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Unit 5

Particles in motion

Introduction

Welcome to this fifth unit of the “Coordinated Science Course.” It is the second unit which focuses on the physical strand of the course and it consists of three main topics:

- Moving particles,
- The behaviour of gas molecules and
- Density.

Hence, in this unit we will discuss kinetic theory, matter, evaporation, behaviour of gas molecules, and density in general. We will, whenever possible provide opportunities for you to try out some basic experiments and to apply principles and formulae learnt within the unit.

Since the units in the Coordinated Science course have been developed in such a way to allow you to continuously see the relationships between Physics, Chemistry and Biology, we shall be referring you to other units in the course where the concept of particles in motion is also dealt with. Hence, in the physics Motion unit (Unit 15), you will be able to use your knowledge of the particulate nature of matter to further advance your thought process in regards to matter. You may already know certain things about matter. Think back to what you have learned in unit 2. Remember that we learned about matter and the states of matter in that unit.

In this unit you will learn about:

- the particulate nature of matter;
- the connection between the temperature of an object and the movement of its particles;
- the process of evaporation in terms of the kinetic theory;
- the relationship between pressure, volume and temperature of a gas;
- how to determine the density of a liquid and of a regularly and an irregularly shaped solid.
We hope that this ‘Physics’ unit will be both interesting and enjoyable to you.

The outcomes for the unit are listed below.

Upon completion of this unit you will be able to:

- *describe* the kinetic theory of matter as a model for matter in terms of particles (atoms and molecules) in motion.
- *investigate* the connection between the temperature of an object and the movement of its particles.
- *explain* that the three states of matter can be understood in terms of inter-molecular and inter-atomic forces and the motion of the atoms and molecules.
- *describe* the process of evaporation in terms of the kinetic theory.
- *explain* how the relationship between the pressure and volume of a gas may be predicted by the kinetic theory.
- *describe* qualitatively the effect of a change in temperature on the volume of a gas.
- *describe* how the relationship between pressure, volume and temperature for a gas leads to the Kelvin scale of temperature.
- *carry out* an experiment to determine the density of a liquid and of a regularly shaped solid using the formula: \( \text{density} = \frac{\text{mass}}{\text{volume}} \)
- *use* the displacement method to find the density of an irregularly shaped solid

**Terminology**

**Density:** It is the mass in grammes (g) of 1 cm³ of a substance or mass in kilogrammes (kg) of 1 m³ of a substance.

**Directly proportional:** When one variable increases in value, the other variable also increases proportionately.

**Evaporation:** A change of state from liquid to gas.
**Inversely proportional:** When one variable increases in value, the other variable decreases proportionately.

**Mass:** The amount of matter in an object measured in grammes or kilogrammes.

**Perfectly elastic collision:** When particles or objects bounce in a straight line upon collision and the total kinetic energy before and after the collision is the same.

**Pressure:** The result of a force(s) exerted over an area of 1 cm² or 1 m².

**Unit volume:** Cubic centimetre (cm³) or cubic metre (m³).

**Volume:** The amount of space an object takes up.

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Table 5.0 below shows the number of formal study hours needed for you to complete this unit and the number of hours that you need to devote for self-study.

<table>
<thead>
<tr>
<th>Category of students</th>
<th>Number of formal study hours needed</th>
<th>Number of hours for self-study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full-time student outside the conventional school setting</td>
<td>6 hours</td>
<td>3 hours</td>
</tr>
<tr>
<td>Full-time student within the conventional school setting</td>
<td>6 hours</td>
<td>3 hours</td>
</tr>
<tr>
<td>OR Part-time student</td>
<td>6 hours</td>
<td>3 hours</td>
</tr>
</tbody>
</table>

Table 5.0: The time needed for you to work on this unit
Topic 5.1: Moving Particles

You will need 2 hours and 10 minutes at the most to complete this topic. It is advisable that you spend another 1 hour and 5 minutes of your own time to further review the activities you have completed. Make sure you read and try to understand everything in order to achieve the specific objectives.

As you may recall, in Unit 2 - The Elements of Chemistry, you learnt about the particulate nature of matter. We are now going to build on what you have learnt there, so if you feel you have forgotten some of the concepts, please go back and do some review. We are going to start off this topic by looking at the kinetic theory of matter, then physical states of matter, Brownian motion and finally evaporation.

5.1.1 The Kinetic Theory of Matter

The Kinetic Theory explains the differences between the three states of matter – solid, liquid and gas. It states that all matter is made up of moving particles which are molecules, atoms or ions. Both solids and liquids are made up of particles that touch one another. In solids, the particles are so tightly bound to each other that they can only vibrate, and not move to another location.

In liquids, the particles have enough free space to move about, but they are still attracted slightly to one another.

In gases, the particles are far apart and can move about freely and faster than in liquids since there is much free space. However, as they move in straight lines they often collide with one another. The collisions between particles are perfectly elastic.

Solids change into liquids, and liquids into gasses, as the particles are heated and are able to move apart from each other, gaining kinetic energy in the process. When the molecules vibrate more quickly upon heating, some of the molecules escape from the liquid state into the gaseous state. This explanation of particles in motion is what the Kinetic Theory is about.
Activity 5.1.1

You should spend approximately 5 minutes on this activity.

Based on what you have read above, you are now invited to use the circle shown in each box to show how you think the particles in the solids, liquids and gases are arranged. (*Remember particles are so small that we cannot see them. We have used a circle as a representation of a particle simply as a matter of convenience.*)

Solid

Liquid

Gas

We hope that you have found this activity very easy to do since you have already learned about the states of matter in Unit 2. However, just in case refer to the Feedback to Activity 5.1.1 to verify your answers.

Feedback to Activity 5.1.1

Well done! We are sure that you will agree that it was not that challenging after all! You should have drawn the circles representing the particles in the solid very close together (see Figure 5.1.2), slightly further apart in the liquid (see figure 5.1.4), and far apart in the gas (see figure 5.1.6). We are going to provide more information on particles in the next section. Please note that you addressed some aspects of this topic in Unit 2, but with a slightly different focus, so go through this section carefully without assuming you know all of it already.

5.1.2 Physical states of matter: solid, liquid and gas

We can commonly define the physical states of matter by their physical characteristics. A solid has a definite shape and volume like the stone in Figure 5.1.2 A liquid has a definite volume, but not a definite shape as water and
“Fanta” in the bottles in Figure 5.2.1. A gas has neither definite volume nor shape like the air in the plastic bag in Figure 5.2.1. However, while these are true characteristics, they are not the best description of the physical state of each example. Hence, let’s take a look at the kinetic theory (explanation of particles in motion) to describe the physical states of matter.

Figure 5.1.1: Different states of matter
Photographed by Alex Souffe, August 2010

5.1.2.1 Solids

Solids - are substances whose particles have low kinetic energy. The particles of solids are held close together by intermolecular forces of attraction. The attraction between the particles of solids is so strong that the particles are held rigidly together. It is this rigidity that gives solids a definite shape and volume. Because the particles are so close together, they appear to vibrate around a fixed point.

When solids absorb heat energy, their temperature is raised as long as no melting occurs. The increase in the energy of the particles causes an increase in the kinetic energy of the particles which leads to an increase in the temperature of the substance. The collisions between the particles occur with greater force, causing the particles to move
**further apart.** Continued heating (i.e. further increase in kinetic energy) may result in a change in the orderly arrangement of the particles in the solid leading to a change in the physical state. As a result, the solid changes to a liquid. The change of state of a particular solid to liquid always occurs at a fixed temperature, which is called its **melting point.** For example, pure ice melts at 0°C as it absorbs heat energy (more details will be provided in later units).

Now you are going to carry out an activity to illustrate the arrangement of particles in a solid.

### Activity 5.1.2

You should spend approximately 20 minutes on this activity.

For this activity you will need 27 beads or large spherical fruits or seeds and some plasticine or glue and small sticks and a board.

**Procedure:** You are required to make your own model of the arrangement of particles in a solid by following the steps below.

1. Collect a set of 27 large spherical fruits or seeds of about the same size (e.g. of the Takamaka) as shown in the picture below. You may use marbles or make some clay beads as alternatives to the fruits or beads. 

2. Use plasticine or glue to stick them together to form a cubic arrangement of 3x3x3 seeds (that is length x breadth x height).

![Figure 5.1.3: Model of the arrangement of particles in solids](image)

Photographed by Louisette Bonte, August 2010

Observe your arrangement carefully. Then answer the questions below.
1. What do the seeds or beads represent in your model?

2. What does the glue or plasticine represent?

3. What is the maximum number of parts or points of contact of a seed in your regular arrangement that is stuck to other seeds?

4. Can the seeds move freely from one place to another?

5. Try to give a “gentle strike” to one of the seeds or shake the table. Is the vibration transmitted to the other seeds?

We hope that you have found this activity interesting. Refer to the Feedback to Activity 5.1.2 to verify your answers.
Feedback to Activity 5.1.2

1. The seeds or beads represent the particles (atoms, molecules or ions).

2. The glue or plasticine represents the bonding (attraction) between the different particles.

3. The maximum touching points is 6 for the seeds found in the middle of the regular arrangement (i.e. where one seed is supported onto the other).

4. The seeds cannot move from one place to another as they are firmly held together by the glue.

5. Yes, the vibrations are transmitted to the other molecules.

Now let us focus on the arrangement of the particles in liquids.

5.1.2.2 Liquids

Liquids - are substances whose particles have enough kinetic energy to overcome the intermolecular forces of attraction and can move from place to place. The attraction between particles in any liquid is great enough to hold the particles near each other, but too weak to prevent the particles from sliding around. Liquids have a definite volume but take the shape of the container.

As the temperature of a liquid is raised, the kinetic energy and velocity of the particles increase. The collisions eventually become so great that all the intermolecular forces between particles are overcome. The particles then begin moving independently between collisions, and a change in physical state occurs resulting in liquid changing into a gas. This process is called evaporation. We will look at evaporation in more detail in section 5.1.4 of this unit.
Activity 5.1.3

You should spend about 15 minutes on this activity.

For this activity you will need 27 beads or plasticine, glue or small sticks and a board. You may re-use the set of 27 large seeds used in activity 5.1.2.

Procedure: You are required to make your own model of the arrangement of particles in a liquid by following the steps below.

1. Use plasticine or glue to stick seeds together in groups of two only.
2. Allow the glue to dry.
3. Arrange them into a pile similar to the model of a solid.

Figure 5.1.5: Model of the arrangement of particles in liquids

Photographed by Louisette Bonte, August 2010

Observe your arrangement carefully before answering the questions below.
1. Gently strike one of the seeds or shake the table. What do you observe?

---

2. Compare the movement of the seeds in the two activities (Activity 5.1.2 and Activity 5.1.3). In which activity did they move more freely?

---

**Feedback to Activity 5.1.3**

1. They move about in pairs.

2. They moved more freely in activity 5.1.3.

Finally, let us focus on the arrangement of the particles in gases.

### 5.1.2.3 Gases

A **gas** is a substance whose particles **have enough kinetic energy to break all intermolecular forces of attraction**. The particles of a gas move independently of each other. The particles move at random because they have overcome the intermolecular forces of attraction.
The particles that make up a gas are completely separated from one another. Because gas particles are separated, the attractive forces between them are extremely small and are insufficient to hold gases in a definite shape or volume. Gases expand freely to fill their containers.

Gas particles are relatively far apart from each other, because they are free to move inside a container. In a closed container, pressure can be applied and you will see that the volume decreases. This means the particles move closer together with the distance between particles decreasing, while the number of particles present stays the same.

