***Evaporation absorbs heat from the surrounding.***

   - Explain how this effect is an important aspect in the life of living organisms

     ◆ ***In evaporation, molecules with low kinetic energy take heat from the surrounding and get vapourised. When air is blown over***

***your body that has a lot of sweat, you feel relieved because of evaporation of sweat. These evaporating molecules take energy from your body and cool it down.***

**Activity of Integration**

Look at the poster in **Fig. 3.10**. The Ice Cream Company FILOFILO Ltd. has employed you as the marketing officer. Write a short feature article for a newspaper advertising ice cream for the company. In your advertisement, explain the ingredients of the ice cream, the state and why the state in which it is sold is important.

**Fig. 3.10: Types of frozen ice cream**

## Summary

**In this chapter, the learners should have learnt that:**

- anything around you or within you is called matter.
- matter is scientifically defined as anything that has mass and can occupy space.
- matter can occur space in three common states: solid, liquid and gas, but may also occur in another fourth state known as plasma.
- a given matter can change from one state to another, either by absorption of heat energy or release of heat energy. For example, change from solid to liquid (melting) takes place by absorption of heat energy while the reverse (freezing) takes place by releasing heat energy. In other words, evaporation takes place by absorption of heat energy while condensation takes place by release of heat energy.
- matter is made up of small particles that are constantly moving and arranged differently in each of the three states:
  - In solids, the particles are closely packed in a regular shape because they have strong forces of attraction between them. The movement of the particle in solid state involves vibration about a mean or average position. Therefore, resulting physical property of matter in solid include: cannot flow, has a definite shape and volume, cannot be compressed.
  - In liquid state, the particles are further apart than in solids and randomly arranged because they have weak forces of attraction between them. The particles move freely and randomly in any direction but within the bulk of the liquid. Therefore liquids can flow, have definite volume but no definite shape and can take the shape of the container in which they are put, they are incompressible.
  - In gas state, the particles are far apart from each other. They have negligible or no forces of attraction between them and are randomly arranged. The particles move freely and randomly in any

direction, colliding with each other and the wall of the container in which they are put. Therefore, gas can flow and spread to fill any available free space, have no definite volume and definite shape and can be compressible.

- the random movement of particles in liquids and solids is called Brownian motion.
- the spreading/movement of substance from the region of plenty (where they are in high concentration) to a region where they are fewer (are in low concentration) is called diffusion.

**End-of-Chapter Questions**

1. The particles in liquids and gases show random motion. What does that mean, and why does it occur?
2. Why does the purple colour spread when a crystal of potassium manganate (VII) is placed in water?
3. Bromine vapour is heavier than air. Even so, it spreads upwards according to the experiment above. Why?
4. **a)** What is diffusion?
   **b)** Use the idea of diffusion to explain how the smell of perfume travels.
5. Write down two properties of a solid, a liquid and a gas.
6. Which word means the opposite of:
   **a)** boiling?
   **b)** melting?
7. Which has a lower freezing point, oxygen or ethanol?
8. Which has a higher boiling point, oxygen or ethanol?
9. Look at the heating curve below.

**a)** About how long did it take for the ice to melt, once melting started?

**b)** How long did the boiling take to complete, once it started?

**c**) Try to think of a reason for the difference in a) and b).

**10** Use the idea of particles to explain why:

**a)** solids have a definite shape.

**b)** liquids fill the bottom of a container.

**c)** you cannot store gases in open containers.

**d)** you cannot squeeze a sealed plastic syringe that is completely full of water.

**e**) a balloon expands as you blow into it.

# CHAPTER 4

# Using Materials

| Key Words | *By the end of this chapter, the learner will have learnt:* |
|---|---|
| • materials<br>• natural<br>• artificial<br>• synthetic<br>• physical properties<br>• recycle<br>• molecular structure<br>• polymers<br>• pollution | *a) to classify materials used in everyday life into natural and synthetic groups, and how this affects their use.*<br>*b) about how the physical properties of polymers determine their uses in everyday life, such as in building, fabrics, fabricating utensils used in homes, etc.*<br>*c) about the molecular structures of materials and relate this to their use.*<br>*d) about how common materials can pollute the environment, and how certain materials can be recycled.*<br>*e) about how heating changes the structure and properties of some materials.* |

**Competency:** The learner will be able to explore how materials are used and relate these uses to their molecular structures.

### Introduction

From the earliest times, humans have depended on different materials to get and cook food, to clothe and shelter and a lot of other uses. The ways we use these different materials depend on the different properties of the materials. In this chapter you will learn more about some of the common substances you can find around your home and school. You will study the physical and chemical properties of these substances. You will learn how these properties make them suitable for what we use them for.

## 4.1: Classifying Materials

### Activity 4.1: Classify materials used in everyday life

- ***Ask the learners work in small groups of 5 – 7.***
- ***Ask them to study the materials in the picture and classify them according to their properties.***
- ***Each group should report their classification to the whole class in a plenary.***

Look at the materials in the picture and try to classify them according to their properties. Remember that when you classify materials you put them in groups. Each group has a common property. Here are some headings under which some of the materials can be grouped:

- hard, soft, flexible (easily bent), shatter easily
- solids, liquids, gases
- metals, non-metals
- elements, compounds
- glass, wood, metals, plastics, etc.

**Figure 4.1: Common materials in the house**

Compare your classifications with that of your classmate next to you. There are many ways of classifying materials. It is possible that your friend has a very different classification from yours.

In the picture, most materials are solids. One way of classifying the solid materials is to put them into groups in a table like this one. Try and complete the table.

**Table 4.1**

| Glass | Wood | Plastic | Ceramics (pottery) | Fibres | Metal |
|---|---|---|---|---|---|
| | Table | Plate | | Towel | |
| | | | | | |

The way we use materials depends very much on their properties. But why do materials have particular properties that make them useful? How are materials made? These are some of the questions you will try and find answers to in this chapter. First, try this simple activity.

### Activity 4.2: Find out what happens to materials when you hammer or heat them

**What you need**

- pieces of wood
- concrete
- glass
- paper
- plastic
- brick
- cloth
- pottery
- rubber
- metallic substance, etc.
- hammer (or a stone)
- Bunsen burner

**What to do**

1. Take each material and hammer or hit it. (Take care: If the material breaks easily, you should wrap it in a piece of cloth before you hit it so that you do not get any pieces in your eyes.)
2. Heat a small piece of each material with the burner.
3. Describe the results in a table.
4. This activity is best done outside.

◆ **Expected table of results are in Table 4.3**

| Material | After heating |
|---|---|
| Pieces of wood | Changed to ash |
| Concrete | No change |
| Glass | No change |
| Paper | Burned and white powder formed |
| Plastic | Burned |
| Brick | No change |
| cloth | Burned and white powder formed |
| pottery | No change |
| rubber | Burned and black solid formed |
| metal (iron) | Glowed red and black solid formed |

What happened to the materials when you hammered them? Did you notice that different materials behaved in different ways? Glass shatters while wood probably squashed into a number of long fibres. It is difficult to shatter the brick but you might have been able to chip off the ends and sides. The metal pieces are flattened.

What happens when the materials are heated? Some of them burn, some may break, and others may be resistant to heat.

All these differences are due to the differences in the structure of the different materials. In the previous section, you studied some of the different ways in which atoms are joined together into molecules and how molecules are arranged in solids. Let us now think more about the structures of some of these materials.

To help you, here is a table which contains a summary of the different kinds of bonds that atoms form when they join together.

| **Bond** | **Properties of materials with these bonds** |
|---|---|
| Ionic | Crystalline solids that are easily broken |
| Covalent | Gases, liquids or solids with a low melting point |
| Covalent giant structure | Very hard solids with high melting points (such as sand) |
| Metallic | Ductile, malleable solids that are good conductors of heat and electricity |

## 4.2: Physical Properties of Materials

### The structure of materials that shatter easily

**Concrete**

Concrete is one of the most useful materials that we make. Concrete is made out of sand, gravel and cement. If you look at a piece of concrete carefully with a magnifying glass or a microscope, you can see that it is made up of lots of long thin crystals which overlap each other. These

crystals come from the cement which is a mixture of two substances (calcium silicate and aluminium silicate). The two substances are made by heating together limestone with clay at a temperature of about 1,400°C in a gas-fired furnace.

The crystals in cement start forming when water is added to it. They are strongest if the concrete is allowed to dry out slowly so that the crystals grow longer and stronger. This is why it is a good idea to wet concrete with water for several days after it has been made. It is these crystals locking together that make concrete so strong and hard. But because concrete is made out of crystals, it is quite easily broken with a hammer because crystalline substances are easily broken.

Limestone and clay are very common all over the world, so cement and concrete are used everywhere.

**Fig. 4.2: Tororo Cement Works using limestone from the quarry behind**

**Glass**

Glasses are usually hard, brittle, transparent materials. Unlike cement, they are non-crystalline solids and the molecules in them are not arranged in any particular pattern. You will remember that a liquid has

a structure in which the molecules are close together but not arranged in any particular pattern.

This means that glass has a structure like a liquid but the molecules are too large to move around. So, glasses are really liquids that behave like solids!

The common kind of glass is made by heating limestone (calcium carbonate) with sodium carbonate and sand (silicon dioxide) in a furnace. The three compounds melt together and run out of the bottom of the furnace as a clear liquid. The liquid can be allowed to cool as a flat sheet of glass or it can be moulded into any shape before it cools and turns to solid.

Other substances, particularly metal oxides, can be added to make different kinds of glass. Some of these glasses are coloured.

**Fig. 4.3**

Although the glass you tested broke easily, certain types of glass like this bulletproof glass are very strong. Some presidents ride in cars with windows made of bulletproof glass.

**Ceramics**

The piece of pottery you tested in **Activity 3.1** was a ceramic. Ceramics are some of the earliest classes of materials made by humans. They are mainly objects shaped out of clay and then hardened by heat.

Ceramic objects are made from clay, which is common all over the world. Clay contains a mixture of compounds (mainly aluminium oxide and silicon dioxide). It has several important properties which have caused it to be used for making pottery objects.

- It can easily be moulded when wet. This is because the molecules in the clay attract water molecules by electrostatic attraction. These water molecules allow the clay molecules to slip easily around each other.
- When clay dries it goes hard.
- If the clay is then heated in a fire or oven, it goes permanently hard.
- When clay is fired, the molecules in the clay react with each other and a hard-giant structure is produced. The structure is similar to the structure of silicon dioxide (sand).

**Fig. 4.4: Homemade clay pots from Arua**

These are handmade pots from Arua. They are made out of soft clay and then fired.

- ***Ask the learners to read section 4.2 in pairs.***
- ***Then, let them present the summary of their findings to the whole class.***
- ***Harmonise their points of discussion by saying that ceramic objects are made from clay.***

## 4.3: Molecular Properties of Materials

**The Structure of materials that do not break easily**

### Plastics

Plastics are synthetic materials. Synthetic materials are that made by humans—they are not found in nature. Although the first plastic was made over 100 years ago, most of the plastics we use in our daily lives have been developed in the last 50 years. They have become very important to us, mainly because they are cheap to make and can easily be moulded into different shapes.

The properties of plastics vary from transparent to opaque, hard to soft, weak to very strong, heat resistant to easily melted. They do not conduct electricity and so many are used as electrical insulators. These properties are very different from the properties of concrete and ceramics and so it is not surprising that the molecular structure of plastics is also very different from the structure of ceramics.

Some atoms, particularly, carbon atoms, can join together in long chains. These long chain molecules are called **polymers**. 'Poly' means 'many' and polymers are compounds that are made of many small molecules joined together to form one long one. This is shown in the diagram below.

**Fig. 4.5: Formation of polythene**

This very common plastic, polythene, is made from small molecules of a gas called ethane.

The main element in most plastics is carbon. Atoms of carbon join together to form long chains, and these are joined to atoms of other elements, particularly hydrogen. There can be thousands of atoms in each molecule that are held together strongly by covalent bonds.

Polythene is a cheap flexible plastic and so it is useful for shopping bags and many other items. But it is not very strong. Other polymers such as nylon are much stronger but they are more expensive. Others such as the 'polycarbonate' that your plastic ruler is probably made of are stiffer but are easily broken.