If enough force is applied to the plunger, the particles get so close together that the gas turns into a liquid. But liquids and solids cannot be compressed because their particles are already close together.

Now try the following activity to show the arrangement of particles in gases.
Activity 5.1.4

You should spend about 15 minutes on this activity.

For this activity you will need 27 beads or plasticine, and a trough or cardboard. You may re-use the set of 27 large seeds that you have used in activity 5.1.3.

**Procedure:** You are required to make your own model of the arrangement of particles in a gas by following the steps below.

1. Use a strip of stiff paper to make a frame with a diameter of 15cm or a trough as shown in Figure 5.1.8.
2. Arrange two layers of seeds inside the frame.
3. Label two of the seeds with the letter “X”.

![Figure 5.1.8: Model of particles arrangement in gases](Image)

Photographed by: Alex Souffe, August 2010

Observe your arrangement carefully, then answer the questions below after you have carried out the different steps.
1. Shake the table or the frame gently. What do you observe?

________________________________________________________________________
________________________________________________________________________

2. Do the two numbered seeds stay in the same place?

________________________________________________________________________
________________________________________________________________________

3. In which of the three arrangements do the seeds move more easily?

________________________________________________________________________
________________________________________________________________________

4. Based on the three activities (Activity 5.1.2, Activity 5.1.3 and Activity 5.1.4) what can you conclude (say) about the arrangement and level (amount) of movement of the particles in the three states of matter?

________________________________________________________________________
________________________________________________________________________

We hope that you have enjoyed the activity. Now refer to the Feedback to Activity 5.1.4 below to check your answers.
Feedback to activity 5.1.4

1. All the seeds moved freely.

2. The two numbered (marked) seeds moved about, along with the other seeds.

3. In the last arrangement (Activity 5.1.4) the seeds moved more easily.

4. Particles in solids are closer together and cannot move from one place to another. In liquids the particles are close together, but are able to move from one place to another. In gases the particles are further apart and can move more easily than in liquids.

Now that we have described the physical properties of matter in terms of the kinetic theory, let us review what you have learnt so far by completing Activity 5.1.5.
Activity 5.1.5

You should spend about 5 minutes on this activity.

Procedure: You are required to use the information provided in sub-topics 5.1.2.1, 5.1.2.2 and 5.1.2.3 above to complete the table summarising the properties of the three states of matter.

<table>
<thead>
<tr>
<th>Properties</th>
<th>Solids</th>
<th>Liquids</th>
<th>Gases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Space between particles</td>
<td>Virtually no spaces between particles</td>
<td>Very large spaces</td>
<td></td>
</tr>
<tr>
<td>Vibration of particles</td>
<td>Move fast from place to place</td>
<td>Move very fast from place to place</td>
<td></td>
</tr>
<tr>
<td>Force of attraction</td>
<td>Strong force</td>
<td>Very weak force</td>
<td></td>
</tr>
<tr>
<td>Shape</td>
<td>Has a definite shape</td>
<td>Take the shape of the container</td>
<td></td>
</tr>
<tr>
<td>Volume</td>
<td>Has a definite volume</td>
<td>Fills any container</td>
<td></td>
</tr>
<tr>
<td>Ability to be compressed</td>
<td>Cannot be compressed</td>
<td>Can be compressed</td>
<td></td>
</tr>
<tr>
<td>Ability to flow</td>
<td>Cannot flow</td>
<td>Can flow</td>
<td></td>
</tr>
</tbody>
</table>

Table 5.2.1a: Differences in the behaviour and arrangement of particles between solids, liquids and gases.

Source: Adapted from Namibia’s Unit 2, 2009.

I’m sure you will agree that this activity provides a very good summary of the properties of solids, liquids and gases. We hope that you have managed to complete the table. Please refer to the Feedback to Activity 5.1.5 below to verify your answers.
Feedback to Activity 5.1.5

<table>
<thead>
<tr>
<th>Properties</th>
<th>Solids</th>
<th>Liquids</th>
<th>Gases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Space between particles</td>
<td>Virtually no spaces between particles</td>
<td>Larger spaces</td>
<td>Very large spaces</td>
</tr>
<tr>
<td>Vibration of particles</td>
<td>Vibrate at one position</td>
<td>Move fast from place to place</td>
<td>Move very fast from place to place</td>
</tr>
<tr>
<td>Force of attraction</td>
<td>Strong force</td>
<td>Weaker force</td>
<td>Very weak force</td>
</tr>
<tr>
<td>Shape</td>
<td>Has a definite shape</td>
<td>Take the shape of the container</td>
<td><strong>Take the shape of the container</strong></td>
</tr>
<tr>
<td>Volume</td>
<td>Has a definite volume</td>
<td>Has a definite volume</td>
<td>Fills any container</td>
</tr>
<tr>
<td>Ability to be compressed</td>
<td>Cannot be compressed</td>
<td>Can only be compressed very slightly</td>
<td>Can be compressed</td>
</tr>
<tr>
<td>Ability to flow</td>
<td>Cannot flow</td>
<td>Can flow</td>
<td>Can flow</td>
</tr>
</tbody>
</table>

Table 5.2.1b: Differences in the behaviour and arrangement of particles between solids, liquids and gases.

Source: Adapted from Namibia’s Unit 2, 2009.

So far we have used the **kinetic theory** and our own model to describe the physical states of matter. Now we will turn our attention to the work done by Robert Brown to shed more light on the particulate nature of matter and the fact that they are always in constant motion.
5.1.3 Brownian Motion

About 200 years ago, a Scottish botanist, Robert Brown, was observing some pollen grains floating in a drop of water through a microscope. He noticed that the pollen grains were continuously moving about in all directions as shown in the diagram.

![Diagram of the pathway of the motion of particles in gases.](image)

Brown was unable to explain his observations, but it is now believed that his experiment is evidence for the existence of atoms and molecules. For example, molecules in a gas move constantly, freely, randomly, in all directions and at high speeds. They are able to do so because the intermolecular forces of attraction between the molecules is negligible when in a gaseous state. This constant motion of the molecules causes them to collide with anything in their path. For example, dust particles will be bombarded by the molecules moving at high speeds, causing them to have a zig-zag motion. This movement is named after Robert Brown and is called **Brownian motion**.

We can easily observe Brownian motion by looking at smoke particles under a microscope. Smoke is really small pieces of solid matter floating in the air. The air particles are too small to be visible.


**Group Activity 5.1.1**

You should spend about 20 minutes on this activity.

For this activity you will need a smoke cell apparatus, matches and cotton wool or other material to produce some smoke.
Procedure:

If you can have access to a laboratory, you may try this activity by using a smoke cell apparatus. The photograph and the steps given below will help you to carry out this activity on Brownian motion.

![Smoke cell apparatus](image)

**Figure 5.1.10: Smoke cell apparatus**

Photographed by: Louisette Bonte, August 2010

1. Fill the smoke cell with some smoke and close it immediately.

2. Place the smoke cell on the stage of the microscope as shown in Figure 5.1.11.


4. Observe carefully through the microscope, the content of the smoke cells and then answer the questions below.
1. Describe what you observed.

_________________________________________________________________
_________________________________________________________________
_________________________________________________________________

2. Explain your observations.

_________________________________________________________________
_________________________________________________________________
_________________________________________________________________

We hope that the activity was at the right level for you. To verify your answers, please refer to the Feedback to Group Activity 5.1.1 below.
Feedback to Group Activity 5.1.1

1. Bright, tiny white dots “jerking” in different directions.

2. The bright tiny white dots are in fact specks of smoke. The jerking movement was due to their collisions with the invisible air particles which were also moving randomly (in all directions).

Please note that Brownian motion also takes place in molecules in a liquid, but to a less obvious extent than in a gas. This is because the particles are closer together and experience greater intermolecular forces of attraction in liquids.

5.1.3 Evaporation

Evaporation is the process where some molecules of a liquid become a gas. It is a type of vaporization of a liquid that occurs only on the surface of a liquid. This is due to the fact that some particles (molecules) of the liquid have more energy than others. As a result they overcome the attraction forces between them and other molecules in the liquid, enabling them to escape from the surface of the liquid as shown in the diagram below.

As the high energy particles escape from the surface of the liquid, the remaining particles have on average less energy, so the liquid cools. This means that the temperature of the liquid is lowered. The cool liquid then cools the surface on which it is resting. This is called evaporative cooling.
Some common examples are when you apply perfume on your skin or when a wet towel is placed on your forehead when you have a fever. In both situations you feel cool due to the evaporation of the liquids. Your body heat is absorbed by the particles of the liquids causing the following effects:

1. an increase in the average kinetic energy of the liquids’ particles and as a result overcoming the attraction forces between molecules and;
2. your body losing heat energy to the liquids particles and as a result you feel cooler.

Hence, a liquid does not have to boil in order to change into a gas (evaporate). However, the change of state of any liquid to a gas is affected by factors that affect the kinetic energy of the particles, namely:

a. the temperature of the liquid;
b. air flow over the liquid (wind);
c. surface area of the liquid;
d. pressure above the liquid;
e. attracting forces between the molecules of the liquid.

We will discuss the concept evaporation further in a later unit.

(Source: http://wiki.answers.com/Q/What_is_evaporation)

Well, you have come to the end of Topic 5.1. Before proceeding to the next topic, let us see how much you have learnt, so far. At this stage, you should be ready to try out the self assessment below.
Self Assessment 5.1

You should spend approximately 10 minutes on this self-assessment. This self-assessment is organised into two sections. The answers are given at the end of this topic. You are strongly advised to answer all questions before you refer to the Answers to Self-assessment 5.1. This will help you learn and reflect better on areas for improvement.

Section A:

Complete these phrases by using the most suitable words.

1. All matter is composed of small particles. Particles can be ________________, ________________, or ________________.

2. The particles of matter are in constant ________________.

3. All collisions between the ________________ of matter are perfectly elastic. ________________ means that the particles bounce upon collision.

4. Particles move in a straight line between ________________.

Section B:

Answer all questions in the spaces provided.

1. What is evaporation?

_________________________________________________________________
2. State four factors that affect the rate of evaporation.

3. Explain how evaporation causes a cooling effect.

Please see our suggestions in the Answers to Self Assessment 5.1 provided at the end of the topic below to see if you were on the right track.
Answers to self-assessment 5.1

Section A
1. Molecules, atoms or ions
2. Motion
3. Particles, elastic

Section B:
1. Evaporation is the process where some of a liquid becomes a gas.
2. Temperature, molecular attraction force, surface area and pressure.
3. Evaporation causes a cooling effect because it is the energy of the molecules in the system that is used by some of the molecules to cause them to overcome the attraction force of the liquid molecules. This leaves the remaining molecules within the system with less energy.

This brings us to the end of topic 5.1. Reflect back on what you learned in this topic. What is significant about moving particles? What happens to these particles as energy is added to them?

In topic 5.2, we will examine the behavior of gas molecules. Judging from what you learned in topic 5.1, I am sure you will be able to predict how gases will behave in some situations. Let’s move on to learn more about gases.

Topic 5.2: The behaviour of gas molecules

You will need 4 hours and 10 minutes at the most to do the activities in this topic. It is advisable that you spend another 2 hour and 5 minutes of your own time to further practise the activities learnt. Make sure you read and understand everything in order to achieve the outcomes.