The differences in these physical properties of plastics can be explained by the structure of the molecules that these polymers are made from. The diagrams below show how the polymer chains are held together in different plastics.

**Fig. 4.6: Polymer chain of polythene**

In polythene, the polymer chains are not held to each other very strongly. This means that polythene is not very strong. The molecules line up in different directions in the plastic.

Most plastics are made from crude oil, coal or natural gas. We have seen that polymers are made from small molecules joined together in a chain. The small molecules, which are usually gases, are first made from the oil. This process takes place at very high pressures and is helped by a substance called a catalyst. (A catalyst is a substance that helps a chemical reaction to take place more easily and faster, but is not itself used up during the reaction.) In many plastics there are

forces between the polymer chains that hold them together. These forces are usually electrostatic and are caused by nitrogen or oxygen atoms in the polymer molecule. In some plastics there are covalent bonds that form strong links between the polymer chains. The examples below show how important these forces between the polymer chains are.

**Fig. 4.6**

**Fig. 4.7: Polymer chain of nylon**

Nylon is used to make clothes, fishing line and ropes. It is very strong and flexible. The polymer molecules contain some nitrogen and oxygen atoms which attract each other by electrostatic forces that hold the chains together. These forces make the molecules of the polymer line up in the same direction. It is the arrangement of molecules in the same direction that makes nylon so strong. Because the forces between the molecules are electrostatic and not chemical bonds, the molecules can slide next to each other. This means that nylon can be stretched quite a lot without breaking.

**Figure 4.8: Polymer chain in melamine**

Melamine is the plastic surface of many desks and tables. In this plastic, there are strong covalent bonds between the polymers. This makes the polymer rigid; it is hard; it cannot be stretched, and it will not melt. When it is heated it burns without melting.

**Figure 4.9: Polymer chain in polyurethane**

Plastics like polyurethane have their polymer molecules very loosely joined together in a random way. This allows the plastics to be squashed or stretched without permanently changing their shape. They are like rubber. They are not at all strong. They can be made into foam like the mattress in the picture by adding chemicals to them which react to form a gas like carbon dioxide as the plastics set.

**Natural Polymers**

The plastics you have been studying so far are all synthetic. There are also many polymers that occur naturally. They are made by living things as they grow. One natural polymer is being made by you at the moment! Your hair and fingernails are made out of it. It is called keratin. You will learn more about this polymer when you study wool later in this chapter.

One very well-known natural polymer is cellulose. This is the polymer that wood is made of. It has a complicated structure made out of atoms of carbon, hydrogen and oxygen. There are covalent bonds and

strong electrostatic forces holding the polymer chains together. These chains all line up next to each other to form the 'grain' of the wood. Because of the bonds and forces holding the molecules together, wood has great strength. It is possible to bend it in the direction of the polymer chains, but it is almost impossible to stretch it or to break it by pulling it. This is why it is such a useful material.

**Figure 4.9: Structure of cellulose**

If wood is crushed, it forms long thin pieces of cellulose called cellulose fibres. These fibres can be made into paper. Do the next activity to find out more about the cellulose fibres in newspaper.

### Activity 4.3: Find out the direction of a fibre in a newspaper

#### What you need

- a sheet of newspaper
- a microscope or good magnifying glass

#### What to do

1. Tear the newspaper down the page.
2. Now try tearing the newspaper across the page.
3. Write down the differences you noticed and what conclusions you made about the direction of the fibres in the paper.
4. If you have a microscope, use it to look at the paper. Can you see the fibres? Are they lying in the direction you concluded in step 3?

5 Roll up a page of a newspaper and try pulling one end while your friend pulls the other. Can you break it?

**Figure 4.10: Newspaper under a microscope**

The way the paper is made causes the fibres to line up roughly in the same direction. Each fibre contains millions of cellulose molecules lined up in the direction of the fibre.

It is difficult to tear the paper across the fibres but much easier to tear it between the fibres. The fibres are very strong if they are pulled; it is very difficult to break them. As you will learn in the next section, there are many other natural polymers that we use to make fibres.

**Fibres**

Fibres, like plastics, are made from polymers. They are used to make thread that can be made into cloth. They can be classified into two main groups: natural fibres and synthetic fibres. Natural fibres can be classified further into three groups: those from animals and those from plants, and also those made out of minerals such as asbestos that are dug out of the ground in quarries. The mineral fibres are long thin crystals that can be spun into a thread. Some examples are shown in the table on the next page.

| Natural fibres | | | Synthetic fibres |
|---|---|---|---|
| From plants | From animals | From minerals | Nylon<br>Polyster<br>Terylene |
| Cotton<br>Sisal<br>Jute<br>Linen<br>Hemp | Silk<br>Wool<br>Mohair | Asbestos | |

An important use for fibres is in making cloth that is then made into clothing. Some clothes are warm while others are cool. Some clothes stretch easily, others do not. Some clothes dry quickly after you wash them; others take a long time to dry. Some clothes last a long time, others wear out quickly. Some feel comfortable to wear, others do not. Many of these differences are caused by differences in the polymer molecules that the fibre is made out of.

### Materials Used for Building Houses

In Uganda, there are many different kinds of houses. What the houses are made of in any area depends on a number of things, such as:

- the availability of building materials.
- the cost of the building materials.
- the space available for building.
- the weather conditions in the area.
- the size of the house.

In this section we are going to look at the different materials used for building some of the different kinds of houses in Uganda. You will investigate the advantages as well as disadvantages of the different materials, and find out why certain materials are used for particular purposes.

Exercise

1. Describe the shape and colour of a typical house in your area.
2. List the materials that the different parts of the house are made of.
3. List the advantages and disadvantages of the materials used.

## Materials Used for Building Walls

There are many different materials used for building house walls. Most houses have walls made of bricks, but the bricks may be made of concrete or mud or fired clay. How strong are these bricks? To answer this question, try the next activity.

### Activity 4.4: Find out the strength of a brick

#### What you need

- mud and/or clay (used for brick-making)
- cement
- sand
- water
- container for mixing cement or mud
- boxes for moulding the bricks (for example, long-life milk or juice cartons with a flat side cut-out)
- bucket
- piece of wood

## What you do

**Making the bricks**

Make several different bricks out of different materials. Here are some ideas for some of the bricks.

- Try these mixtures for your bricks:
  - Two parts of cement added to two parts of sand.
  - One part of cement added to three parts of sand.
  - Three parts of cement added to one part of sand.
  - Mud suitable for brick-making.
- Add water to each mixture until it is a firm paste.
- Mould each mixture into a box and label it carefully.
- Leave the bricks to dry for a week (not in the sun).

**Testing your bricks—compression**

- Test the compression strength of your bricks with a bucket on top of the brick as shown. Fill the bucket with water. What happens to the brick? Test all the bricks using the same piece of wood (why?).
- Write the results in a table. If your brick breaks in this test you will have to make another one for the next test!

**Testing your bricks—bending**

- Test the strength of each brick by hanging a bucket underneath it as shown. Make sure that the testing experiment is exactly the same for each brick.

Making your own bricks

Testing the compression strength of your bricks

***Testing the tensile strength of your bricks***

| | |
|---|---|
| ▪ Write down in the table how much water you put into the bucket before the brick broke. (Your brick may not break at all. Congratulations! You have made a good strong one.) | |

You have tested the bricks in two ways. The first way tests the compressive strength of bricks. You have applied a force to compress it. The second one tests the tensile strength of the brick. You have applied a force to pull or to bend the brick.

A material that is difficult to break by pulling is said to have good tensile strength. A material that is difficult to break by crushing is said to have good compressive strength.

What conclusions can you make about the strength of your bricks? When bricks are used, they are compressed by the bricks above them. The material the bricks are made of must have a good compressive strength but it does not need to have a high tensile strength. The materials should also be cheap. Cement is quite expensive but sand and mud are cheap. Bricks must also be able to stand up to the rain and the heat of the sun.

Which of your bricks do you think has the best value for money to build a house?

**Summary**

You should know:

- that we can classify solid materials into glass, wood, metal, plastics, ceramics and fibres. The way we use these materials depends on their properties.
- that cement is made by heating together limestone (calcium carbonate) with clay (mainly aluminium silicate) at a temperature of about 1,400 °C. Concrete is made out of sand, gravel and cement. When the concrete sets, long crystals form which lock together. These make concrete hard, but it can easily be broken with a hammer. Building materials such as concrete and bricks must have a good compressive strength, but do not need to have a high tensile strength.
- glass has the structure of a liquid but behaves like a solid because the molecules are too large to move around. We make glass by heating limestone (calcium carbonate) with sodium carbonate and sand (silicon dioxide) in a furnace.
- ceramics are made from clay that has been dried and then heated (fired). Firing the clay produces a hard, three-dimensional structure.
- plastics are formed from long chains of carbon atoms together with atoms of other elements. They are manufactured from crude oil, coal or natural gas. The properties of a plastic depend on the structure of the polymer molecules, and particularly the kind of forces holding molecules together. Cellulose is a natural polymer from which wood is made.
- both natural and synthetic fibres are made from polymers. Mineral fibres are made from minerals that form long thin crystals. The properties of fibres depend on the structure of the polymer from which they are made. For example, the polymer molecules in wool are like small springs. This means that wool stretches easily, whereas nylon polymer molecules are long and straight and so

they cannot stretch easily. Some fibre polymers, such as the polymer in wool, can attract water molecules, whereas the nylon polymer does not attract water molecules strongly.

**End-of-Chapter Questions**

1. Plastics, metals and ceramics are very important and useful materials. Select one of them and describe what life might be like if the material you have selected was no longer available.
2. Describe how you could improve your home to make it cooler in dry season and warmer in wet season. Give reasons for your suggestions.
3. Each of the following objects is made of a fibre. In each case describe the most useful properties you would want the fibre to have. Of the fibres you have studied, which would be the most suitable for each of these uses:
   a) A set of seat covers for a car?
   b) A sweater for cold weather?
   c) A baby's nappy?

# CHAPTER 5

# Temporary and Permanent Changes to Materials

| Key words | *By the end of this chapter, the learner will have learnt to:* |
|---|---|
| ◆ physical change<br>◆ chemical change<br>◆ temporary change<br>◆ permanent change | *a) explain the permanent changes undergone by many substances when they are heated or burnt.*<br>*b) distinguish between temporary (reversible) and permanent (irreversible) changes to matter under different conditions.* |

**Competency:** The learner will be able to recognise occurrence of temporary and permanent changes, and their importance in everyday life.

### Introduction

You must have come across many changes taking place around you. Some of these changes can be reversed while others cannot. In this section, you will find out how to identify or categorise the different kinds of changes and what happens to chemical substances when they change during reactions.

## 5.1: Temporary (Physical) and Permanent (Chemical) Changes

### Activity 5.1a: Demonstrate temporary (physical) change

In this activity you will investigate what happens to a piece of fat placed on a hot saucer.

- ***Let the learners form small groups and let the group leaders collect the materials.***
- ***Ask the learners to do activity in 10 minutes and then report in a plenary.***

### What you need

- a piece of fat
- ice cold water
- ice bath
- a hot saucer/frying pan
- metallic cup
- source of heat

**Fig. 5.1: Cube of fat on saucer**

### What to do

1. Place a piece of fat on a saucer/frying pan placed on a heating source
2. Observe for five minutes
3. Pour the molten fat into a metallic cup and place the cup in an ice bath
4. Observe for ten minutes

**Results:**

1) Name the condition to which fat is subjected

- ***The fat is subjected to heat***

2) How does this condition affect the fat?

- ***The heat makes the fat melt***

3) How is this change used in everyday life for the benefit of man?