As you have seen in Topic 5.1, solids, liquids and gases behave differently when they gain heat energy. Now we are going to investigate the behaviour of
particles (molecules) in a fixed mass of gas when subjected to variations in pressure, volume and temperature.

To find the laws linking pressure, volume and temperature experimentally, each factor has to be kept constant (the same) while the relation between the other two factors is tested. We will start off by looking at the relationship between pressure and volume of a fixed mass of a gas at constant temperature.

5.2.1 Relationship between gas pressure and gas volume

The relationship between the pressure applied to a gas and the volume it occupies will be demonstrated by conducting a simple experiment using a plastic syringe or a bicycle pump similar to the arrangement shown in the diagram below.

Total Pressure = Pressure due to Weight + Pressure due to Atmosphere

![Materials Needed](image)

**Figure 5.2.1: Apparatus for pressure and volume measurements**

Set up ad photographed by Louisette Bonte, August 2009.

The pressure on the gas will be changed by applying different forces. The magnitude of the force could be controlled by using standard weights or different objects of the same mass (e.g. books) to be placed on top of the plunger of the syringe. The total pressure acting on the gas consists of the standard weights (or the books). (We are going to ignore atmospheric pressure).
You are now going to carry out an activity to illustrate the effect of pressure on a gas.

Activity 5.2.1

You should spend about 25 minutes on this activity.

Experimental Steps:

Refer to Figure 5.2.1 to help you to better comprehend the following steps.

1. Set the plunger at the 100 cm$^3$ mark of a dry syringe.
2. Plug the tip of the syringe inserting it into a tiny hole in the rubber stopper. (You may use an alternate method).
3. Clamp the syringe-stopper arrangement in an upright position, as shown in the diagram. Do not tighten the syringe too much, for the cylinder will be distorted and the plunger will not move freely. This will affect your results.
4. Carefully place one weight on top of the plunger. (If necessary steady and centre the weight, and take the reading of the volume of gas trapped in the syringe).
5. Record the reading in the table below.
6. Repeat by adding 2 weights and record the volume. Continue in this manner until a pressure of 4 weights is obtained and all readings are recorded in Table 5.2.1 below.

Please note that if the syringe does not return to the original volume when the weights are removed, you should NOT attempt to correct it!
<table>
<thead>
<tr>
<th>Pressure (weight)</th>
<th>Volume measurement</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Result 1 (R1)</td>
<td>Result 2 (R2)</td>
<td>Result 3 (R3)</td>
<td>Average volume in cm³</td>
</tr>
<tr>
<td>1 × 1 kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 × 1 kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 × 1 kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 × 1 kg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5.2.1: Pressure and volume measurements

7. Repeat the experiment at least 3 times and record your results in Table 5.2.1, then calculate the average volume for each of the different sets of values of volume.

Please remember that the average volume is calculated by adding the three values of volume and dividing the sum by three as shown below.

\[
\frac{(R1 + R2 + R3)}{3}
\]

Now answer the questions that follow.

1. What happens to the volume of the air in the syringe as the pressure (number of books) is increased?

2. Do you think there is a change in the number of particles inside the syringe?
3. Do you think the mass of the air has changed with an increase in the external pressure?

We hope that the activity was interesting for you. To verify your answers, please refer to the Feedback to Activity 5.2.1 below.

**Feedback to Activity 5.2.1**

1. The volume decreases as the pressure is increased.
2. No, there is no change in the number of particles.
3. No, there is no change in mass.

In the event that you could not do the above experiment, we believe that you may have fiddled with a bicycle pump (inflator) where you have blocked the exit while you applied a downward force on the handle. In so doing, you noticed that the volume of the trapped air decreased as the pressure on the handle was increased.
**Activity 5.2.2**

You should spend approximately 30 minutes on this activity.

To help you better understand the relationship between pressure and the volume of a fixed mass of gas at constant temperature, consider the data given in Table 5.2.2 below.

<table>
<thead>
<tr>
<th>Pressure (p) (x 100 kPa)</th>
<th>Volume (V) (dm$^3$)</th>
<th>$P \times V$</th>
<th>$1/V$</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) 0.5</td>
<td>2.0</td>
<td>0.5 x 2.0 = 1.0</td>
<td>0.5</td>
</tr>
<tr>
<td>b) 1.0</td>
<td>1.0</td>
<td>1.0 x 1.0 =</td>
<td></td>
</tr>
<tr>
<td>c) 2.0</td>
<td>0.5</td>
<td>2.0 x 0.5 =</td>
<td></td>
</tr>
<tr>
<td>d) 4.0</td>
<td>0.25</td>
<td>4.0 x 0.25 =</td>
<td></td>
</tr>
<tr>
<td>e) 10.0</td>
<td>0.1</td>
<td>10.0 x 0.1 =</td>
<td></td>
</tr>
</tbody>
</table>

Table 5.2.2: Data of pressure and volume


1. Complete Table 5.1.1 by calculating the reciprocal of volume ($1/V$) for each of the values of volume given in the table. (Check your answer by referring to the feedback section at the end of the topic).

2. Now, use the data to draw two graphs:
   i. Pressure against volume. Plot the pressure (in kilopascal) on the vertical (Y) axis and volume (in dm$^3$) on the horizontal (X) axis. Draw a best fit curved line through your points.
ii. Pressure against reciprocal volume. Use the values for pressure and the reciprocal of volume to draw a second graph. Plot the reciprocal volume (i.e. one over $v$ (1/v)) on the horizontal (X) axis and pressure on the vertical (Y) axis. Be sure to start with $x = 0$ at the origin. Draw a straight best fit line through your points, and extend your line to the (Y) axis.
3. Now answer the following questions.
   
i. What is the shape of:
   
   a. the graph of pressure (p) against volume (V)

   b. pressure (p) against reciprocal volume (1/V)?

   ii. Extend the graph of pressure against reciprocal volume (1/V) with a dotted line. Where does it cut the x and y axes?

   iii. What is the relationship between pressure and the reciprocal volume? Explain your answer.

   iv. What is the relationship between pressure and the volume? Explain your answer.
v. Complete the fourth column in Table 5.2.2 by multiplying the corresponding values of P and V. (The first one has been done for you). What do you notice?

I hope that you have found the activity easy to complete. Please refer to the Feedback to Activity 5.2.2 below.

**Feedback to Activity 5.2.2**

1. | Pressure (p) | Volume (V) | P x V     | 1/V |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>a. 0.5</td>
<td>2.0</td>
<td>0.5 x 2.0 = 1.0</td>
<td>0.5</td>
</tr>
<tr>
<td>b. 1.0</td>
<td>1.0</td>
<td>1.0 x 1.0 = 1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>c. 2.0</td>
<td>0.5</td>
<td>2.0 x 0.5 = 1.0</td>
<td>2.0</td>
</tr>
<tr>
<td>d. 4.0</td>
<td>0.25</td>
<td>4.0 x 0.25 = 1.0</td>
<td>4.0</td>
</tr>
<tr>
<td>e. 10.0</td>
<td>0.1</td>
<td>10.0 x 0.1 = 1.0</td>
<td>10.0</td>
</tr>
</tbody>
</table>

Table 5.2.2: Data of pressure and volume


2. The two graphs you have drawn should look similar to the ones shown
3.  i (a) A smooth curve.  (b) A straight line.
   ii At the origin (i.e.0,0).
   iii They are directly proportional.
   iv They are inversely proportional.  When one quantity is doubled the other one is halved.
   v All the answers are the same (1.0) or constant.

Good work!  We are now going to move on to the last stage of this section; the Mathematical relationship between pressure and volume and how the relationship can be explained by the kinetic theory.

5.2.2 Mathematical expression of the relationship between pressure and volume

Your observations in the above activity are no different from those made by scientists many, many years ago.  They proved that for a fixed mass of gas at constant temperature, its pressure and volume are inversely proportional.  This can be recognized in two ways:

When the pressure of a fixed mass of a gas is reduced, the volume increases, but the value of pressure multiplied by the value of volume gives a constant value.
When the pressure of a fixed mass of a gas is halved, the volume is doubled, and so on.

In fact their findings can be expressed in the form of a law as follows:

**The pressure of a fixed mass of gas is inversely proportional to its volume, provided the temperature remains the same (constant).**

The above relationship was first proved by a scientist, named Robert Boyle in 1662. The relationship is known as **Boyle’s Law**, in honour of its discoverer.

In symbolic or Mathematical form it can be put as \( p \propto \frac{1}{V} \).

At this stage we will ask you to refer to Table 5.2.2. Choose any value of \( \frac{1}{V} \) and multiply it by the corresponding value obtained by multiplying \( p \) and \( V \) (constant). For example: (a) \( 0.5 \times 1.0 = 0.5 \), (b) \( 1.0 \times 1.0 = 1.0 \), and so on. You should have noticed that all the answers correspond to the different values of \( p \) in Table 5.2.2.

Therefore, we can say that \( p = \text{constant} \times \frac{1}{V} \). Once again refer to Table 5.2.2. What do you notice about the product of each corresponding set of values \( (p \times V) \)?

Good observations! All the values are the same. Therefore, \( p \times V = \text{constant} \) (normally denoted by \( k \)). Now let us focus on the first (a) and fourth (d) set of values given in Table 5.2.2. We will consider the first set of values where the pressure 0.5 could be called the **initial pressure** and is denoted by \( "p_1" \), and the volume 2.0 could be called **initial volume** and is denoted by \( "V_1" \), and the product of \( p_1 \) and \( V_1 \) is 1.0. This can be represented symbolically as:

\[
p_1V_1 = 1.0 \cdots \text{equation (1)}
\]

Similarly, let us consider the pressure in (d) as pressure in the second instance which is denoted by \( "p_2" \) and the volume in the second instance which is denoted by \( "V_2" \) and the product of \( p_2 \) and \( V_2 \) is 1.0 as well. This can also be represented symbolically as:
\[ p_2 V_2 = 1.0 \] equation (2)

Given that the products of the two sets of values (a) and (d) are equal, the two equations could be combined to give:

Both products have the same value of 1.0, which is a constant \( k \).

\[ p_1 V_1 = k = p_2 V_2 \]

This equation is based on Boyle’s law, involving the relationship between pressure and volume of a fixed mass of a gas at constant temperature. Therefore, it is not surprising that this equation \( p_1 V_1 = p_2 V_2 \) is known as the **Boyle’s Law equation**. You should have also noticed that the value \( p_2 \) (4) was made eight times greater than \( p_1 \) (0.5) and \( V_2 \) (0.25) was reduced to a volume eight times less compared to \( V_1 \) (2.0).

Now you should be ready to apply the **Boyle’s Law** equation to solve problems. We shall start off by taking you through one example.

**Example 5.2.1**

A sample of gas collected in a 400 cm\(^3\) container exerts a pressure of 100 kPa (kPa means kilopascal) on the wall of the container. What would be the volume of this gas if the pressure is increased to 200 kPa? (Assume that the temperature remains constant.)

**Steps for solving the problem:**

List what is given and what is unknown.

\[ p_1 = 100 \text{ kPa} \]
\[ V_1 = 400 \text{ cm}^3 \]
\[ p_2 = 200 \text{ kPa} \]
\[ V_2 = ? \]
Think of the relationship, and then write the original formula:

\[ p_1V_1 = p_2V_2 \]

Next, see if you can predict what will happen. In this case the pressure has increased, so the volume should decrease.

Then, adjust the original formula to make the unknown the subject. In this case the subject is \( V_2 \).

\[ \frac{p_1V_1}{p_2} = \frac{p_2V_2}{p_2} \]

\[ V_2 = \frac{p_1V_1}{p_2} \]

Substitute values:

\[ V_2 = \frac{100\text{kPa} \times 400\text{cm}^3}{200\text{kPa}} \]

Answer: \( V_2 = 200 \text{ cm}^3 \)

Please note that from this example the pressure has doubled (from 100 to 200 kPa so, as we predicted, the volume of the gas has reduced by half (from 400 to 200cm³).

**Activity 5.2.3**

You should spend approximately 15 minutes on this activity.

Now try these questions. Show your work in the box provided.

1. A student partially filled a syringe with 100 cm³ of air at a pressure of 1 atmosphere. The nozzle of the syringe was sealed. The piston was pushed in slowly until the volume was 50 cm³. What is the pressure being exerted on the gas now?
2. A mass of a gas occupies a volume of 1200 cm³ at a fixed temperature and a pressure of 2 atmospheres. Calculate the volume of the gas when the pressure is increased to 3 atmospheres and the temperature is kept constant.
1. List what is given and what is unknown:

\( p_1 = 1 \text{ atm}; V_1 = 100 \text{ cm}^3; V_2 = 50 \text{ cm}^3 \)

\( p_2 = ? \)

\( p_1 V_1 = p_2 V_2 \)

\[
\frac{p_1 V_1}{V_2} = \frac{p_2 V_2}{V_2}
\]

\( p_2 = \frac{1 \text{ atm} \times 100 \text{ cm}^3}{50 \text{ cm}^3} \)

Pressure = 2 atm

2. List what is given and what is unknown:

\( p_1 = 2 \text{ atm}; V_1 = 1200 \text{ cm}^3; p_2 = 3 \text{ atm}; \)

\( V_2 = ? \)

\( p_1 V_1 = p_2 V_2 \)

\[
\frac{p_1 V_1}{p_2} = \frac{p_2 V_2}{p_2}
\]

\( V_2 = \frac{p_1 V_1}{p_2} \)

\( V_2 = \frac{2 \text{ atm} \times 1200 \text{ cm}^3}{3 \text{ atm}} \)
\[ V_2 = 800 \text{ cm}^3 \]

\[ \text{Volume} = 800 \text{ cm}^3 \]

Well done! I hope that you did not find these questions too challenging.

### 5.2.3 Boyle’s Law and the Kinetic Theory

Now that you are familiar with both Boyle’s law and the Kinetic theory you are ready to study the relationship between the two. In order to gain a better understanding of the relationship between Boyle’s law and the kinetic theory, you should try the simple activity suggested below.

Remember, the kinetic theory explains the behaviour of particles and Boyle’s law is about the relationship between pressure and volume of a gas.
Activity 5.2.4

You should spend about 15 minutes on this activity.

Study the diagram carefully and then follow the experimental steps closely. You do not need to have access to a laboratory to do this activity.

![Photo of marked plastic bag]

Figure 5.2.3a: Photo of marked plastic bag.
Photographed by: Louisette Bonte, September 2010

Experimental steps

1. Use a new plastic bag that has no holes.

2. Remove all the air from the plastic bag by flattening it on a table.

3. Use a marker to draw three lines across the plastic bag so that it is divided into approximately four equal parts as shown in Figure 5.2.3a.

4. Use a straw to half fill the plastic bag with air by blowing gently. (Caution: do not make it too hard as the plastic will burst.)

5. Remove the straw and tie the bag firmly at the three quarter mark (i.e. the upper line) so that the air does not escape.

6. Hold the bag at the point it has been tied firmly and gently twist it until the twisted part reaches the half way mark. Feel the bag as you twist.
Using your observations in the activity you have carried out about the air in the plastic bag after it was twisted, complete the table below by putting a tick in one of the boxes that best represents your observations or inferences for each quantity.

<table>
<thead>
<tr>
<th>Quantities</th>
<th>Remain the same</th>
<th>Increased</th>
<th>Decreased</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Volume of air</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. Temperature of the air</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. Pressure of the air</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d. Distance between air particles</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5.2.3: Table to record observations

Figure 5.2.3b: Photo of marked and twisted plastic bag.

Photographed by: Alex Souffé, September 2010
Feedback to Activity 5.2.4

Good observations!

Remained the same (b), Decreased (a) and (d), Increased (c).

We hope that you were not too nervous while twisting the bag. The air particles were subjected to an external pressure causing them to move closer together. By being closer together, the same number of moving molecules occupied less volume, but their rate of collision with the wall of the plastic bag increased. The decrease in volume has also resulted in a decrease in the surface area of the inside wall, and the increase in collision rate on the reduced area of wall of the bag led to the increase in pressure (bag felt harder).

In terms of the particle theory there is far more impact (i.e. as if more particles are exerting forces) on each square centimetre (cm$^2$) of the inner sides of the plastic bag, causing an increase in the pressure which is in accordance with Boyle’s Law.

5.2.4 Relationship between volume and temperature of a gas

Now we are going to study the relationship between volume and temperature of a gas at constant pressure. If you have access to a laboratory and the assistance of a science teacher you may try this experiment. Study the diagram carefully and then follow the experimental steps.
Activity 5.2.5

You should spend about 15 minutes on this activity.

Experimental Steps:

Refer to the Figure 5.2.4 to help you to better understand the whole process.

![Diagram of set up to investigate the relationship between volume and temperature of a gas.](image)

1. Use a plastic or glass syringe which measures in cm$^3$.
2. Remove the piston and lubricate it.
3. Insert the lubricated piston into the syringe and leave it at the half way mark.
4. Use a short piece of rubber tubing and a clip to seal the outlet of the syringe so that it is half filled with air.
5. Use a retort stand to submerge the syringe in a beaker of tap water in a vertical position.
6. Use a thermometer to measure the temperature of the water.
7. Leave it for 3 minutes so that the temperature of the trapped air becomes the same as that of the water.

8. Record the temperature and the volume of the trapped air.

9. Without adjusting the syringe, repeat step 5 but use boiling water instead of tap water and record the measurement after 1 minute.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Temperature (°C)</th>
<th>Gas volume (cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tap water (30 °C)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hot water (90 °C)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Questions**

1. What did you notice?

2. If the syringe was placed in very cold water instead, what would have happened?
Feedback for activity 5.2.5

1. When the syringe of air was placed in hot water (90 °C) the plunger moved outwards and the volume of the trapped air was increased.

2. In cold water the plunger would move inwards and the volume of air would decrease.

Good! What you have done has also been proven by scientists. They carried out even more controlled experiments to understand the relationship between the volume and the temperature of gases. Let us consider some of the measurements that they obtained. To help you better understand, let us consider the data given in Table 5.2.4 below.

<table>
<thead>
<tr>
<th>Volume in mm³</th>
<th>Temperature in °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>127</td>
<td>16</td>
</tr>
<tr>
<td>134</td>
<td>32</td>
</tr>
<tr>
<td>139</td>
<td>46</td>
</tr>
<tr>
<td>152</td>
<td>71</td>
</tr>
<tr>
<td>159</td>
<td>89</td>
</tr>
</tbody>
</table>

Table 5.2.4: Measurements of volume and temperature
Activity 5.2.6

You should spend about 15 minutes on this activity.

Use the information in the table to draw a graph of volume against temperature in °C. Plot the volume (in mm³) on the vertical (Y) axis and the temperature (in °C) on the horizontal (X) axis. Through the points on your graph, draw the best fit straight line, and extend your line until it intersects both the (Y) and (X) axes. (Scale: 1 small square represents 5 mm³ on the vertical axis and 5 °C on the horizontal axis)

Figure 5.2.5: Grid for drawing the graph of volume against temperature

Sketched by Lionel Goonetilleke, September 2010

Questions

1. What does the graph indicate about the way the volume of the air
changes as the temperature increases?

2. What is the volume of the gas when the temperature is 0 °C?

3. What is the temperature when the volume of gas is 0 mm³?
Feedback for activity 5.2.6

You should have obtained a graph similar to the one shown below in figure 5.2.6.

Graph showing volume against temperature

![Graph showing volume against temperature](image)

Figure 5.2.6: Graph of volume against temperature

Sketched by Lionel Goonetilleke, September 2010

1. The volume of the gas increases uniformly (indicated by the straight line graph) as the temperature of the gas increases and vice versa.

2. about 124 mm³

3. about -273 °C

Well done! So far you have learnt that matter is made up of particles. Particles in gases are further apart and are free to move at different speeds depending on their temperature. When the temperature of a gas is lowered the speed of the particles also lowers and they occupy less volume (space). If the cooling process is continued the gas changes state. Normally, this happens to all gases.
From the graph the limit of coldness is -273 °C. This value (-273 °C) is referred to by scientists as the **absolute zero**. Remember the scientists obtained this value through very careful experiments. The scale starting from absolute zero (-273 °C) is called the **kelvin** or the **absolute temperature scale**.

**One division** on the Kelvin scale is equal to **one division** on the Celsius scale. Hence, -273 °C is equal to 0K, 0 °C is equal to 273K and 100 °C is equal to 373K. To convert from a Celsius temperature (t) to Kelvin temperature (T) simply add 273 to the Celsius value; i.e. \( T = t + 273 \).

### Activity 5.2.7

You should spend 15 minutes on this activity.

To help you apply this equation (\( T = t + 273 \)) we are going to ask you to complete Table 5.2.5. The first one has been done for you.

<table>
<thead>
<tr>
<th></th>
<th>Volume (mm(^3))</th>
<th>Temperature (°C)</th>
<th>Temperature (K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a)</td>
<td>127</td>
<td>16</td>
<td>289</td>
</tr>
<tr>
<td>b)</td>
<td>134</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>c)</td>
<td>139</td>
<td>46</td>
<td></td>
</tr>
<tr>
<td>d)</td>
<td>152</td>
<td>71</td>
<td></td>
</tr>
<tr>
<td>e)</td>
<td>159</td>
<td>89</td>
<td></td>
</tr>
</tbody>
</table>

Table 5.2.5: Measurements of volume and absolute temperature
Feedback for activity 5.2.7

We hope you found this easy! Check your answer by referring to the feedback below.

<table>
<thead>
<tr>
<th></th>
<th>Volume (mm³)</th>
<th>Temperature (°C)</th>
<th>Temperature (K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a)</td>
<td>127</td>
<td>16</td>
<td>289</td>
</tr>
<tr>
<td>b)</td>
<td>134</td>
<td>32</td>
<td>305</td>
</tr>
<tr>
<td>c)</td>
<td>139</td>
<td>46</td>
<td>319</td>
</tr>
<tr>
<td>d)</td>
<td>152</td>
<td>71</td>
<td>344</td>
</tr>
<tr>
<td>e)</td>
<td>159</td>
<td>89</td>
<td>362</td>
</tr>
</tbody>
</table>

Table 5.2.5: Measurements of volume and absolute temperature

We have used the calculated data for Table 5.2.5 found above to draw a graph of volume against absolute temperature (K).
The graph of volume against absolute temperature in kelvin that we have drawn is also a straight line, like the graph of volume against temperature in degrees Celsius. However, the marked difference is that the line passes through the orgin (00), so there is a direct proportionality between the absolute temperature and the volume of a fixed mass of a gas. This means that as the temperature increases so too does the volume. Furthermore, the graph passing through the origin indicates that at 0 K, the volume of the gas is also zero but in reality the gas will turn to liquid before reaching 0 K.