- ***The helps in the making of cheese, ice cream, etc.***

### Activity 5.1b: To demonstrate permanent (chemical) change

- ***In this activity the learners will investigate what happens to a piece of wood when burnt in air.***
- ***Distribute the materials to different groups and let the learners do activity 5.1b and report results in a plenary***

**What you need**

- wood splints
- source of heat

**What you do**

1 Ignite a piece of dry wooden splint in a flame and allow it burn in air.

2 Collect the product of burning wood on a white tile

**Results**

1. How does the product of burning differ from the original material?
   - ***A white powder is formed.***
2. Suggest a process, if any by which the product of burning can be reversed to wooden splint.
   - ***The product cannot be reversed back to the original material.***
3. Explain what has happened to matter in the original wooden splint.
   - ***The matter in the original material changed into a new product.***
4. How can this change be utilised by man for his benefit?
   - ***The change can be utilized in making new things.***

## Changing Substances

- ***Lead a class discussion on changing substances from one state another.***
- ***Ask the learners what they understand by the term "change"***
- ***Give examples of changes which occur naturally in everyday life***
- ***What do we mean by a change? When something changes it goes from one kind of substance to a different one. When we boil water in a kettle, we change the water into water vapour. When we burn paper, it changes from paper to a black substance that we call carbon.***
- ***Emphasise that in the next activity, the learners will investigate how they can change substances by heating them.***
- ***Distribute the materials according to groups***

### Activity 5.2: What kinds of changes can be caused by heating substances?

#### What you need

- burner
- tin lid
- test tube
- a pair of tongs
- bits of wood
- a stone
- a piece of glass
- salt
- sugar
- candle wax
- bread
- steel (nail)
- lead
- copper
- zinc
- bits of plastics
- copper sulphate,
- copper carbonate
- sulphur and other substances your teacher may give you

**What to do**

1. Choose the most sensible way of heating a substance, either in a test tube or in a tin lid, and heat it.
2. Carefully observe any changes that happen.
3. Stop heating and note any changes that happen as the substance cools down.
4. Record the changes in a table.

**Fig. 5.2: Heating substances**

Can you think of ways to classify the changes that happen when you heat substances? You could have one group of substances that did not change at all and another group that caught fire. What other groups could you have? One way of classifying changes is to put them in two groups:

- Group 1 – substances which changed and then changed back to the original substance when they cooled down.
- Group 2 – substances which changed to something completely different.

We call the first group **temporary changes** and the second group **permanent changes**.

Make a list of the substances you heated that were changed temporarily and another list of the substances that changed permanently.

## Temporary changes in everyday life

Can you name a few examples where temporary changes take place in everyday life? You should be able to name examples which are often used in the house, especially in the kitchen.

We use a sieve to separate foods from the boiling water when food is prepared. In the building industry large sieves are used to separate different sized stones from each other for use in different kinds of concrete.

Temporary changes happen when tea leaves are separated from the tea we drink.

**Fig. 5.3: Using a sieve to separate stones**

When water evaporates from drying clothes and puddles, this is a temporary change because it will go into the air and eventually change back to water in clouds or in rain. When we wash clothes or water plants the changes are physical changes because the water does not change into something else.

But, what about eating food or sweating?

Are these physical or chemical changes?

- ***Eating is a chemical change and sweating is a physical change.***

Can they be changed back?

- ***They cannot be changed back to the original substance.***

## Permanent changes in everyday life

You will remember that when a change is permanent, new substances are formed that cannot be changed back into the original ones. This means that substances change **chemically** during permanent changes. These changes are called **chemical reactions**. New substances are formed during chemical reactions.

### Activity 5.3: What happens when magnesium burns?

This should be a demonstration. Ask the learners to make carefully observation during the activity
Ensure that you wear safety spectacles when doing this experiment

**What you need**

- a piece of magnesium ribbon
- a burner
- a pair of tongs

***You must wear safety spectacles!***

**What to do**

1. Clean a 3 cm length of magnesium ribbon. Look carefully at the ribbon.
2. Use the tongs to hold the end of the strip in the flame.
3. Burn the magnesium in air after igniting it in the flame.

***Warning: Don't look directly into the bright light of the burning magnesium!***

4. Look carefully at the substance formed when the magnesium burns. Write down your observations about how the magnesium has changed.

The bright metal changed into a white powder. Can you change it back into the metal? This change is permanent. It is a chemical change. The magnesium has changed into a new substance which is called magnesium oxide.

There are many examples of chemical reactions in everyday life.
A rusting truck is one such example.

A slow chemical change. This iron is slowly changing into iron oxide. The common name for iron oxide is rust.

There are many examples of chemical reactions in everyday life. A rusting truck is one such example.

**Figure 5.4: Rusting school truck**

Cooking food is also a chemical change. Eating food is a chemical change. (You cannot change your waste products back into food, can you?)

**Fig. 5.5: Food cooking in a pot**

**A slow chemical change**

This iron is slowly changing into iron oxide. The common name for iron oxide is **rust**.

**Fig. 5.6: Rusting iron nails**

In Life Science you will learn more about two important chemical reactions: **respiration** and **photosynthesis**. These are both reactions that take place in nature.

The chemical change that takes place when we burn a match, a candle or a fire is a chemical reaction. It gives out energy in the form of heat and light. Chemical reactions very often give out energy.

**Fig. 5.7: Wood burning**

Name a few more examples of chemical reactions which take place in nature, or which are used in industry and everyday life.

## 5.2: Differentiating between Temporary (Physical) and Permanent (Chemical) Changes

You have already found that substances can undergo different kinds of changes. The changes may be **temporary** or **permanent**.

- ***Ask the learners to name other changes which undergo permanent or temporary changes.***

Temporary changes, such as ice melting are usually **physical changes** in which no new substance is made. Physical changes are simple changes which can be reversed. Examples of physical changes are the changes of state, size, shape and temperature. Changes such as melting, boiling, dissolving, freezing and condensing are all physical changes. They can all easily be reversed.

Permanent changes, such as wood burning are usually **chemical changes** in which new substances are made. Chemical changes are not easily reversed and are often called **chemical reactions**.

**Chemical Changes**

Strike a match or light a paraffin lamp and observe carefully what happens.

Can you get the wood of the matchstick back from the ash? Can you get paraffin back from the smoke of the paraffin lamp?

You cannot get wood of the matchstick back from the ashes or paraffin from the smoke. New substances have been formed. It is not possible to reverse these changes. The changes are **permanent**.

Did you notice that energy was released? Heat and light energy were given off. This kind of change is known as **chemical change**. Chemical changes are permanent and involve a change in energy.

## Classifying Changes as Physical or Chemical

### Activity 5.4: Classify changes as physical or chemical

Below is part of a conversation among learners who were carrying out a practical activity. Read and follow the conversation. Use the questions and the responses bellow to identify changes that took place during the practical activity.

**Aita:** (*Recording the group's notes about a practical*): What happened?
**Akuma:** It went fizzy (foamy).
**Aita:** Did you see any new substances?
**Akuma:** No!

**Wadri:** What shall I write down that was formed?
**Musema:** A blue colour.

### Task 1

i) Identify the type of change the learners were following in this group practical. Give reason for your answer.
ii) Identify the changes which are temporary in the text.
iii) What one criterion is used to identify chemical change from the conversation?

### Task 2

Make a table showing the differences between physical and chemical changes deriving from the different activities you have done.

| Physical Changes | Chemical Changes |
|---|---|
| | |
| | |
| | |
| | |
| | |
| | |

- ***Accept any responses which describe characteristics of chemical and physical changes in table 5.1.***

**Activity of integration**

Most of the people in a certain village called Bileafe where much tobacco is grown, bought vehicles after tobacco sales. However, soon many of the vehicles either broke down or were parked at home since fuel became too expensive for the people to afford.

As a student of Chemistry, develop a message for the owners of the cars in this village, explaining why the vehicles should be kept well even if they are spoilt, where they should be kept, and what kind of change they will undergo if not properly kept.

You can use the resources in **Fig. 5.6** to help you develop the message.

**Fig. 5.6: Cars parked**

## Summary

In this chapter, you have learnt that:

- pure substances have fixed melting and boiling points.
- mixtures do not have single fixed melting and boiling points. They melt or boil over a range of temperatures.
- a physical change does not produce any new substance. A chemical change results in the formation of new substances. During chemical changes energy is often given off or taken in. Physical changes are usually easy to reverse but chemical changes are difficult to reverse.
- chemical reactions can be written in the form of an equation:

  reactants → products
- a chemical reaction which takes in energy is called an endothermic reaction; a chemical reaction that gives off energy is called an exothermic reaction.
- synthesis, decomposition, combustion and neutralisation are all kinds of chemical reactions.
- a synthesis reaction is one in which simple molecules join together to form a more complex one.

## End-of-Chapter Questions

1 Substances can undergo two kinds of change, physical and chemical. List four observations that will tell you that a substance has changed chemically.

2 Draw a table with two columns labelled physical change and chemical change. Write down each of the following changes in the correct column: water boiling; a car rusting; petrol burning; sugar dissolving in tea; food being digested; bleach cleaning a dirty cloth; beer fermenting; ice cream melting; wind blowing; milk turning sour; seawater evaporating.

3 **a)** Name the two products formed when a candle burns. Explain how you would find out that these two products have been formed.
**b)** Explain why these same two products are formed when petrol, paraffin and butane gas are burned.

4 Copy and complete the following sentence: Matter is something that takes up _____and has_____

5 Identify two substances that sublime.

6 Identify and list the physical and chemical changes that take place during the burning of a candle.

# CHAPTER 6

# Mixtures, Elements and Compounds

## Mixture

| Key Words | *By the end of this chapter, the leaner will have learnt to:* |
|---|---|
| ◆ pure substance<br>◆ element<br>◆ compound | *a) demonstrate the criteria for determining whether a substance is pure or not.*<br>*b) distinguish between elements, mixtures and compounds.*<br>*c) devise means of separating components of different mixture.*<br>d) *distinguish between miscible and immiscible liquids.* |

**Competency:** The learner will be able to recognise occurrence of temporary and permanent changes, and their importance in everyday life.

## Introduction

All the different forms matter or substances are chemical in nature. Chemicals can broadly be classified into elements, compounds and mixtures. In this chapter you will learn about each of these classes of matter and their properties.

## Determining Purity of a Substances

A pure substance is one that contains only one type of atoms or molecules. The physical properties of a pure substance include a well-defined melting point or boiling point.

In this section, you will learn about the chemical elements and how they are the building blocks from which all other substances are made. Over 150 years ago, a Russian chemist called Mendeleev thought of a way of classifying the elements. He called it the **Periodic Table of the Elements**. The Periodic Table below contains all the elements.

## Questions

- What is an element?
- Do you know the names of any of the common elements?
- Which of the elements do you know: iron or carbon or sulphur or oxygen?

## 6.1: Criteria for Determining Purity

### Activity 6.1: Investigate melting point of pure water and impure water

In this activity, you will find out the difference in melting point of pure and impure water.

### What you need

- 100 g of crushed ice made from distilled water
- 100 g of crushed ice made from tap water
- thermometer
- stop clock
- plastic cup

### What you do

**Task I**

1. Put 100 g of the crushed ice made from the distilled water in the plastic cup
2. Insert the thermometer into the ice in the plastic cup and immediately start the stop clock
3. Watch the ice as it melts while occasionally stirring with the thermometer until the ice completely melts. Stop the clock as soon as the ice completely melts. Note the time taken for the ice to melt.

**Task II**

4. Repeat procedure 1 to 3 above using the ice from tap water
5. Record your findings in the table 6.1 below.

### Results

**Table 6.2: Results showing melting and boiling points**

| | Melting point ($^0$C) | Time taken to melt (min) |
|---|---|---|
| Ice from distilled water | | |
| Ice from tap water | | |

### Discussion

Compare the values of melting points you have obtained with the true values given in the textbooks. From your comparisons:

a) Which of the two samples of water is pure and impure? Give reasons for your answer

- ***Accept answers which have sharp values of melting and boiling points for pure substance.***

b) What conclusion can you make about the freezing point of a pure a substance? Can this conclusion be enough to test the purity?

- ***Accept any conclusion related to fixed freezing point for a pure substance.***

c) What is the effect of impurity on the melting point of a substance?

- ***The effect of impurity on melting point is that it lowers it.***

### Activity 6.2: Investigate how to test for purity using boiling point of a liquid

How can we know that a given colourless liquid is water and it is pure?