The graph we have drawn in Figure 5.2.7, is similar to what scientists obtained a long time ago. In fact these findings can be expressed in the form of a law as follows:

The volume (V) of a fixed mass of gas is directly proportional to its absolute temperature (T) provided the pressure of the gas is kept constant.

The above relationship was first proved by a scientist, named Jacques Charles in 1787. This is known as Charles’ Law, in honour of its discoverer.
In symbolic or mathematical form it can be stated as $V \alpha T$.

At this stage we will ask you to refer to Table 5.2.4. Choose any value of volume and divide it by the corresponding value of absolute temperature. You should notice that all the answers are the same.

Therefore we can say that $V / T = k$.

Now let us focus on the first (a) and the third (c) sets of values given in Table 5.2.4. We will consider the first set of values where the volume could be called the initial volume and is denoted by "$V_1" and the corresponding initial absolute temperature could be called "$T_1" and the quotient of $V_1 / T_1$. This can be represented symbolically as:

$V_1 / T_1 = 0.439$ which to the nearest hundredth is 0.44 equation (1).

Similarly, let us consider the volume in (c) as volume in the second instance and is denoted by "$V_2" and the temperature in the second instance and is denoted by "$T_2" and the quotient of $p_2$ and $V_2$ is 1.0 as well. This can also be represented symbolically as:

$V_2 / T_2 = 0.436$ which to the nearest hundredth is 0.44 equation (2)

Given that the quotient of the two sets of values (a) and (c) are equal, the two equations could be combined to give:

$V_1 / T_1 = V_2 / T_2$

This relationship $V \alpha T$ is read as "volume is directly proportional to the absolute temperature”

The answers to both questions are the same which is 0.44, a constant ($k$).

$V_1 / T_1 = k = V_2 / T_2$

This equation is based on the Charles’ law, involving the relationship between volume and absolute temperature of a fixed mass of a gas at constant pressure. Therefore it is not surprising that this equation “$V_1 / T_1 = V_2 / T_2$” is known as the Charles’ Law equation. Now you should be ready to apply Charles’ Law equation to solve problems. We shall start off by taking you through one example.
Example:

A sample of gas collected in a 400 cm$^3$ container is at 27 °C. What would be the volume of this gas if the temperature is increased to 57 °C? (Assume that the pressure remains constant.)

Steps for solving the problem:

List what is given and what is unknown.

$V_1 = 400$ cm$^3$

$T_1 = (27 + 273) \text{ K} = 300\text{K}$

$T_2 = (57 + 273) \text{ K} = 330\text{K}$

$V_2 = ?$

Think of the relationship, then write the original formula:

$\frac{V_1}{T_1} = \frac{V_2}{T_2}$

Next, see if you can predict what should happen. In this case the absolute temperature has increased, so the volume should increase because there is a direct proportionality between the two quantities.

Then, adjust the original formula to make the unknown the subject. In this case the subject is $V_2$.

$\frac{V_1 T_2}{T_1} = \frac{V_2 T_2}{T_2}$

$V_2 = \frac{V_1 T_2}{T_1}$

$V_2 = \frac{400\text{cm}^3 \times 330\text{K}}{300\text{K}}$

$V_2 = 440 \text{ cm}^3$

(NB: From this example you should have noticed that as the temperature increased the volume increased as well.)
Activity 5.2.8

You should spend 10 minutes on this activity.

Now try these questions.

1.  A student partially filled a syringe with 100 cm$^3$ of air at a temperature of 32 ºC. The nozzle of the syringe was sealed. The syringe was then placed in refrigerator at a temperature of 7 ºC for one hour. What was the volume of the gas? (NB: Throughout the exercise the pressure of the air in the syringe remained constant and the friction of the plunger was negligible).

2.  A fixed mass of a gas occupies a volume of 1200 cm$^3$ at a temperature of 17 ºC. The gas was heated and the volume increased to 1407 cm$^3$ and the pressure was kept constant throughout. Calculate the temperature to which the gas was heated?

Feedback for activity 5.2.8

1.  List what is given and what is unknown.

\[ V_1 = 100 \text{ cm}^3; \; T_1 = (32 + 273) \text{ K}; \; T_2 = (7 + 273) \text{ K}; \; V_2 = ? \]

\[ V_2 = \frac{V_1 T_2}{T_1} \]

\[ V_2 = \frac{100 \text{ cm}^3 \times 280 \text{ K}}{305 \text{ K}} \]

\[ V_2 = 91.80 \text{ cm}^3 \]

2.  List what is given and what is unknown.

\[ V_1 = 1200 \text{ cm}^3; \; T_1 = (17 + 273) \text{ K}; \; V_2 = 1407 \text{ cm}^3; \; T_2 = ? \]
\[ T_2 = \frac{T_1 V_2}{V_1} \]

\[ T_2 = \frac{290K \times 1407\text{cm}^3}{1200 \text{cm}^3} \]

\[ T_2 = 340 \text{ K or 67 ºC} \]

Well done! Now you are ready to handle any questions involving Charles’ Law and ready to study the relationship between pressure and temperature of a gas.

### 5.2.5 Relationship between pressure and temperature of a gas

Now we are going to study the relationship between pressure and temperature of a fixed mass of a gas at constant volume. If you could have access to a laboratory and the assistance of a science teacher you may try this experiment. Study the diagram carefully and then follow the experimental steps.

![Bourdon gauge](Bourdon gauge)
![Tripod](Tripod)
![Thermometer](Thermometer)
![Retort stand](Retort stand)
![Round bottomed flask](Round bottomed flask)
![Beaker](Beaker)

**Figure 5.2.8**: Photograph of set up to investigate the relationship between pressure and temperature of a gas.

Photographed by Lionel Goonetilleke, August 2010
Activity 5.2.9

You should spend 10 minutes on this activity.

Experimental Steps:

1. Refer to Figure 5.2.8 to help you to better understand the whole process. Normally, students are asked to:

   - Set up the apparatus as shown in figure 5.2.8.
   - Seal the glass container to ensure that the air in it does not escape. This will ensure that the volume of air is kept constant throughout the experiment.
   - Heat the water around the round-bottomed flask in stages (e.g. 30, 40, 50, 60 and 70 °C) to increase the temperature of the air.
   - At each stage, the pressure of the air is measured on the Bourdon gauge (the flexible plastic tubing should be as short as possible to reduce the amount of air of different temperature).
   - Record your data for pressure and temperature in the table below.

<table>
<thead>
<tr>
<th>Pressure (N/m²)</th>
<th>Temperature (°C)</th>
<th>Temperature (K)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(Remember that you have to convert all the temperature measurements in degrees Celsius to Kelvin by adding 273 to each value.)

In the event that you cannot do the experiment, study the data given in table 5.2.5 below.
<table>
<thead>
<tr>
<th>Pressure (kPa)</th>
<th>Temperature (°C)</th>
<th>Temperature (K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>102</td>
<td>27</td>
<td>300</td>
</tr>
<tr>
<td>111</td>
<td>52</td>
<td>325</td>
</tr>
<tr>
<td>119</td>
<td>77</td>
<td>350</td>
</tr>
<tr>
<td>122</td>
<td>87</td>
<td>360</td>
</tr>
</tbody>
</table>

Table 5.2.6: Pressure and Temperature measurements

2 Use the data you have obtained from the experiment or the ones in Table 5.2.6 to draw a graph of pressure (y-axis) against temperature in °C (x-axis).

Figure 5.2.9: Grid for drawing the graph of pressure against reciprocal temperature
Questions

1. What is the shape of the graph?

2. Use the graph to work out the gas pressure when the temperature is 80 °C.

3. Extend the graph with dotted line. Where does it cut the x and y axes?

4. What is the relationship between the Kelvin temperature and the pressure of the fixed mass and constant volume of gas?

5. Explain in term of the behaviour of particles what causes the increase in pressure as the temperature increases?
Feedback for activity 5.2.9

2. If you have used the data from Table 5.2.5, your graph should be similar to the one given below.
Answers to questions:

1. Straight line.

2. 237.5 °C

3. At the origin (at 0 K, 0 N/m²).

4. For a fixed mass of gas, at constant volume, the pressure (p) is directly proportional to the absolute temperature (T).

5. As the temperature is increased the particles move faster and strike the wall of the container at a higher rate with greater force. This results in higher pressure.

From the graph you have drawn, you should have noticed all the usual signs of a simple proportion:

a. The graph is a straight line passing through the origin (0,0).

b. Doubling the absolute temperature (K) of the air doubles the pressure.

c. Dividing the pressure of the air by its absolute temperature always produces the same (constant) value.

Your observations are not too different from those made by scientists many years ago. In fact they used better equipment and they obtained more accurate results than you did. From their findings they were able to sum up their
observations in a law which states that:

The pressure of a fixed mass of gas is directly proportional to its absolute temperature provided the volume of the gas is kept constant.

This is known as the **Pressure Law**.

In Mathematical form it can be stated as $p \alpha T$.

At this stage we will ask you to refer to Table 5.2.5. Choose any value of pressure and divide it by the corresponding value of absolute temperature. You should notice that all the answers are the same.

Therefore we can say that $p \div T = k$.

Now let us focus on the first (a) and third (b) set of values given in Table 5.2.5. We will consider the first set of values where the volume could be called the initial pressure and is denoted by “$p_1$” and the corresponding initial absolute temperature could be called “$T_1$” and the quotient of $p_1 \div T_1$ can be represented symbolically as:

$$p_1 / T_1 = 0.34 \quad \text{equation (1)}.$$

Similarly, let us consider the pressure in (b) as pressure in the second instance and is denoted by “$p_2$” and the temperature in the second instance and is denoted by “$T_2$” and the quotient of $p_2$ and $T_2$ is 0.34 as well. This can also be represented symbolically as:

$$p_2 / T_2 = 0.34 \quad \text{which to the nearest hundredth is 0.34 \quad \text{equation (2)}}$$

Given that the quotient of the two sets of values (a) and (b) are equal, the two equations could be combined to give:

$$p_1 / T_1 = k = p_2 / T_2$$

The answers to both questions are the same which is 0.34, a constant ($k$).
This equation is based on the **Pressure law**, involving the relationship between pressure and absolute temperature of a fixed mass of a gas at constant volume. Hence, this equation “\( \frac{p_1}{T_1} = \frac{p_2}{T_2} \)” is known as the Pressure Law equation. Now you should be ready to apply this Law to solve problems. We shall now invite you to go through one example.

**Example:**

A driver pumps each tyre of his car very early in the morning and sets out on a long journey. The temperature was 22 °C and the pressure in each tyre was 230 kPa. At the end of his journey the temperature of the air in the tyres has increased to 42 °C.

Calculate the pressure of the air in the tyres just at the end of his journey. Assume that the volume of the tyres does not change.

**Steps for solving the problem:**

1. List what is given and what is unknown.

   \[ p_1 = 230 \text{ kPa} \]
   \[ T_1 = (22 + 273) \text{ K} = 295 \text{K} \]
   \[ T_2 = (42 + 273) \text{ K} = 315 \text{K} \]
   \[ p_2 = ? \]

2. Think of the relationship, then write the original formula:

   \[ \frac{p_1}{T_1} = \frac{p_2}{T_2} \]

3. Next, see if you can predict what should happen. In this case the absolute temperature has increased, so the pressure should increase because there is a direct proportionality between the two quantities.