### What you need

- three unknown liquids A, B and C (any of liquids may be pure water, pure ethanol or mixture of the two)
- six test tubes, rack, petri dish
- anhydrous copper(II) sulphate
- boiling water over flame
- thermometer
- anhydrous cobalt (II) chloride paper

**CAUTION**
**Use eye protection**
**Ethanol is flammable**
**Keep a safe distance when heating**

### What you do

1. Label your test tubes. Two of them as 'A', another two as 'B' and the last two as 'C', as shown below.
2. Put 3 $cm^3$ of liquid 'A' in each of boiling tubes labelled 'A'. Do the same for liquid 'B' in test tubes labelled 'B', and for liquid 'C' in test tubes labelled C.
3. Use one test tube labelled 'A' and dip the end of anhydrous cobalt (II) chloride paper into the liquid. Note any change in table 6.2.
4. Put a spatula end full of anhydrous copper (II) sulphate in a petri dish, add 3 drops of liquid 'A' and record your observation.
5. Repeat instructions 3 – 4 for one of the test tubes of liquid 'B' and one for liquid 'C'.
6. Put a thermometer in the remaining test tube of 'A'. Put the test tube in boiling water and note and record the constant temperature at which the liquid boils.
7. Repeat instruction 6 for the remaining test tube 'B'. Again note and record the boiling point for liquid 'B'.
8. Repeat instruction 6 for remaining test tube for 'C' and note and record the boiling point for liquid 'C'.

### Results

| LIQUID | A | B | C |
|---|---|---|---|
| Boiling point | | | |
| Observation on testing with cobalt(II) chloride paper | | | |
| Observation on testing with anhydrous copper (II) sulphate | | | |

### Discussion

1. Given that boiling point of water is 100 $^0$C and for ethanol is 21 $^0$C (at sea level), judging from your results above, which liquid was:
   a) pure water?
   b) pure ethanol?

c) mixture of ethanol and water?

2. On the basis of your findings, give reason for your answer in each case. Can anhydrous copper (II) sulphate and cobalt (II) chloride be used to test for purity? Explain using evidence from your experiment.

- ***The answers will depend on the results of the experiment.***
- ***Ensure that the learners first carry out the experiment before answering the questions.***

## 6.2: Elements, Compounds and Mixtures

### Activity 6.2: Think-pair-share

In this activity you will find out the substances which are elements, compounds and mixtures.

### What you need

- Diagrams of elements, compounds and mixtures

### What you do

1. Obtain a copy of the diagrams for elements, compounds and mixtures.
2. Work in pairs to identify which diagrams represent the elements, the compounds and the mixtures. You should to be able to explain your choices.
3. Compare your answers with that of another group. If you disagree, you have to discuss the example with each other and agree on the right answer.
4. Then write the correct answers as you have agreed.

### Elements and Compounds

Substances are classified in two groups: mixtures and pure substances. We can classify pure substances into two more groups. We call these two groups **elements** and **compounds**.

The group called compounds contains substances like water, sugar and salt. The group called elements contains substances like the metals: copper, iron and aluminium, and the gases: nitrogen, oxygen and hydrogen.

What is the difference between compounds and elements? Read on.

### Compounds

Most of the pure substances that we use every day are compounds. The examples are water, salt, sugar, white flour, polythene, nylon, polyester, aspirin, paracetamol, etc.

Compounds are pure substances but they can be broken down chemically into simpler substances. There is a simple way you can do this with water using electricity. This process is called **electrolysis**.

### Activity 6.3: Split water into simpler substances

**What you need**

- cells and cell holder
- thick household copper wires
- plastic bottle
- small test tubes
- water
- dilute sulphuric acid

**What you do**

1 Make an electrolysis cell from the bottom of a plastic bottle and two thick copper wires as shown below.

**Fig. 6.1**

2 Pour water into it and put two test tubes full of water upside down over the wires. Add a little dilute sulphuric acid to the water to make it a better conductor of electricity. Connect it to the three electrical cells.

**Fig. 6.2**

a. Watch what happens. Do you see any gases?

The equipment in this activity is called an **electrolysis cell**. It is made out of two pieces of thick household copper electrical wiring. These are called the **electrodes**. When the electrodes are connected to electricity, you can see bubbles of gas on them and some gas will be collected in the test tubes.

You will see more gas collected in the test tube above the **negative electrode** than above the **positive electrode**. The positive electrode is the one connected to the positive pole of the cell.
In this activity, water is broken down into two simpler substances. The substances are the gases: hydrogen and oxygen.

Hydrogen is the gas that is produced at the negative electrode. The volume of hydrogen that is made is bigger than the volume of oxygen.

The two gases made in this activity are both elements, and water is a compound. It is a compound of hydrogen and oxygen.

We can write an **equation** to show this reaction:

water → hydrogen + oxygen

The element sodium is a metal that is so soft that it can be cut with a knife. It is very reactive and is therefore kept under paraffin.

The element chlorine is a green poisonous gas. But when these two elements join together, the compound, sodium chloride is formed.

Sodium chloride is the chemical name for table salt. The compound, table salt, that we must eat if we are to stay alive, is made from two harmful or poisonous elements.

Very often, when two elements join to make a compound, the compound is very different from both of the elements.

**Elements**

An element is a substance that *cannot* be broken up into simpler substances. It cannot be broken up by a physical process because it is a pure substance. It cannot be broken up by a chemical reaction either.

Elements are the simplest substances. A few examples of elements are copper, gold, silver, iron, aluminium, oxygen, hydrogen, nitrogen, carbon and sulphur.

All compounds are made from elements. All substances are made from elements. There are 92 elements.

When you burned magnesium in oxygen, a compound called **magnesium oxide** is formed from two elements, magnesium and oxygen.

We can write an equation to show this:

$$\text{magnesium} + \text{oxygen} \rightarrow \text{magnesium oxide}$$

Magnesium is a metal and oxygen is a gas. Magnesium oxide is not like either of these. It is a white powder. The element oxygen is a gas and it is one of the gases in the air.

The next activity shows how two or more elements, sulphur and iron, can react together to form a compound.

### Activity 6.4: Forming compounds of sulphur and iron

Can the elements, sulphur and iron form a compound?

#### What you need

- 7 g iron filings
- 4 g powdered roll sulphur
- magnet
- test tube
- burner

#### What to do

1. Mix the iron filings and sulphur thoroughly.
2. Test the mixture with a magnet. Hold the magnet above the mixture. What do you observe? Which element is attracted by the magnet?
3. Put the mixture in a test tube and clamp it. Heat only a small part of the mixture. Stop the heating as soon as the mixture starts to glow. What happens to the mixture?

**Fig. 6.3**

4. Take the new solid out of the test tube. Look closely at it. What does it look like? Does the magnet have any effect on it?

5 Do you agree that a completely new substance was formed by the reaction? What are the main differences between the new substance and the mixture of iron filings and sulphur?

The compound formed by the reaction between iron and sulphur is called iron sulphide. The properties of iron sulphide are very different from those of the mixture, or of iron, or sulphur.

Make a list of the properties in a table like the one below.

| ***Substance*** | ***Appearance*** | ***Effect of magnet*** |
|---|---|---|
| Iron filings | | |
| Sulphur | | |
| Product (iron sulphide) | | |

In the mixture of iron and sulphur, the iron particles and sulphur particles could easily be separated when you used a magnet. In the compound, however, the iron atoms and the sulphur atoms are joined together by the chemical reaction to form the compound, iron sulphide. They cannot be easily separated.

This reaction can be written down like this:

**iron + sulphur ⟶ iron sulphide**

In the mixture, atoms of iron and atoms of sulphur were not joined together. When the reaction started, they joined together chemically to form molecules of the compound iron sulphide.

***Assignment***

Find out which elements combine to form the following compounds: water, carbon dioxide, candle wax, sugar, salt, polythene, starch (white flour), lime, sand.

## Classifying Elements

How can we classify the 92 elements? There are many ways. One simple way is to classify them into metals and non-metals. The table below shows some well-known elements in these two classes.

| Metals | Non-metals |
|---|---|
| aluminium | oxygen |
| iron | nitrogen |
| magnesium | carbon |
| copper | iodine |
| gold | chlorine |

### Non-metals

At the beginning of this chapter you looked at the differences between metals and non-metals. You have seen that most non-metals have the following properties:

- They are poor conductors of electricity.
- They are poor conductors of heat.
- They are not malleable.
- They cannot be pulled out into wires (are not ductile).
- They are not shiny.
- They have low densities.
- They do not make ringing sounds when dropped on a hard surface.

### Activity 6.5: Finding out if non-metal elements burn in air

#### What you need

- small samples of carbon
- phosphorus and sulphur
- combustion spoon
- burner
- jars with covers
- water
- blue litmus paper

#### What to do

1. Put a small sample of each non-metal in a combustion spoon.
2. Carefully heat it.
3. What do you observe? Look carefully at the colour of the flame. See whether any smoke is formed.
4. Lower the burning element into a jar with a bit of water in the bottom.
5. Allow the burning element to burn out just above the water.
6. Take out the combustion spoon and shake the jar to dissolve any gases in the water.

**Fig. 6.4**

The gases formed when sulphur and phosphorus burn are unpleasant. This part of the activity is best done by the teacher.

7 Test the water with blue litmus paper. Write your results in a table.

| Non-metal | Brief description of the reaction | Product | Test with blue litmus | Word equation |
|---|---|---|---|---|
| Sulphur | melts and burns with yellow flame | sulphur dioxide | red | Sulphur + oxygen sulphur dioxide |
| Carbon | bluish flame | Carbon dioxide | red | Carbon + oxygen carbon dioxide |
| Phosphorous | | Phosphorous pentoxide | white | Sulphur + oxygen sulphur pentoxide |
| | | | | |

**Table 6.5: Results of testing solutions of oxides of non-metals with litmus paper**

**Activity of Integration**

To gain an understanding of mixtures and the concept of separation of mixtures, prepare an article to help feeding mothers in your community to find the element of iron in iron-fortified breakfast cereal flakes. Through this article, the mothers should be able to see how the iron component of this mixture (cereal) retains its properties and can thus be separated by physical means.

**Fig. 6.7: Label on cereal flakes**

## Summary

In this chapter, you have learnt that:

- elements can be classified into metals and non-metals.
- metals differ physically from non-metals. Most metals are shiny, strong, dense, malleable and ductile, and also conduct electricity and heat. These properties of metals have made them very useful to us.
- most metals react with oxygen to form metal oxides. This process is called corrosion. The corrosion of iron and steel (an alloy of iron) is

called rusting. Water and oxygen cause iron and steel to rust. Iron and steel can be prevented from rusting by coating them with a number of substances. Tin, zinc, chromium, paint, grease and plastic are all used to coat iron to stop it from rusting.

- metals are mixed with other metals (and sometimes with non-metals) to make substances called alloys. Alloys have properties that the original metals do not have. These properties are often very useful to us.
- many metals react with water or acids. When this happens, hydrogen gas is formed. Some metals are more reactive than others. When metals react with water, they form the metal oxide as well as hydrogen.
- non-metal elements also react with oxygen to form oxides. Non-metal elements will react with the more reactive metals.

## End-of-Chapter Questions

**1** Here is a list of mixtures:
a) maize meal and *salt*
b) dirty *water*
c) *iron* and copper filings
d) *currants* and rice.
Describe, in each case, a process you could use to get the substance in italics in a pure form out of the mixture.

**2** If you mixed two substances together and then heated them, describe two observations that you could make if you wanted to know whether a chemical reaction had taken place.

**3** Here is part of the label on a packet of potato chips.

| **Nutritional information** | **Per 100 g** |
|---|---|
| Calcium | 100 mg |
| Magnesium | 125 mg |
| Iron | 27 mg |
| Phosphorus | 420 mg |

Use **Fig. 6.1** to answer these questions:
a) Write down the chemical symbols for calcium, magnesium, iron and phosphorus.

b) These substances are all elements, but one is different from the other three. State which one is different and describe what it is that makes it different.

**4** Look at the chemicals listed below and answer the questions about them. You can use **Fig. 6.1** to help you.

| | |
|---|---|
| iron | water |
| sand | oxygen |
| gold | carbon dioxide |
| helium | carbon |
| rust | seawater |

a) Name the two metals.
b) Name a gas that is not an element.
c) Name two compounds.
d) Name a mixture.
e) Name a non-metallic element that is a solid.

**5** Here is a crossword puzzle to help you remember the names and symbols of some common elements.

i) Write the names of the elements that have the following symbols:

**Across**

1. H 3. Au 6. Na 11. Fe 12. Zn 15. Cu 17. Pb 24. I 25. Ca 26. K

**Down**

2. O 4. Li 5. Ag 8. C 10. N 14. U 16. Pt 19. He 20. S 23. Sn

ii) Write down the symbols of the following elements:

**Across**

9. chlorine 18. a metal that is a liquid 22. neon 30. magnesium 31. bromine

**Down**

7. manganese 13. cobalt 21. a metal used in coins 27. argon 28. silicon 29. a metal that burns brightly in air

**6** What does this term mean? Give an example.

a) filtrate

b) residue

**7** You have a solution of sugar in water. You want to obtain the sugar from it.

a) Explain why filtering will not work.

b) Which method will you use instead?

**8** Describe how you would crystallise potassium nitrate from its aqueous solution.

**9** How would you separate salt and sugar? Mention any special safety precaution you would take.

**10** Now see if you can think of a way to get clean sand from a mixture of sand and little bits of iron wire.

**11** Seawater can be purified using this apparatus:

a) i) What is the maximum temperature recorded on the thermometer, during the distillation?
   ii) How does this compare to the boiling point of the seawater?

b) In which piece of apparatus does evaporation take place? Give its name.

c) i) Which is the condenser: A or B or C?
   ii) Where does the supply of cold water enter?

d) Distillation is used rather than filtration to purify seawater for drinking. Why?

**12** Argon, oxygen, and nitrogen are obtained from air by fractional distillation. Liquid air at -250 °C is warmed up, and the gases are collected one by one.

a) Is liquid air a mixture, or is it a pure substance?

b) Explain why fractional distillation is used rather than simple distillation.

c) During the distillation, nitrogen gas is obtained first, then argon and oxygen. What can you say about the boiling points of these three gases?

# CHAPTER 7

# Air

| Key Words | *By the end of this chapter, the learner will have learnt to:* |
|---|---|
| ◆ air<br>◆ rusting<br>◆ burning<br>◆ oxides<br>◆ pollution | *a) explain that air is mixture of gases that can be separated.*<br>*b) explain the effect of air pollution on atmosphere.*<br>c) *demonstrate and explain that processes such as burning and rusting use oxygen from air to form oxides* |

**Competency:** The learner appreciates air is a mixture of gases in which oxygen is the active constituent, and he/she can describe processes that may affect air quality.

## Introduction

Air is the space above the earth's surface. It is also referred to as the atmosphere. It is a layer that is composed of a mixture of gases. It is about 700 km thick. We live in the lowest layer, the troposphere. Here the gas is at its most dense, thanks to gravity. As you go up, it quickly thins out. In fact, 90% of the mass of the atmosphere is in the lowest 16 km. Here in the troposphere, we usually call the atmosphere air.

Clean air has specific composition of gases that can be expressed in percentages. This composition of clean air has its natural importance that supports different forms of life and processes that take place in air. This composition had its natural means of maintaining the balance.

Unfortunately, it may no longer be possible to refer air as clean because some other foreign gases have been deposited into it, hence the term pollution of air. The foreign particles in air are called pollutants.

## 7.1 Air as a Mixture of Gases

This pie chart shows the gases that make up clean air:

**Fig. 7.1: Composition of air**

The composition of the air changes very slightly from day to day, and place to place. For example:

- there is more water vapour in the air around you on a damp day.
- pollutants such as carbon monoxide and sulphur dioxide are likely to be given out from busy cities and industrial areas. But since air is continually on the move, the pollutants get spread around too.

**Oxygen: the gas we need most**

Most of the gases in air are essential to us. For example, we depend on plants for food, and they depend on carbon dioxide. And without nitrogen to dilute the oxygen, fuels would burn too fast for us. But the gas we depend on most is **oxygen**. Without it, we would quickly die. We need it for the process called **respiration**, which goes on in all our cells.

glucose + oxygen ⟶ carbon dioxide + water+ energy

The energy from respiration keeps us warm, and allows us to move, and enables hundreds of different reactions to go on in our bodies. (And note that respiration, in some form, takes place in the cells of all living things, not only in humans.)

**Activity 7.1: Find the percentage of oxygen in the air**

**What you need**

- two glass syringes
- combustion tube
- copper wire
- source of heat

**What you do**

1. Connect combustion tube packed with copper wire to two gas syringes A and B. At the start, syringe A contains 100 $cm^3$ of air. B is empty.

**Fig. 7.2: Measuring the percentage of active air**

2 Heat the tube containing copper using a Bunsen burner. Then push in the plunger of syringe A as shown above. This forces the air into B. When A is empty, push in the plunger of B, forcing the air back to A. Repeat several times. As the air is pushed to and fro, the oxygen in it reacts with the hot copper, turning it black.

3 Stop heating the tube after about 3 minutes, and allow the apparatus to cool. Then push all the gas into one syringe and measure its volume. It is now less than 100 $cm^3$.

4 Repeat steps 1 and 2 until the volume of the gas remains steady. This means all the oxygen has been used up. Note the final volume.

**Results**

1 What was the volume of air that remained?

- ***Accept answers derived from the experimental results.***

2 What was the volume of air used up?

- ***Accept volume calculated from experimental results i.e. original volume of syringe ($V_1$) – final volume on the syringe ($V_2$).***

3 Why did the volume of air decrease?

- ***Volume reduced because oxygen (active part of air) was used up.***

4 Calculate the fraction and percentage of the air used.

- ***Fraction of air used =***

$$\frac{original\ volume\ of\ syringe\ (V1) - final\ volume\ on\ the\ syringe\ (V1)}{original\ volume\ of\ syringe\ (V1)}$$

- ***Percentage of air used=***

$$\frac{original\ volume\ of\ syringe\ (V1) - final\ volume\ on\ the\ syringe\ (V1)}{original\ volume\ of\ syringe\ (V1)} \times 100\%$$

5 What conclusion can you make from your calculation?

- ***Accept answers which correspond to the value of oxygen gas in the air (20 – 21%).***

**Questions**

1 What percentage of air is made up of:
**a)** nitrogen? **b)** oxygen? **c)** nitrogen + oxygen?

2 About how much more nitrogen is there than oxygen in air, by volume?

3 What is the combined percentage of all the other gases in air?

4 Mount Everest is over 8.8 km high. Climbers carry oxygen when attempting to reach its summit. Explain why.

5 Which do you think is the most reactive gas in air? Why?

6 **a)** Write down the name and formula of the black substance that forms in the experiment above.
**b)** Suggest a way to turn it back into copper

## 7.2: Separating Components of Air

**Separating Gases from Air**

As you saw, air is a mixture of gases. Most of them are useful to us. But first, we must separate them from each other. How can we separate gases? There is a very clever way. First, the air is cooled until it turns into a liquid. Then the liquid mixture is separated using a method you met in Chapter 2: fractional distillation.

**Boiling points of the gases in air (°C)**

**Table 7.1: Boiling points of gases**

| | | |
|---|---|---|
| carbon dioxide | -32 | |
| argon | -108 | |
| krypton | -153 | *Increasing* |
| oxygen | -183 | |
| argon | -186 | |
| nitrogen | -196 | |
| Neon | -246 | |
| helium | -269 | |

**Table 7.1. Boiling points of gases**

**The Fractional Distillation of Liquid Air**

This method works because the gases in air have different boiling points. (Look at the table below.) So, when liquid air is warmed up, the gases boil at different temperatures, and can be collected one by one.

**Fig. 7.3**

**The steps**

The diagram shows the steps.

1 Air is pumped into the plant and filtered to remove dust particles.

2 Next, water vapour, carbon dioxide, and pollutants are removed (since these would freeze later and block the pipes). Like this:

- First the air is cooled until the water vapour condenses to water.
- Then it is passed over beds of adsorbent beads to trap the carbon dioxide, and any pollutants in it.

3 Now the air is forced into a small space, or compressed. That makes it hot. It is cooled down again by recycling cold air as shown in the diagram above.

4 The cold, compressed air is passed through a jet into a larger space. It expands rapidly, and this makes it very cold.

Steps 3 and 4 are repeated several times. The air gets colder each time. By 2200 °C, it is liquid, except for neon and helium. These gases are removed. They can be separated from each other by adsorption on charcoal.

5 The liquid air is pumped into the fractionating column. There it is slowly warmed up. The gases boil off one by one, and are collected in tanks or cylinders. Nitrogen boils first. Why?

Liquid nitrogen is used in medical research, to keep tissue samples frozen

A patient on oxygen, to help breathing

*Easy: slicing through steel with an oxy-acetylene flame*

**Fig. 7.4: Uses of oxygen**

**Some Uses of Oxygen**

- Planes carry oxygen supplies, and so do divers and astronauts.
- In hospitals, patients with breathing problems are given oxygen through an oxygen mask, or in an oxygen tent. This is a plastic tent that fits over the bed. Oxygen-rich air is pumped into it.
- In steel works, oxygen is used in converting the impure iron from the blast furnace into steels.
- A mixture of oxygen and the gas acetylene ($C_2H_2$) is used as the fuel in oxy-acetylene torches for cutting and welding metal. When this gas mixture burns, the flame can reach 6000 °C. Steel melts at around 3150 °C, so the flame cuts through it by melting it.

**Some Uses of Nitrogen**

- Liquid nitrogen is very cold. (It boils at 2196 °C.) So, it is used to quick-freeze food in food factories, and to freeze liquid in cracked pipes before repairing them. It is also used in hospitals to store tissue samples.
- Nitrogen is un-reactive, so it is flushed through food packaging to remove oxygen and keep the food fresh. (Oxygen helps decay.)

**Some Uses of the Noble Gases**

The noble gases are un-reactive or inert. This leads to many uses.

- Argon provides the inert atmosphere in ordinary tungsten light bulbs. (In air, the tungsten filament would quickly burn away.)
- Neon is used in advertising signs because it glows red when a current is passed through it.
- Helium is used to fill balloons since it is very light, and safe.

**Questions**

**1** In the separation of air into its gases:

**a.** why is the air compressed and then expanded?

**b.** why is argon obtained before oxygen?

**c.** what do you think is the biggest expense? Explain.

2 Give two uses of oxygen gas.
3 A mixture of oxygen and acetylene burns with a much hotter flame than a mixture of air and acetylene. Why?
4 Nitrogen is used to keep food frozen during transportation. Which properties make it suitable for this?
5 Give three uses of noble gases.

## Pollution can Affect the Atmosphere

### The Air: a Dump for Waste Gases

Everyone likes clean fresh air. But every year we pump billions of tonnes of harmful gases into the air. Most harmful gases come from burning fossil fuels.

### The Fossil Fuels

These are coal, petroleum (or crude oil) and natural gas. Natural gas is mainly methane, $CH_4$. Coal and petroleum are mixtures of many compounds. Most are hydrocarbons—they contain only carbon and hydrogen. But some contain other elements, such as sulphur.

Fossil fuels provide us with energy for heating and transport, and generating electricity. But there is a drawback: burning them produces harmful compounds. Look at the table below.

### The Main Air Pollutants

This table shows the main pollutants found in air, and the harm they do:

**Table 7.2: Main pollutants of air**

| Pollutant | How is it formed? | What harm does it do? |
|---|---|---|
| Carbon monoxide, CO colourless gas, insoluble, no smell | Forms when the carbon compounds in fossil fuels burn in too little air. For | Poisonous even in low concentrations. It reacts with the haemoglobin in blood, and |

| Pollutant | How is it formed? | What harm does it do? |
|---|---|---|
| | example, inside car engines and furnaces. | prevents it from carrying oxygen around the body—so you die from oxygen starvation. |
| Sulphur dioxide, $SO_2$ an acidic gas with a sharp smell | Forms when sulphur compounds in the fossil fuels burn. Power stations are the main source of this pollutant. | Irritates the eyes and throat, and causes respiratory (breathing) problems. Dissolves in rain to form acid rain.<br>Acid rain attacks stonework in buildings, especially limestone and marble—they are calcium carbonate. It lowers the pH in rivers and lakes, killing fish and other river life. It also kills trees and insects. |
| Nitrogen oxides, NO and $NO_2$ acidic gases | Form when the nitrogen and oxygen in air react together, inside hot car engines and hot furnaces. | Cause respiratory problems, and dissolve in rain to give acid rain. |
| Lead compounds | A compound called tetra-ethyl lead used to be added to petrol to help it burn smoothly in car engines. It is still added in some countries.<br>On burning tetra-ethyl lead, it produces particles of other lead compounds. | Lead damages children's brains. It also damages the kidneys and nervous system in adults. |

**Reducing Air Pollution**

These are some steps being taken to cut down air pollution.