4. Then, adjust the original formula to make the unknown the subject. In this case the subject is \( p_2 \).

   \[ \frac{p_1 T_2}{T_1} = \frac{p_2 T_2}{T_2} \]

   \[ \frac{p_1 T_2}{T_1} = p_2 \]
\[ p_2 = \frac{p_1 T_2}{T_1} \]

\[ p_2 = \frac{230 \text{ kPa} \times 315 \text{ K}}{295 \text{ K}} \]

\[ p_2 = 245.6 \text{ kPa} \]

(NB: From this example you should have noticed that the temperature increased and the pressure increased as well.)

Well, you have come to the end of Topic 5.2. Before proceeding to the next topic, let us see how much you have learnt, so far. At this stage, you are ready to try out the self assessment exercise below.
Self-assessment 5.2

You need approximately 30 minutes to do the self assessment which is organised into two sections. The answers are given at the end of this topic. You are strongly advised to answer all questions before you refer to the Answers to Self-assessment 5.2. This will help you learn and reflect better on areas for improvement.

Part A:

Complete these sentences with the most suitable words:

1. The three states of matter are ________________, ________________ and ________________.

2. The particles of a solid have ________________ kinetic energy. This is because the particles in solids experience strong ________________ forces of attraction.

3. The intermolecular forces of attraction between particles in a liquid are great enough to hold the particles near each other, but ________________ to prevent the particles from sliding around.

4. ________________ have a definite volume, but take the shape of their container.

5. The velocity or kinetic energy of the particles of liquids or gases increases as the ________________ increases.

6. Based on Boyle’s law, for a ________________ mass of a gas, at constant ________________ the product of ________________ ×
7. At the absolute temperature (-273ºC) particles have ____________ energy than at zero degree Celsius.

Part B:

Complete the table and the questions below.

1. Complete the table by converting the different temperatures.

<table>
<thead>
<tr>
<th>Temperature in (ºC)</th>
<th>Temperature in (K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. -273</td>
<td>0</td>
</tr>
<tr>
<td>b. -100</td>
<td></td>
</tr>
<tr>
<td>c.</td>
<td>273</td>
</tr>
<tr>
<td>d. 37</td>
<td></td>
</tr>
<tr>
<td>e.</td>
<td>373</td>
</tr>
</tbody>
</table>

For question 2 to 4, select and circle the best response.

2. When the temperature of a gas rises at constant volume, its molecules
   A. move closer to one another.
   B. move with greater average speed.
   C. collide with one another less often.
   D. exert smaller forces on one another.

3. As part of the décor for parties, inflated balloons are used. During the day when it is much warmer, the balloon becomes larger and much smaller than during the night when it is much cooler.
How does the behaviour of the air molecules in the balloon explain this?

A. The molecules become larger and move slower.
B. The molecules evaporate at a faster rate.
C. The molecules move more quickly and collide with the balloon walls more often.
D. The molecules repel each other and collide with the wall.

4. A student places her thumb firmly on the outlet of a bicycle pump, to stop the air from coming out. What happens to the pressure and to the volume of the trapped air as the pump handle is pushed in?

<table>
<thead>
<tr>
<th>Pressure</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>increases</td>
</tr>
<tr>
<td></td>
<td>decreases</td>
</tr>
<tr>
<td>B</td>
<td>decreases</td>
</tr>
<tr>
<td></td>
<td>remains the same</td>
</tr>
<tr>
<td>C</td>
<td>decreases</td>
</tr>
<tr>
<td>D</td>
<td>increases</td>
</tr>
<tr>
<td></td>
<td>remains the same</td>
</tr>
</tbody>
</table>

5. A sealed syringe contains 90 cm$^3$ of air at a pressure of 1.0 atmosphere. A pressure of 1.5 atmospheres is applied to the piston and this causes a change in the volume of the gas. What is the volume of the gas?
Please see our suggestions in the Answers to Self Assessment for Topic 5.2 provided at the end of this topic to see if you were on the right track.

**Answers to self-assessment 5.2**

**Part A**

1. Solids, liquids and gases
2. Low, intermolecular
3. Insufficient
4. Liquids
5. Temperature
6. Fixed, temperature, pressure x volume
7. Less

**Part B**

1. b) 173K; c) 0 °C; d) 310; e) 100 °C,
2. B
3. C
4. A
5. 60cm³
Now that we have come to the end of topic 5.2, what do you recall about the behavior of gas molecules? How do they react to increase or decrease in temperature or pressure?

Ever wondered why things sink and float? You may be able to find the answer in the next topic. Let’s move on to find out!

**Topic 5.3: Density**

You will need 1 hour 40 minutes at the most to complete this topic. It is advisable that you spend another 50 minutes of your own time to further practise the activities learnt. Make sure you read and try to understand everything in order to achieve the specific objectives.

We will start off this topic by posing two simple trivial questions:

1. Which is heavier, a kilogram of lead or a kilogram of foam (polystyrene)?

   It is not surprising that your answer to the first question is that they are the same in mass for they are both one kilogram. However, the one kilogram of lead occupies less space (volume) than the one kilogram of foam. Lead is more compact than foam.

2. Which is heavier: wood or iron?

   Regarding the second question, most people tend to give iron as the answer but it could be either iron or wood. Can you guess why? Yes! It depends on the size of the pieces being compared: a large piece of wood being compared with a small piece of iron or a large piece of iron.
In science, whenever we want to compare things, we have to make a fair comparison by fixing (keeping constant) some parameters, for example volume, mass, length and so on. Let us for example consider equal volume of the two materials (wood and iron) and then the mass will be measured in kilogram (kg) or gram (g) using a beam balance.

Say for example, let us take the mass of a regular shaped piece of wood and a piece of iron of length 10cm, width 4cm and height 5cm each. The mass of the piece of wood is, let us say, 160g and that of the iron is 1560 g.

![Figure 5.3.1: Regular shaped pieces of wood and iron](image)

The volume of the two blocks is calculated by using the equation:

\[
\text{Volume} = \text{length} \times \text{width} \times \text{height}
\]

Now let us calculate the volume of the piece of wood and the piece of iron.

<table>
<thead>
<tr>
<th>Volume of Wood</th>
<th>Volume of Iron</th>
</tr>
</thead>
</table>
Volume of Wood | Volume of Iron
---|---
\[ V = l \times w \times h \]
\[ = 10 \text{ cm} \times 4 \text{ cm} \times 5 \text{ cm} \]
\[ = 200 \text{ cm}^3 \]
\[ V = l \times w \times h \]
\[ = 10 \text{ cm} \times 4 \text{ cm} \times 5 \text{ cm} \]
\[ = 200 \text{ cm}^3 \]

Figure 5.3.2: Calculating the volume of the piece of wood and the piece of iron

We know that the mass of the two objects are:

Mass of wood = 160g
Mass of Iron = 1560g

The calculations show that the regularly shaped pieces of wood and iron of mass of 160g and 1560g, respectively both have the same volume of 200 cm$^3$. Now we can confidently say that, in this example, when equal volumes of iron and wood are compared, iron is heavier than wood.

In Physics, whenever we are comparing the mass of equal volumes of two substances to determine which one is heavier, the property we are in fact comparing is the \textit{density} of the substances.

\textbf{5.3.1 What is density?}

Density is a measurement which is influenced by a number of factors namely - how tightly packed the particles are within a substance, how heavy each particle of that particular substance is and the space the substance occupies (i.e. how large or small it is). You can therefore understand that though a hockey ball and a cricket ball may be roughly of the same size, the cricket ball is denser as it has more matter packed in the same volume (space).

As a matter of fact for us to do a fair comparison of the two balls we need to measure the density of each one. In so doing, we have to compare the mass of equal volume of each ball. Density is defined as mass per unit volume (i.e. the mass of 1 cm$^3$ or 1 m$^3$) of the substance. The commonly used formula to determine the density of an object is mass of the object divided by its volume.
[\( d = \frac{m}{V} \) or \( \rho = \frac{m}{V} \), the letter (\( d \)) or \( \rho \) (Greek letter ‘rho’) is used to represent density, \( m \) to represent mass, and \( V \) to represent volume].

The SI unit used to indicate density is kilogram per cubic metre (\( \text{kg/m}^3 \)) or gram per cubic centimetre (\( \text{g/cm}^3 \)). The procedure for converting 1000 kg/m\(^3\) to 1 g/cm\(^3\) is given below.

\[
\frac{1000\text{kg}}{1\text{m}^3} = \frac{1000\text{g}}{1\text{m}^3} \times \frac{1000}{100 \times 100 \times 100} = \frac{1\text{g}}{1\text{cm}^3} = 1\text{g/cm}^3
\]

To convert \( m^3 \) to \( cm^3 \) we multiply by 100x100x100 because 1 m is equal to 100 cm and volume is calculated by multiplying length x width x height.

The formula for calculating density is:

\[
\text{Density} = \frac{\text{mass}}{\text{volume}}, \text{ which may be represented symbolically as } d = \frac{m}{V} \text{ or } \rho = \frac{m}{V}
\]

Now we can work out the density of the wood and iron stated in the example above.
Wood | Iron
---|---
Mass = 160g, Volume = 200cm³
\[ \rho = \frac{m}{V} \]
\[ \rho = 160g/200 \text{ cm}^3 \]
\[ \rho = 0.8 \text{ g/cm}^3 \]

Mass = 1560g, Volume = 200cm³
\[ \rho = \frac{m}{V} \]
\[ \rho = 1560g/200\text{cm}^3 \]
\[ \rho = 7.8 \text{ g/cm}^3 \]

Figure 5.3.2: Calculating the density of a piece of wood and a piece of iron

Remember, density tells us the mass of unit volume of the substance, therefore, 1 cm³ of the wood has a mass of 0.8g, and 1 cm³ of the iron has a mass of 7.8g. Evidently, 1 cm³ of iron is nearly 10 times heavier than 1 cm³ of wood. Now, you will be given the opportunity to go through the steps for solving problems involving density, mass and volume.

Given certain known values, we can use the formula to calculate the density, the mass and the volume of any given object. We will start off with an example of how to use the formula to solve for the density.

**Example 5.3.1: Solving for Density**

Remember, when solving for density, you must use the formula
[density = mass ÷ volume] exactly as it is given. Here is an example where density is the unknown, and the steps for solving the problem.

**Problem 5.3.1:**

Mary finds that a piece of an unknown material has a mass of 54.0g and a volume of 20.0 cm³. What is the density of the material?
Step 1: List the “known values” and the “unknown values”.

\[ d = ? \]
\[ m = 54.0 \text{ g} \]
\[ V = 20.0 \text{ cm}^3 \]

Step 2: Write the correct formula.

\[ d = \frac{m}{V} \]

Step 3: Substitute the known values in the equation.

\[ d = \frac{54.0 \text{ g}}{20 \text{ cm}^3} \]

Step 4: Calculate your answer, including units.

\[ d = 2.7 \text{ g/cm}^3 \]

**Example 5.3.2: Solving for Mass**

This time we are going to solve for mass. We must start with the original formula \([\text{density} = \text{mass} ÷ \text{volume}]\), and isolate the unknown values like shown below, so that mass becomes the subject.

Step 1: Write the correct formula.

\[ d = \frac{m}{V} \]

Step 2: Multiply both sides by \(V\).

\[ V \times d = \frac{m}{V} \times V \]

Notice that the Vs cancel out and ‘m’ the unknown is on the right hand side of the equation.

\[ V \times d = \frac{m}{V} \times V \]
Step 3: By convention you have to rearrange the formula so that the unknown appears on the left hand side of the equation, as shown below.

\[ \text{mass} = \text{volume} \times \text{density} \]

\[ m = V \times d \]

Now that you have worked out the mathematical formula for solving mass as the unknown, you are ready to solve a problem.