- In modern power stations, the waste gas is treated with slaked lime (calcium hydroxide). This removes sulphur dioxide by reacting with it to give calcium sulphate. The process is called flue gas desulphurisation.
- Most countries have now banned lead in petrol. So, lead pollution is much less of a problem. But it can still arise from plants where lead is extracted, and from battery factories.
- The exhausts of new cars are fitted with catalytic converters where harmful gases are converted to harmless ones. See below.

**Catalytic Converters for Car Exhausts**

When petrol burns in a car engine, harmful gases are produced, including: oxides of nitrogen, carbon monoxide, CO unburned hydrocarbons from the petrol. These can cause cancer. To tackle the problem, modern car exhausts contain a catalytic converter.

In this case, the harmful gases are adsorbed onto the surface of catalysts, where they react to form harmless gases. The catalysts speed up the reaction. The converter usually has two compartments, marked A and B as shown below:

**Fig. 7.5**

**Activity of Integration**

Air pollution is becoming an increasing concern as we learn more about the adverse health effects of poor air quality in Kampala. Imagine you are an environmental engineer and you are given a contract to sensitise the community of Kampala City Council Authority (KCCA) about quality of air.

**Fig. 7.7: Support tools**

Prepare a radio talkshow, outlining the source and effect of air pollution on people and their environment, and what should best be done to prevent it and clean it up. Also indicate what the people must know about the composition of air and chemicals to determine how to mitigate poor air quality.

## Summary

In this chapter, you have learnt that:

- air is made up of a mixture of gases. It is approximately four-fifths nitrogen, one-fifth oxygen, with small amounts of other gases which include carbon dioxide, argon and water vapour.
- carbon dioxide is made by green plants, humans and animals when they respire. It is also made when fuels that contain carbon, such as wood, coal, oil and gas, burn. It is removed from the atmosphere by photosynthesis.
- we can make carbon dioxide by pouring acid onto some marble chips. Carbon dioxide is a colourless, odourless gas that is heavier than air. It turns limewater milky.
- carbon dioxide dissolves in water. This is important because it allows plants that are under the water to photosynthesise. A solution of carbon dioxide water is slightly acidic.
- carbon dioxide is the gas in fizzy drinks. It is also the gas that makes bread and cakes 'rise'. We make carbon dioxide in cooking by using yeast and baking powder.

- carbon dioxide is used in certain fire extinguishers. Solid carbon dioxide is used to keep things like medical supplies cool in cool boxes. It is a white solid and has a temperature of –78 °C.
- oxygen is a colourless, odourless gas that is used up when substances burn. The substances combine with oxygen, giving out heat energy. The same reaction happens in the cells of living things when they respire. Oxygen will relight a glowing splint.
- oxygen is soluble in water. When water plants and animals respire, they use this dissolved oxygen. Oxygen is produced in the water by water plants when they photosynthesise.
- we use oxygen for welding steel and also to help sick people in hospital breathe better.

## End-of-Chapter Questions

1 Which of the following gases makes up around one-fifth of the air?

d) argon C) nitrogen
e) carbon dioxide D) oxygen

2 Which of the following describes photosynthesis?

**1** Oxygen reacts with starch to produce carbon dioxide and water.
**2** Carbon dioxide and water react to produce starch and oxygen.
**3** Yeast uses sugar to make carbon dioxide and alcohol.
**4** Carbon dioxide turns limewater milky.

3 Which of the following reactions uses up carbon dioxide from the air?

a) burning wood c) respiration
b) fermenting yeast d) photosynthesis

4 How much oxygen will there be in a litre of air?

a) 100 $cm^3$ c) 500 $cm^3$
b) 800 $cm^3$ d) 200 $cm^3$

5 You are given two test tubes of a colourless gas. Explain how you could find out if the gas is oxygen or carbon dioxide.

6 Many fuels contain carbon.

a) Name one of the gases that would be produced when fuel burns.

b) Design an experiment to find out whether the methylated spirits in your burner contains carbon.

7 Some wet rotting leaves were placed in a jar of jam. A small open tube of limewater was also put in the jar and the lid was screwed onto the jar. After a day or two the limewater looked milky.

- Explain why the limewater turned milky.
- Explain what the experiment tells you about what happens when leaves rot.

8 When you unscrew the top of a bottle of fizzy drink, you see bubbles coming up. Explain how you would try to find out if the bubbles were carbon dioxide. Draw a picture showing what you would do.

9 Observe - explain

Write a sentence explaining each of these observations. If you do not know the answer, use your scientific knowledge to suggest one.

a) Rainwater is always slightly acidic.

b) If you cover a fire with sand, it stops burning.

c) Water plant leaves are often covered with bubbles when the sun shines on them. If the bubbles are collected, they will relight a glowing splint.

d) The equipment in sketch (a) was set up. A week later the water levels were as shown in sketch (b).

e) Fires burn more strongly when a wind is blowing.

# CHAPTER 8

# Water

This is part of River Nile in Uganda

| *Key Words* | *By the end of this chapter, the learner will have learnt to:* |
|---|---|
| ◆ natural resource<br>◆ water cycle<br>◆ sewage<br>◆ recycle | *a) outline the occurrence of water as natural resource; demonstrate physical and chemical properties of water and explain the importance of water in everyday life.*<br>*b) demonstrate how water is recycled by the natural process.*<br>c) *explain and demonstrate the process of water and sewage treatment.* |

**Competency:** The learner will be able to investigate evaporation and condensation as natural processes which are essential for replenishing supplies of fresh water in the water cycle.

### Introduction

Water is a common liquid. Most of it is found in seas and oceans where it contains dissolve salts, making it unsuitable for many living things. It usually known as salty water (non-fresh water). Less than 3% of water occurs as fresh water found in lakes, rivers, wells and springs. Some form of water occurs as water vapour in the atmosphere.

The presence of water and its supply is very vital to all forms of life.

Water is a colourless, odourless and tasteless liquid. It is an oxide of hydrogen. Each molecule of water is made of two atoms of hydrogen and one of oxygen. We write its formula as $H_2O$. Water is such a common substance that we do not think much about it. And yet it is a very unusual and surprising substance in many ways. Here are two reasons why it is surprising:

- The first surprising thing about water is that it is a liquid. Other similar substances like ammonia ($NH_3$), hydrogen sulphide ($H_2S$) and hydrogen chloride (HCl) are gases.
- The second unusual thing about water is that when it cools below 4 °C it does not contract like other substances. It expands! This means that ice, or solid water is less dense than liquid water and floats on it.

Do you think it would be possible for life to exist on earth if water was a gas at the normal temperatures found on earth?

Do you think it would be possible for life to exist in water if ice formed at the bottom of water?

If water were not such a surprising substance we would not be here!

## 8.1 Properties of Water

All substances have physical and chemical properties. Physical properties are the properties that we can measure, such as the temperature at which a substance melts or boils, its density, or whether it is a solid, liquid or gas. The chemical properties of a substance are the kinds of chemical reactions it takes part in.

**Physical Properties of Water: Freezing and Boiling Points**

You may remember from your work in primary Integrated Science that the boiling point of water is 100°C and the freezing point of water is 0°C. You may have learnt that this is a test for water.

If you have a colourless liquid that looks like water, you can find its boiling and freezing points. If the boiling and freezing points are 100°C and 0°C respectively, then the liquid must be water because no other liquid has these two properties.

All this, however, is not quite true. Firstly, if you live near the coast and you boil water, you will find that it boils at less than 100°C. The boiling point of water differs from place to place, such as in Uganda.

In Kampala which is close to Lake Victoria, at a lower altitude, the boiling point is 100°C. For every 500 metres above sea level, the boiling point drops about 1°C. What is the boiling point of water where you live? Can you calculate roughly how high above sea level you are?

Water boils at a lower temperature if the atmospheric pressure is low. You learnt in the previous section that atmospheric pressure is lower at higher altitudes. This is why the boiling point of water is lower in Arua (96°C) than in Kampala (98°C). Any impurities in the water will raise the boiling point and lower its freezing point. In some countries rain freezes on the roads during winter nights. This makes the roads slippery and dangerous. To make the roads less slippery, salt is spread on these roads. The salt lowers the freezing point of the water and prevents the formation of ice when the temperature drops below 0°C at night. You can show this by adding some salt to crushed ice and taking the temperature of the mixture. The temperature will drop below 0°C and you will notice that some of the ice melts.

**Physical Properties of Water: Density**

You will remember from Primary Seven that one cubic centimetre of water has a mass of 1 g and that 1 cubic decimetre has a mass of 1 kg. This is the density of water—water has a density of 1 g/cm$^3$ or 1 kg/dm$^3$. But this also is not quite always true. Try the following activity.

**Activity 8.1. Finding out what happens to a fresh egg when you put it in water?**

**What you need**

- egg
- water
- jam jars
- salt
- spoon

**What you do**

1. Fill the jar about two-thirds with pure water. Put in the egg. Note what happens.
2. Add salt to the water and stir. Now what happens to the egg?
3. Can you explain what you observe?

**Predict, observe and explain**

1. Pour some salt water in a jar and then very carefully pour pure water on top of the salt water. It will stay on top because it is less dense.
2. Predict what will happen when you put in the egg. Test your prediction.
3. Explain what you observe.

In this activity the egg does not change but the water does. A fresh egg sinks in pure water but floats in salt water. This is because the egg has a density of just over 1.1 g/cm$^3$ (you could measure it) and so it sinks in pure water because it is denser than pure water.

When you put an egg in salt water it floats. This tells you that the density of the salt water is more than the egg, and is also more than pure water. So, the density of water increases when substances dissolve in it. This is important in the oceans: very salty water is dense and sinks. This sinking process causes many of the world's ocean currents and these affect our weather.

**Chemical Properties of Water**

You know from primary that water is a good **solvent**. Many things dissolve in water to form solutions and sometimes these solutions have important chemical properties. They may be acidic or alkaline, for example. The next activity shows a simple chemical test for water.

**Activity 8.2: Finding out if a colourless liquid contains water**

There are many liquids that are not water. If we have a colourless liquid how can we find out if it contains water?

**What you need**

- anhydrous copper(II) sulphate
- tap water
- methylated spirits
- paraffin
- distilled water
- salt solution
- sugar solution
- vinegar
- watch glass
- teaspoon

**What to do**

1. Place a few crystals of anhydrous copper sulphate on the watch glass.
2. Add drops of tap water to the anhydrous copper sulphate. In a table like the one below, record your observations.
3. Wash off the copper sulphate and dry the watch glass.
4. Repeat steps 1 to 3 with the other liquids and record your observations.

***Fig. 8.1. Testing for water***

| **Liquid** | **Observations** |
|---|---|
| Tap water | ***anhydrous copper(II) sulphate turned blue*** |
| sugar solution | ***anhydrous copper(II) sulphate turned blue*** |
| Paraffin | ***anhydrous copper(II) sulphate didn't change*** |
| … | |

Did you notice that most of the liquids turned the copper sulphate blue? Water will make anhydrous copper sulphate turn from **white** to **blue**.

Which of the liquids tested contained water?

You may be surprised to find that a liquid like methylated sprits may contain water. It is often very difficult to get all the water out of many liquids, even out of a liquid such as petrol.

**Water and pH**

Do you remember any work you did on acids and alkalis? Acids and alkalis are solutions of some compounds in water. Lemon juice is an example of an acid solution. Washing soda solution is alkaline. Acids have a sharp taste while alkalis have a nasty bitter taste. Acids and alkalis react with each other—they neutralise each other.

Do you remember this pH scale?

Pure water has a pH of 7 but water is such a good solvent that it is not often pure. Rainwater has a pH of about 5 to 6 because it has carbon dioxide dissolved in it, which makes it slightly acidic.

Strong acids are found at the bottom of the scale and strong alkalis at the top. Weak acids are found in the middle of the scale below 7 and weak alkalis in the middle above 7.

You can tell whether a solution is acidic or alkaline with litmus. Litmus is an **indicator**—it turns red when it is in acid solutions and blue in alkalis.

You can find the pH of a solution using universal indicator paper, which changes to a different colour depending on the pH of the solution it is dipped in.

### Water Cycle

The water cycle is vital to supporting all life on earth. Without it, nothing would grow or survive. This set of activities introduces the stages of the water cycle to the learners so they can see all the different processes at work. The activities can be used to enable the learners gain a broader picture of why water is essential to life.

**Fig. 8.4: Water cycle**

## Activity 8.4: Making a model water cycle

### What you need

A) a clear plastic jar (they should label their jars so that they can observe and record what is happening)
B) cling film or sheets of clear plastic
C) rubber band
D) soil
E) seed
F) measuring cup
G) water

### What to do

1. Ensure that the plastic jar is clean and dry.
2. Add a layer of soil to the bottom of the jar. The layer should be about 2 cm deep.
3. Sprinkle about half a teaspoon of chickenfeed over the soil.
4. Cover the seeds with another layer of soil that is also about 2 cm deep.
5. Measure 60 ml of water using the measuring cup. Slowly pour this over the soil. Make sure the water is poured evenly over the soil surface.
6. Cover the top of the jar with cling film or plastic and secure it with a rubber band.
7. Place the jars on a window sill or other place where they can remain in direct sunlight. Over the next few days, the learners should examine their jars and record what they can see.

### Results

1. How did the appearance of the jar and plastic cover change?
   - ***Accept clear and sensible observations of the learners.***
2. Did droplets appear on the inside or outside of the jar?
   - ***The droplets will appear outside of the jar.***
3. Where do you think the droplets came from?
   - ***The droplets came from the air which contains water vapour.***
4. What happened to the seed?
   - ***The seed transpired or released water vapour.***

5 What role did sunlight play in the change from liquid water to water vapour?

- ***The sunlight heated the liquid water to change it to water vapour.***

## 8.2 Understanding the Occurrence of Water

### Everyone needs water

**Fig. 8.2: Learners studying about borehole as source of water**

We all need water.

**At home,** we need it for drinking, cooking, washing things (including ourselves) and flushing toilet waste away.

**On farms,** it is needed as a drink for animals and to water crops.

**In industry,** they use it as a solvent and to wash things, and to keep hot reaction tanks cool. (Cold-water pipes are coiled around the tanks.)

**In power stations,** it is heated to make steam. The steam then drives the turbines that generate electricity.

### So, where does the water come from?

Much of the water we use is taken from rivers. But some is pumped up from the ground below where water that has drained down through the soil lies trapped in rocks.

This underground water is called **groundwater**. A large area of rock may hold a lot of groundwater, like a sponge. This rock is called an **aquifer**.

### Is it clean?

**Fig. 8.3**

River water is not clean. Even if it looks clean, it will contain particles of mud, animal waste and bits of dead vegetation. But worst of all are the **microbes**: bacteria and other tiny organisms that can make us ill.

Over 1 billion people around the world have no access to clean water. They depend on dirty rivers for their drinking water. And over 2 million people, mainly children, die each year from **diarrhoea** and diseases such as **cholera** and **typhoid**, caused by drinking infected water.

## 8.3 Water and Sewage Treatment

### Water Pollution

What should we do with water after we have used it?

Think how often we use water for cleaning things. We use water for cleaning because it dissolves substances so easily. We make water dirty when we use it for cleaning because many things dissolve in it. Every day we throw away a lot of water that has things dissolved in it.

What happens to this impure water? If we let it get into our rivers and wells, it will pollute the water and we will not have clean water to drink and use. Many of the plants and animals that need clean water will also suffer or die. When this happens, we call it water pollution.

We have sewage works which clean polluted water. We need the sewage works because we need the water which is such a good and useful solvent.

Waste from sinks and toilets are called sewage. It is mainly water, but it contains many solids that are dissolved in it. The sewage also contains substances that are not soluble, such as faeces and toilet paper. It also contains harmful bacteria which can cause serious diseases. It is very important that we treat our sewage to make sure it does not pollute our rivers and our wells.

In many towns the sewage from toilets goes to the sewage works. In the sewage works the sewage is filtered and the water is cleaned. It is dangerous to drink unpurified river water and groundwater, even if it looks clean. The bacteria that make us sick are too small to be seen with the naked eyes. The picture showing some bacteria was taken using a microscope. The bacteria are less than one hundredth of a millimetre long. The diagram below shows how water is purified before we use it, and also how it is treated after we use it.

**Liquid Waste (Sewage/Wastewater) Treatment**

Wastewater (liquid waste) from flushing the toilet, bathing, washing sinks and general cleaning goes down the drain and into a pipe, which joins a larger sewer pipe under the road. The larger pipe also joins a major pipe that leads to the treatment centre.

**Stage One: Screening**

Screening is the first stage of wastewater treatment process. Screening removes large objects like, diapers, nappies, sanitary items, cotton buds, face wipes and even broken bottles, bottle tops, plastics and rags that may block or damage equipment.

Special equipment is also used to remove grit that gets washed into the sewer.

**Stage Two: Primary Treatment**

This involves the separation of organic solid matter (or human waste) from the wastewater. This is done by putting the wastewater into large settlement tanks for the solids to sink to the bottom of the tank. The settled solids are called 'sludge'.

At the bottom of these circular tanks, large scrappers continuously scrape the floor of the tank and push the sludge towards the centre where it is pumped away for further treatment. The rest of the water is then moved to the secondary treatment.

**Stage Three: Secondary Treatment**

The water, at this stage, is put into large rectangular tanks. These are called aeration lanes. Air is pumped into the water to encourage bacteria to break down the tiny bits of sludge that escaped the sludge scrapping process.

**Stage Four: Final Treatment**

Next, the 'almost' treated wastewater is passed through a settlement tank. Here, more sludge is formed at the bottom of the tank from the settling of the bacterial action. Again, the sludge is scraped and collected for treatment. The water at this stage is almost free from harmful substances and chemicals.

The water is allowed to flow over a wall where it is filtered through a bed of sand to remove any additional particles.

**Activity of integration**

**How clean is that water?**

Clean water is important to a person's health and lifestyle, and it is engineers who ensure that our water is safe to drink and use. Environmental and civil engineers help maintain the quality of our water resources.

Write a short newspaper article, explaining what water quality is, giving examples from your own experiences of good and bad water quality, and what might be the cause of "bad" water quality.

## Summary

In this chapter, you have learnt that:

- water is a colourless, odourless and tasteless liquid and is the compound formed between hydrogen and oxygen. Unlike other similar compounds of hydrogen, it is a liquid at the normal temperatures found on earth. Ice, which is solid water, is unusual because it is less dense than liquid water and floats on top of it. Both these unusual properties are essential to life on earth.
- Pure water has a boiling point of 100°C and a freezing point of 0°C at sea level. It has a density of 1 g/cm$^3$. The chemical test for water is that it turns white anhydrous copper sulphate blue.
- Hard water is water that does not lather easily with soap. Hardness is caused by substances that are dissolved in the water. These substances are usually salts of the elements of calcium or magnesium, which have dissolved in the water in the rivers or under the ground.
  Sometimes hard water can be softened by boiling the water. This kind of hardness is usually caused by the presence of calcium hydrogen carbonate (also called calcium bicarbonate) in the water.
- we need water for drinking, cooking, washing; in agriculture and industry. Because some countries are dry, they must recycle their water and reuse it. There are many underground water sources, but it often takes hundreds of years for rain to replace them when we use them, so we must try and use water from dams or reservoirs wherever possible.
- Water is a very good solvent. Dissolved substances often alter the pH of water, making it alkaline or acidic.

## End-of-Chapter Questions

1. (a) Name five sources of natural water.

   (b) How do you normally make the water from those sources safe for drinking?
2. Describe an experiment that can be conducted to show that living materials contain water.
3. Describe one method you can use to purify water at home.
4. Describe the process of recycling water naturally.
5. How does water get polluted?
6. Describe human activities that can cause water pollution.
7. Describe the stages of sewage treatment. Why is sewage treated?

# CHAPTER 9

# Rocks and Minerals

| Key Words | *By the end of this chapter, the learner will have learnt:* |
|---|---|
| ◆ rock<br>◆ mineral<br>◆ igneous rock<br>◆ magma<br>◆ earth solution<br>◆ precipitates<br>◆ ion<br>◆ sedimentary rock<br>◆ metamorphic rock<br>◆ cycle<br>◆ ore<br>◆ prospecting<br>◆ remote sensing<br>◆ geochemical | ▪ *how igneous, sedimentary and metamorphic rocks are formed, and that they are made up of minerals, and that some minerals are useful (k, u, s).*<br>▪ *to identify the physical properties of rocks and distinguish between the different types (s).*<br>▪ *the process of weathering and how weathered rock particles form the basis of soil (u, s).* |

**Competency:** The learner appreciates that rocks are composed of different minerals and these determine the properties of the rocks.

### Introduction

The study of rocks, minerals and earth's surface is called geology. A person who studies these is called a geologist. To gain knowledge about rocks and minerals, let us first define the terms "rocks and "minerals".

## 9.1 What are Rocks and Minerals?

### Activity 9.1: Identifying rocks and minerals

In this activity, you will describe the given samples and try to identify whether they are rocks or minerals.

**What you need**

- samples of rocks and minerals

**What to do**

1. Obtain the samples of the rocks or minerals from the teacher to study.
2. Label the samples as A, B, C and D

A

B

C

D

**Fig. 9.1: (A) Granite (B) Limestone (C) Mica (D) Feldspar**

**Results**

| Specimen | Description | Is it a rock or a mineral | Name of rock or mineral |
|---|---|---|---|
| A | | | |
| B | | | |
| C | | | |
| D | | | |

**Table 9.1. Results showing rocks and minerals**

### Activity 9.2: Study minerals

In this activity, you will study and describe a sample of a mineral.

**What you need**

- sample of quartz
- hand lens

**What you do**

1. In Activity 9.1, you have already identified a mineral. In this activity you will study another mineral called quartz.
2. Obtain the mineral from your teacher, or use the photo below to study.
3. Observe the mineral and answer the question in the table below.

**Fig. 9.2: Quartz**

| Questions | Observations |
|---|---|
| 1. What is the chemical composition of quartz? | |
| 2. Is the quartz the same mineral throughout? | |
| 3. Describe some features of quartz (e.g. shape, colour and hardness) that you can identify | |

**Table 9.2. Properties of quartz**

## 9.2 Minerals

Minerals are building blocks of all rocks. They are natural substances in which the particles are arranged in patterns. Minerals often occur in beautiful shapes called **crystals**. Metals, gems and industrial materials of many kinds are made of minerals. Examples of minerals are quartz, mica and feldspar as seen in **Fig. 8.1** and **Fig. 8.2**.

Only eight elements: oxygen, silicon, aluminium, iron, calcium, sodium, potassium and magnesium make up 99% of all minerals. For example, quartz is made up of silicon and oxygen. These are the two most common elements that make up the earth.

Some minerals are made up of only one metal element, such as gold, silver or platinum, and are called **native metals.**

## Characteristics of Minerals

Minerals have different properties and characteristics as described below.

**Hardness** is an important property of minerals. A mineral is harder than the other if it can scratch it, without getting scratched itself. The scale for hardness of minerals was invented by an Australian called Frederic Mohs in 1812. The scale ranges from 1 – 10 points. Ten (10) on the point scale is the hardest, and one (1) on the scale is the softest. If a mineral is higher on the Mohs than another, it can scratch the one that is lower. Consider the Mohs scale below (left) and some common objects rate on the scale (right).