**Problem 5.3.2**

Lead has a known density of 11.40 g/cm\(^3\). What would be the mass of a 1.5 dm\(^3\) piece of lead?

Step 1: List the **known values** and the **unknown values**.

\[ m = ? \]

\[ d = 11.40 \text{ g/cm}^3 \]

\[ V = 1.5 \text{ dm}^3 \]

Please, notice that the unit for density is given in g/cm\(^3\), but the unit of volume is in dm\(^3\). We have to change dm\(^3\) to cm\(^3\). Hence, this problem requires an additional step.

Remember 1 dm\(^3\) is equal to 1000 cm\(^3\) because 1 dm = 10 cm, so

\[ 1 \text{ dm}^3 = 10 \text{ cm} \times 10 \text{ cm} \times 10 \text{ cm} = 1000 \text{ cm}^3. \]

Step 2: Change the unit of volume so that it is the same as the volume component in the unit for density.
Use the factor label method:

\[ 1.5 \text{ dm}^3 \times \frac{1000 \text{ cm}^3}{1 \text{ dm}^3} = 1500 \text{ cm}^3 \]

Please note that the dm\(^3\) units appear above and below the line, so they cancel out, leaving cm\(^3\).

Please note that not all questions will require this step. You will have to make this very important decision when solving questions of this kind.

Step 3: Write the correct formula (adjusted formula)

\[ m = V \times d \]

Step 4: Substitute the known values in the adjusted formula

\[ m = V \times d \]

\[ m = 1500 \text{ cm}^3 \times 11.40 \text{ g/cm}^3 \]

Step 5: Calculate the answer including units

\[ m = 1500 \text{ cm}^3 \times 11.40 \text{ g/cm}^3 \]

\[ m = 17100 \text{ g} \]

or \[ m = 17.10 \text{ kg} \]

You should note that we may even use the standard form or scientific notation to express the correct answer as follows:

\[ m = 17100 \text{ g} \]

\[ m = 1.71 \times 10^4 \text{ g} \]
Now you are ready to try one out on your own. You are invited to solve problems involving volume, mass and density in Activity 5.3.1.

Activity 5.3.1

You should spend approximately 10 minutes on this activity.

Solve the problem involving density in the space provided below, and show all your calculations.

Steel has a density of 7.8 g/cm³. How much space (what volume) would 75.0 g of steel occupy?

We believe that you have found the problem rather easy to solve. Please refer to the Feedback to Activity 5.3.1 at the end of the topic to verify your answers.
Feedback to Activity 5.3.1

1. When solving for volume, we must take the original formula, and isolate the unknown like shown below:

Step 1: List the known quantities and the unknown quantities.

\[ d = 7.8 \text{ g/cm}^3 \]
\[ m = 75.0 \text{ g} \]
\[ V = ? \text{ cm}^3 \]

Step 2: Rearrange the formula for density.

\[ d = \frac{m}{V} \]

i) \[ V \times d = \frac{m}{V} \times V \]

ii) \[ \frac{V \times d}{d} = \frac{m}{d} \]

\[ V = \frac{m}{d} \]

Steps to follow:

1. Multiply both sides of original formula by volume; making \( m \) the subject, but we want \( V \) as the subject, so go to step 2.
2. Divide both sides by \( d \), giving \( V = \frac{m}{d} \)

Step 3: Substitute the known values in the equation.

\[ V = \frac{m}{d} \]

\[ V = \frac{75.0 \text{ g}}{7.8 \text{ g/cm}^3} \]

Step 4: Calculate your answer, including units

\[ V = 9.615 \text{ cm}^3 \]
According to us, you have completed the most difficult part, and you are now ready to carry out an experiment or use given data to determine the density of a regularly shaped solid using the formula: 
\[
density = \frac{mass}{volume}
\]

5.3.2 Measuring the density of regular and irregular solids

Now that you know how to calculate the density of regular solids mathematically, we are going to provide you with the techniques of how you could take the necessary measurements experimentally for both regular and irregular solids. You need to have access to a science laboratory or the following materials: a ruler, a mass balance, measuring cylinder, a piece of string, water, regularly shaped and irregularly shaped solids. Then carry out the experiment by following the steps listed in Activity 5.3.2 for regular shaped solids and Activity 5.3.3 for irregular shaped solids.

5.3.2.1 Measuring the density of regularly shaped solids

Activity 5.3.2

You should spend about 10 minutes on this activity.

You are required to determine the density of a regularly shaped solid (e.g. cubes, cuboids, cylinders). The experimental steps to find the density of regularly shaped solids are as follows:

1. Find the mass of the regular shaped solid (e.g. rectangular glass block) by using a suitable balance.
2. Measure the length, width and height of the glass block and calculate its volume.
3. Draw a table and record your measurements.
4. Use the appropriate formula to calculate the density of the glass.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mass of solid</td>
<td>g</td>
</tr>
<tr>
<td>2. Length of solid</td>
<td>cm</td>
</tr>
<tr>
<td>3. Width of block</td>
<td>cm</td>
</tr>
</tbody>
</table>
4. Height of block cm

5. Volume of block \( V = l \times w \times h \) cm³

6. Density of glass g/cm³

Table 5.3.1: Table to record the results regarding the density of a regular solid

We know that you have found this to be a very simple task. Try to compare the value you have obtained with the one given in the table of densities of common substances in section 5.3.5. Don’t be surprised if you do not get the same value, but it is important for you to try to understand what could have contributed to the difference. There are several possible reasons:

1. errors in measuring the length, width or height of the block;
2. errors in measuring the mass of the block;
3. errors in calculating the volume or the density of the glass; and
4. the glass might not be of the same type.

Please note that the main sources of errors in scientific experiments are generally due to:

1. mistakes made by the person carrying out the experiments for example in taking measurements;
2. faulty equipment; and
3. errors in calculations.

Now you may be wondering how you can determine the density of irregular solids. We will help you by providing you with the steps that you should follow. Since the shape of an irregular solid does not have a definite length, width, or height, **it is impossible to use the formula involving length, width and height to calculate its volume.** Instead you must use the displacement method. The procedure is given in Activity 5.3.3.
5.3.2.2 Measuring the density of irregularly shaped solids

Activity 5.3.3

You should spend about 10 minutes on this activity.

You are required to determine the density of an irregularly shaped solid (e.g. a small stone). The experimental steps to find the density of irregularly shaped solids are as follows:

1. Find the mass of the irregularly shaped solid (e.g. stone) by using a suitable balance.
2. Put some water into a measuring cylinder and measure the volume of water.
3. Record the volume of water.
4. Tie the stone with a piece of thread and immerse the stone gently and completely in the water. (Ensure that there is enough water to cover the stone completely).
5. Record the reading of the water level in the measuring cylinder (while the stone is fully submerged).
6. Find the volume of the stone by subtracting the reading in step 3 from the reading in step 5.
7. Use the appropriate formula to calculate the density of the stone for you now have the measurements of both the volume and the mass of the stone.
Now that you are in a position to calculate the density of solids, it is time for us to figure out how to calculate the density of liquids.

### 5.3.2.3 Measuring the density of liquids

Before turning your attention to the procedure for measuring the density of liquids, we are going to ask you to reflect on a common observation made by many people in Seychelles, given in the bubble.

*Their observation is based on their experience in swimming in sea water and fresh water. They found that it is more difficult to swim in fresh water than in sea water. As a result of their swimming difficulties, they say that “fresh water is heavier than sea water.”*
Based on your scientific background, what would you consider to be incorrect with their assumption?

You should have noticed that they are correct in saying that it is more difficult to swim (float) in fresh water, but they are incorrect in saying that fresh water is heavier than sea water. Their observations are due to other factors in physics which we are going to address in later units.

Now that you are in a position to calculate the density of solids, we will provide you with the steps to determine the density of liquids.

Activity 5.3.4

You should spend approximately 10 minutes on this activity.

You are required to determine the density of a liquid (e.g. water, juice etc.). The experimental steps to find the density of a liquid are as follows:

1. Measure the mass of an empty container (e.g. measuring cylinder).
2. Measure the volume of some liquid (e.g. 50 cm$^3$) by using the same measuring cylinder.
3. Measure the mass of the container and the liquid.
4. Record the results.
5. Find the mass of the liquid by subtracting the reading in step 1 from the reading in step 3.
6. Use the appropriate formula to calculate the density of the liquid for you now have the measurements of both the volume and the mass of the liquid.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mass of empty container</td>
<td>g</td>
</tr>
<tr>
<td>2. Volume of liquid</td>
<td>cm$^3$</td>
</tr>
</tbody>
</table>
3. Mass of liquid and container  \( \text{g} \)

4. Mass of liquid  \( \text{g} \)

5. Density of liquid  \( \text{g/cm}^3 \)

| Table 5.3.3: Table to record the results regarding the density of a liquid |

Try to confirm your answer through the internet or through your teacher or peers.

### 5.3.3 Density of some common substances

The table below shows the density of a few common substances. Try to familiarize yourself, but there is no need to learn them by heart.

<table>
<thead>
<tr>
<th>Substance</th>
<th>Density</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kg/m³</td>
</tr>
<tr>
<td>Air</td>
<td>1.3</td>
</tr>
<tr>
<td>Foam polystyrene</td>
<td>100</td>
</tr>
<tr>
<td>Cork</td>
<td>250</td>
</tr>
<tr>
<td>Wood</td>
<td>700</td>
</tr>
<tr>
<td>Ethanol</td>
<td>800</td>
</tr>
<tr>
<td>Ice</td>
<td>920</td>
</tr>
<tr>
<td>Water</td>
<td>1000</td>
</tr>
<tr>
<td>Glass</td>
<td>2500</td>
</tr>
<tr>
<td>Aluminium</td>
<td>2700</td>
</tr>
<tr>
<td>Steel</td>
<td>7800</td>
</tr>
</tbody>
</table>
Table 5.3.4: Table showing the density of different substances

<table>
<thead>
<tr>
<th>Substance</th>
<th>Density (g/cm³)</th>
<th>Mass Density (g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead</td>
<td>11400</td>
<td>11.40</td>
</tr>
<tr>
<td>Mercury</td>
<td>13600</td>
<td>13.60</td>
</tr>
<tr>
<td>Gold</td>
<td>19300</td>
<td>19.30</td>
</tr>
</tbody>
</table>


**Activity 5.3.5**

You will need about 5 minutes to complete this activity.

Use the information in the table to answer questions 1 to 7 in this activity:

1. The density of ethanol is ________________.
2. The substance which has a density of 2.70 g/cm³ is ____________.
3. One cubic metre (m³) of mercury has a mass of ____________.
4. The mass of 1 cm³ of gold is ________________.
5. ________________ is a solid substance which is denser than ice, but less dense than Aluminium.
6. ________________ substances have densities greater than 1.00 g/cm³.
7. The mass of 10 cm³ of lead is ________________.

We hope that you have found the activity quite easy to complete. Please refer to Feedback to Activity 5.3.5 below to verify your answers.
Feedback for Activity 5.3.5

1. 0.80 g/cm³
2. Aluminium
3. 13600 kg
4. 19.3 g
5. Glass
6. Six
7. 114.0 g

We are sure that you got them all right. Good attempt! You should now be ready to have a go at our final self assessment in this unit.
Self assessment 5.3

You need about 15 minutes to complete this self assessment for Topic 5.3.