**Table 9.3: Mohs scale of hardness**

| | |
|---|---|
| 1 | Talc |
| 2 | Gypsum |
| 3 | Calcite |
| 4 | Fluorite |
| 5 | Apatite |
| 6 | Orthoclase |
| 7 | Quartz |
| 8 | Topaz |
| 9 | Corundum |
| 10 | Diamond |

**Table 9.4: Hardness of common objects**

| | |
|---|---|
| Finger nail | 2.5 |
| Copper coin | 3.5 |
| Iron nail | 4.5 |
| Glass | 5.5 |
| Steel knife | 6.5 |
| Emery board | 9.5 |

### Activity 9.3: Identify minerals using "hardness scale"

In this activity, you will put four samples of rock in order of their hardness.

### What you need

- mineral samples (magnetite, quartz, calcite and azunite)
- iron nail
- glass
- steel knife

### What you do

1. This is a scratching activity. It should be done in groups. The table of common objects above shows that a steel knife has a hardness of 6.5. Scratch the mineral samples using the knife. Be careful when handling the knife.
2. Does the knife scratch all the samples?
3. Use the iron nail, glass and your fingernail to scratch all four samples. Use the results to put the samples in order of hardness.
4. Record the hardness in order in the table. Write your description of each in the correct space in the table.

### Results

**Table 9.5: Hardness of some mineral samples**

| Sample | Mineral samples | Description of the mineral | Hardness scale |
|---|---|---|---|
| A | Magnetite | | |
| B | Quartz | | |
| C | Calcite | | |
| D | Azunite | | |

Although a mineral may have a specific **colour**, this is not a reliable enough property to identify it. A better method is to crash it into a powder.

The colour of a powdered mineral is called its **streak.** This can be seen by rubbing a mineral on a white tile. Some minerals do not produce a streak, while other powdered minerals have different coloured streak than the mineral itself.

Many groups of people worldwide use powdered minerals as decorations for painting materials.

**Figure 9.3: 'Imbalu' boy being circumcised**

In Uganda, the Bagisu use some kind of clay mixed with white sorghum flour for decoration when performing the 'imbalu' dance in preparation for circumcision. The powder of the clay and sorghum flour are mixed with water and applied to the bodies and faces of the boys as in **Fig. 9.3**.

The table below shows colours found in some common rocks.

**Table 9.6: Colours of some minerals**

| Name of coloured rock | Colour of streak | Where coloured rock is collected |
|---|---|---|
| Haematite | Red | Found in pebbles (murram) |
| Kaolin | White | In creek or river beds |
| Charcoal | Black | Produced in fires |

Different colours in minerals are caused by the different chemicals in them. The red colour of haematite is caused by lots of iron (also known as rust). These coloured rocks can mix to form other colours. Charcoal is commonly mixed with kaolin to make grey. The powders are also mixed with egg, juice or blood to make paste to make a paste that can be painted onto rocks or body.

**Fig. 9.4: Body painting using powder from sandstone/iron oxide in Uganda**

**Crystals**

Many minerals have a specific crystal structure. The word 'crystal' comes from Greek word *kryos,* meaning 'icy cold'. In ancient times it was believed that quartz crystals were composed of water that had frozen and so solid that it could never melt.

Because each mineral has a different crystal structure and colour, they reflect light differently. **Lustre** is a term that refers to the way a mineral reflects light.

Some crystals have an internal structure that causes them to break apart more easily in particular directions. These are called **cleavage planes.**

**Fig. 9.5: Cleavage planes**

## 9.3: Rocks

### Activity 9.4: To study granite rock

In this activity, you will study the properties and formation of granite.

### What you need

- granite rock
- hand lens

### What you do

1. In Activity 9.1, you identified a rock.
2. You obtain a sample of granite for this activity from your teacher
3. Observe the granite and answer the following questions in the table below.

**Table 9.7: Properties of granite**

| Questions | Observations |
|---|---|
| 1. Which minerals make granite? | |
| 2. How does granite form? | |
| 3. Describe some physical properties of granite (e.g. shape, colour and hardness) that you are able to identify | |

### Ores

Ores are rocks or minerals containing elements that can be extracted. For example, iron is extracted from an ore called **haematite**, and aluminium from the ore **bauxite**. Below is a Table of some economically important minerals in Uganda.

**Table 9.8: Minerals in Uganda**

| Mineral | Source | Use |
|---|---|---|
| Gold | | |
| Limestone | | |
| Iron ore | | |
| Copper | | |
| | | |

## 9.4: Formation of Rocks

### Types of Rocks

***Fig. 9.6: Formation of rocks***

**Igneous Rocks**

Igneous rocks are formed when molten rock from the crust and upper mantle cools. The molten rock is called magma when it is still below the surface and lava when it reaches the surface. Magma is found in the outer mantle: it is a hot, liquid rock that is under pressure from the rocks above it. When it cools, it turns to solid rock. When liquid magma rises to the surface from volcanoes, the cooling occurs quickly and forms lava. Igneous rocks are made of material that was once molten. They usually contain crystals that are formed as the molten material cools.

The crystals found in rocks are formed when solutions of minerals cannot absorb any more dissolved minerals. Some of each mineral type precipitates out of solution to form the centre of a crystal. This then provides a surface for more mineral ions to precipitate onto. The crystal becomes larger until the solution disappears.

If the rock cools quickly, only very small crystals can form before the rock becomes solid. Rapid cooling occurs when magma is released from volcanoes onto the surface of the earth's crust.

If magma rises from the mantle into the crust without reaching the earth's surface, then the magma cools more slowly, allowing the formation of larger crystals. Many of these crystals contain valuable minerals that are used for a wide range of industrial processes. Heat and pressure are the usual reason for minerals becoming dissolved; a reduction of heat and pressure usually leads to the formation of crystals.

Examples of igneous rocks are granite and basalt (Fig. 9.7 and 9.8).

**Fig. 9.7: Pieces of granite**

**Fig.9.8: Pieces of basalt**

**Sedimentary Rocks**

Sedimentary rocks are formed by the weathering of existing rocks at the earth's surface, the accumulation and fossilisation of living material, or the precipitation of dissolved materials out of solution in water. Weathering processes release small mineral particles that accumulate to form sediment. Over time, layers of sediment build up to form sedimentary rock. The sediments include different-sized mineral particles.

The smallest particles are clays, followed by silts and then sands. These particles are important in the formation of soils. Larger particles of gravels and small boulders can also be found in sediments.

The particles are transported by streams and rivers and then deposited as sediment.

Each layer of sediment becomes more compact and harder because of the pressure created by the newer deposits above them. Examples of sedimentary rock are limestone, sandstone and shale.

***Fig. 9.9: A Piece of Limestone***

***Fig. 9.10: Sandstone***

**Metamorphic Rocks**

Metamorphic rocks are created from existing rocks when the heat (above 150°C) or pressure (above 1.5 × 108 Pa or 1480 atm), or both heat and pressure, causes changes in the rock crystals without melting the existing rock. The existing rock, therefore, changes in structure, becoming a metamorphic rock. The changes in structure can be chemical or physical or both.

Sedimentary and igneous rocks can become metamorphic rocks, and a metamorphic rock can become another metamorphic rock. Metamorphic rocks are usually harder than sedimentary rocks.

Examples of metamorphic rocks are marble and slate (**Fig. 8.7** and **8.8**).

When the earth's crust first formed, all the rocks were igneous. These rocks were slowly eroded, releasing small

**Fig. 9.11: A Piece of shale**

particles that formed sediment, and these sediments built up over time to form sedimentary rocks. The rocks that make up the earth's crust are always moving, which creates the heat and pressure needed to form metamorphic rock. All rock types are constantly eroded and formed in the rock cycle (**Fig. 8.9**). Table 1.1 compares the characteristics of the different rock types.

**Table 9.9: Showing characteristics of the different rock types**

| Igneous | Sedimentary | Metamorphic |
|---|---|---|
| Made from liquid magma | Made from other rock fragments | Made from existing rock |
| Magma cools to form solid rock | Rock fragments become buried and increased pressure forms a rock | The original rock is changed in form by heat and pressure |
| Mineral crystals sometimes present; the size of the crystals depends on the speed of cooling | Crystals absent | Mineral crystals present |
| No fossils present | Fossils may be present | No fossils present |

**Fig. 9.12: A piece of marble**

**Fig. 9.13: A piece of slate**

## 9.5: The Rock Cycle

**States of Rock**

- Igneous
- Metamorphic
- Sedimentary
- Magma
- Sediment

**Changes of State of the Rock**

- Melting
- Cooling
- Heat and Pressure
- Weathering and erosion
- Compaction and cementation

**Fig. 9.14: Rock cycle**

The figure above shows the rock cycle relationship between three rock types: sedimentary, metamorphic and igneous. The diagram also shows the interactions between these types, their origins and the processes by which they are interconnected.

### Activity 9.5: Rocks and the cycle

#### What you need

- for the first part you will need to be able to access the Interactive Rock Cycle website (www.cambridge.org/links/scspenv4000)
- for the second part, which can be done on a different day, your teacher will provide you with a selection of rocks.

#### What you do

1. For the first part of the practical, go to the web page and look at the interactive diagram.
2. For the second part of the practical, choose one of the rocks.

3 Observe and describe your chosen rock, thinking about things like shape, colour, weight, softness or hardness.
4 Return your rock to the table, and put a letter by it. Each rock should end with a different letter by it.
5 Working on your own, select another rock. This time, do not pick it up.
6 Spend about five minutes writing a description of your rock without anyone else knowing which one it is.
7 Swap your description with someone else and take it in turns to work out which rock has been described.

## 9.6: Extraction of Rocks and Minerals from the Earth

Minerals provide us with a wide range of materials that we use in everyday life. Coal and oil provide energy and many chemicals used in industry. Metallic **ores** provide us with the metals and alloys needed to make products such as computers, mobile phones, cars, wires and nails. The demand for minerals continues to increase, both in developed and developing countries.

**Fig.9.15: Mubende gold mining**

**Activity of Integration**

| ID# | Hardness | Brightness | Granular | Holes | Luster | Reactivity | Bouyancy | Rock Name | Classification |
|---|---|---|---|---|---|---|---|---|---|
| | Number | Light or Dark | Yes of No | Yes or No | Dull or Shiny | Fizz or No | Float or Sink | (use flow chart) | I, S, or M |

**Fig. 9.16: Record of rock characteristics**

Different rock types vary by region, and so knowing their properties, identifying them and classifying them as sedimentary, igneous or metamorphic is important before you start building.

- ***Igneous rocks*** are formed directly from the cooling of magma and make up the majority of the earth's crust.
- ***Sedimentary rocks*** are often called "secondary" rocks, because they form from small pieces of other types of rocks, or from minerals that were previously dissolved in water (like the silt in lakes, rivers and seas). These are commonly found in dry areas.
- ***Metamorphic rocks*** are those that have been changed over time due to different chemical surroundings, heat and pressure.

Using information in **Fig. 9.16**, prepare a short radio message for people living in your home town, detailing why is it important to know rock properties before they build in it, and how these characteristics might affect their caverns (caves).

## Summary

In this chapter, you have learnt that:

- a rock is:
  a) a solid.
  b) naturally occurring.
  c) is made up of minerals or mineral like matter.
- some rocks are composed of just one mineral. Pyrite and quartz are two common rocks that fit this category. Most rocks are a solid mixture of several minerals like granite.
- rocks are classified by how they are formed. There are three basic groups: igneous, sedimentary and metamorphic.
- in each group of rocks, distinctions are made for texture or grain size and chemical or mineral content.
- minerals are building blocks of all rocks.
- Mohs scale of hardness is used to identify common minerals.

### End-of-Chapter Questions

1 What is a mineral?
2 Name two examples of minerals.
3 What are the three properties of minerals?
4 Name two ways we use minerals.
5 What is a rock?
6 What would you find if you cut open the earth?
7 Name the three types of rocks.
8 What do we call the process in which rocks change from one type to another?
9 How do people use rocks?
10 What forces cause metamorphic rocks to form?

11 What type of rock forms in layers?
12 What causes sedimentary rock to form?
13 Which item is made of graphite?
14 Name the two types of rock that you are least likely to find fossils.
15 What is meant by a rock cycle?

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