The feedback is given at the end of the topic. Once again you are strongly advised to answer all questions before you refer to the feedback. This will help you learn and reflect better on areas for improvement.

Part A

Each question in Part A has four possible responses. Answer all the questions by selecting and circling the most suitable response.

1. In Physics SI units are used for different measurements. Which of the following is the SI unit used to measure density?
   A  g/cm²
   B  cm³/g
   C  kg/m³
   D  kg/m²

2. Each of the solids shown in the diagram has the same volume. Which solid has the lowest density?
   A  50 g  B  70 g  C  80 g  D  90 g

3. Which items does a student need to determine the density of a liquid?
   A  beam balance and force metre
   B  beam balance and measuring cylinder
   C  metre rule and measuring cylinder
4. A lady bought a rectangular piece of soap of a mass of 300 g as shown below. What is the density of the soap?

![ soap dimensions diagram ]

A 2.0 g / cm³  B 13.6 g / cm³  C 20.0 g / cm³  D 30.0 g / cm³

5. The four cylinders below are full of different liquids. They have the same mass. Which measuring cylinder contains the liquid with the greatest density?

![ cylinders diagram ]

A  B  C  D

6. Two students record the volume of a liquid from the scale on the measuring cylinder. They then put the measuring cylinder containing the liquid on a balance and record the mass.

Figure 5.3.3: Two girls measuring the mass of a cylinder containing a liquid
What else needs to be measured before the density of the liquid can be calculated?

A  the depth of the liquid in the measuring cylinder
B  the mass of the empty measuring cylinder
C  the temperature of the liquid in the measuring cylinder
D  the volume of the empty measuring cylinder

**Part B**

Answer the following question in the space provided below:

1. The mass of 60 identical glass beads is found to be 66 g and the total volume of the marbles is found to be 25.70 cm³. Explain how you would find the density of the marbles experimentally.

Please include the following in your answer:

i. The apparatus you would use;

ii. All the measurements that you would take;

iii. State how you would use your measurements to obtain a value for the density of the glass beads.
Please refer to the Answers to self assessment 5.3 at the end of this topic below to verify your answers. Do not be disappointed if you did not get all the answers correct.
Answers to self-assessment 5.3

Part A:

1. C
2. A
3. B
4. A
5. D
6. B

Part B

1. i) measuring cylinder, beam balance, beaker
   ii) Measurements to be taken:
   - mass of dry empty beaker (M₁)
   - mass of dry beaker with glass beads (M₂)
   - initial volume of water in the cylinder (V₁)
   - Final volume of the water in the cylinder with the glass beads from the glass beaker (V₂)
   iii) Density of glass beads = \(\frac{\text{Total mass of glass beads}}{\text{Volume of water displaced by glass beads}}\)
      \[D = \frac{M₂ - M₁}{V₂ - V₁}\]

We have now completed the study on Particles in Motion. We are sure that you have gained a lot of new knowledge on the particulate nature of matter, their behaviour and the density of matter.

In the next unit you will be learning about “Cellular organisation”.
In this unit you learned that the three states of matter, i.e. - solids, liquids and gases, are made up of particles. The particles are always in motion, but the degree of their movement depends on the strength of the intermolecular forces of attraction they experience. Hence, particles in solids experience a large attraction force and the particles cannot move from one place to another like in liquids and gases which experience a much smaller force of attraction. Particles that are free to move always do so in straight lines.

When particles of matter gain energy, they move faster causing an increase in temperature and even a change of state. For example, when liquid particles absorb heat energy, some gain more heat than others. The ones with high enough energy escape the body of the liquid and move freely away, as a gas. This process is called evaporation. It is affected by a number of factors and it results in the liquid becoming cooler, as well as smaller in volume and mass over a period of time as the liquid has turned into a gas.

We then addressed the behaviour of particles (molecules) in a fixed mass of gas when subjected to variations in pressure, volume and temperature. From this we learned three relationships.

The first relationship is that for a fixed mass of gas at constant temperature, its pressure and volume have an inverse proportionality. That is, when the pressure of the gas is halved, the volume is doubled, and so on.

The second one is that the volume (V) of a fixed mass of gas is directly proportional to its absolute temperature (T) provided the pressure of the gas is kept constant. That is, when the temperature is doubled, the volume is also doubled and so on.

The third one is that the pressure of a fixed mass of gas is directly proportional to its absolute temperature provided the volume of the gas is kept constant. That is, when the absolute temperature is doubled, the pressure is also doubled and so on.

Finally, we learned that the density of a substance is a measure of how much mass is present in a given unit of volume (i.e. mass per cubic centimetre) of that substance.

Now you are ready to move onto Unit 6.
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Unit 6

Cellular organisation

Introduction

“What are living organisms made of?” and “what makes them so different from each other?” are questions that have been of interest to scientists for a long time in history. In the mid-1600s, Robert Hooke discovered the presence of cells, but it was only two centuries later that three German biologists confirmed that cells are small building blocks of all living things.

In this unit you will learn about the microscope and how it is a useful instrument in the study of cells. You will get opportunities to learn how to use a simple light microscope and make slides of plant and animal cells. Drawings and photographs of plant and animal cells as seen under the electron microscope will be available for you to interpret and describe.

Correspondingly, you will learn about the structure of a typical plant cell and an animal cell, as well as the functions of the organelles therein. We will also look at osmosis and its consequences on plant cells and animal cells. We will also study a few specialized cells to see how their special structures relate directly to the specific functions which they perform. Finally, you will be able to differentiate between cells, tissues and organs and understand how these work together to perform related functions.

Hence, in this unit you will learn about the following:

- instruments used for magnification;
- how to use a microscope;
- animal and plant cells, tissues, organs and systems;
- osmosis and;
- some types of specialised animal cells and specialised plant cells.

The knowledge that you now have from the study of particles in motion in Unit 5 will be useful in helping you better understand osmosis in Topic 6.3. The contents of Topic 6.3: Osmosis, provide useful background knowledge for the understanding of certain concepts in other units. The knowledge of:

(i) turgor pressure will be used to show the importance of turgor in the support mechanism of plants in Unit 14;
(ii) Osmosis in plant cells will help you comprehend the uptake of water by osmosis in plant roots when you study transport systems in plants in Unit 23;

(iii) The importance of water concentration to animal cells will be useful when you study homeostasis in Unit 38.

The contents of this unit will also be useful when learning about chemicals from plants in Unit 17.

Upon completion of this unit you will be able to:

- define a tissue.
- define an organ system.
- define the term osmosis.
- draw the structure of a typical animal cell and a typical plant cell to show the cell membrane, cytoplasm, nucleus, cell wall, vacuole and chloroplast.
- explain how different types of cells perform different functions and how their structure is related to their function.
- investigate the effects of solutions of different concentrations on animal cells and plant cells.
- state that all living organisms are made up of cells.
- state the functions of the following parts of plant and animal cells: cell membrane, cytoplasm, nucleus, cell wall, vacuole and chloroplast.
- interpret light micrographs and simple electron micrographs of plant and animal cells.

**Terminology**

**Cell membrane:** A cell membrane is a selectively permeable boundary which regulates what enters and leaves the cell.

**Cell wall:** The cell wall is the membrane that forms outside the cell membrane in plant cells and other organisms such as bacteria, archaea, fungi and algae. It provides support and protection to the cell. It also is a pathway for movement of water.
and mineral salts.

**Chloroplast:** Chloroplasts are cells which contain the pigment chlorophyll which is necessary for a plant to photosynthesise. Chloroplast is the site of photosynthesis, where carbon dioxide, water and light energy are used to make sugars for the plant.

**Cytoplasm:** Cytoplasm is the jelly-like substance in a cell that contains organelles. It provides shape to the cell and is the region where many metabolic reactions occur.

**Endoplasmic reticulum:** This is a system of flattened membrane-bounded sacs of two kinds: rough endoplasmic reticulum and smooth endoplasmic reticulum.

**Golgi apparatus:** These are membrane-bound sacs responsible for the secretion of waste products from the cell and the transportation of cell materials such as enzymes and lipids.

**Hypotonic solution** A hypotonic solution is a solution with a high water potential. It is a weak solution or a solution of low concentration.

**Hypertonic solution** A hypertonic solution is a solution with a low water potential. It is a concentrated solution.

**Isotonic solution** Isotonic solutions are two solutions that have the same water potentials. They are solutions of the same concentration.

**Lysosome:** Lysosome is an organelle containing a large range of digestive enzymes used for digestion and removal of excess or worn out organelles, food particles and engulfed viruses and bacteria.

**Mitochondria:** Mitochondria are rod-shaped organelles. It is the site for the production of high-energy compounds such as ATP. It is referred to as the power house of the cell.

**Nucleus:** The nucleus is a large membrane-bounded organelle that contains the genetic material in the form of DNA molecules.

**Organ:** An organ is made up of different tissues which work together and contribute towards one particular function in the life of an organism.
Osmosis: Osmosis is the passage of water molecules from a region of high water concentration, through a semi-permeable membrane to a region of low water concentration.

Plasmolysis: Plasmolysis is the shrinking of the cytoplasm away from the cell wall of a plant. The cell becomes flaccid. This is due to water loss from osmosis.

Semi-permeable membrane: A semi-permeable membrane is a partially permeable membrane that controls the entry and exit of nutrients and waste.

System: A system is a group of organs which work together to perform several related functions for the proper functioning of an organism.

Tissue: A tissue is a group of cells of the same type or different types working together to perform a particular function.

Turgidity: This is the state of a plant cell that has taken in water through osmosis, to a point where no more water can enter the cell. When the cell becomes swollen and hard, it is said to be turgid.

<table>
<thead>
<tr>
<th>Student Category</th>
<th>Recommended formal study time per week.</th>
<th>Recommended self-study time per week.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full time student outside the conventional school setting.</td>
<td>8 hours and 40 minutes</td>
<td>4 hours and 20 minutes</td>
</tr>
<tr>
<td>Full time student within the conventional school setting and Part-time student.</td>
<td>8 hours and 40 minutes</td>
<td>4 hours and 20 minutes</td>
</tr>
</tbody>
</table>

Table 6.0: Proposed study time for full time and part-time students
Topic 6.1: What are organisms made of?

You will need 2 hours and 30 minutes at the most to do the activities in this topic. It is advisable that you spend another 1 hour 15 minutes of your own time to further learn about plant and animal cells and their functions.

We have already seen in the unit on biological classification that there is a vast number of species of living organisms on earth. These living organisms are very different from each other and yet all the different species of organisms share one thing in common. This is that they are all made up of cells.

What do you know about cells? Complete the Burr diagram below to show four ideas that you have about cells.

![Burr diagram](image)

Figure 6.1.1: Burr diagram to note ideas on cells.

I have no doubt that you have mentioned some important ideas about cells. If you do not have many ideas about cells at the beginning of this unit, do not worry. You will learn a lot about cells in this unit; hence you can complete the Burr diagram as you work through the unit or even when you have completed the unit.
6.1.1 What are cells?

Cells are the smallest building blocks of life. Living things are made up of trillions of cells of different types. Nonetheless, some organisms like the amoeba have only one cell compared to organisms like ourselves that have many cells.

**Reflection 6.1.1**

You should spend no more than 5 minutes on this activity.

Refer back to Unit 1: Biological Classification. Go to Topic 1.4: Hierarchical Classification and study Table 1.4.1 again. Look for the kingdoms of organisms that have only one cell and those that have many cells.

Organisms that have only one cell, also referred to as unicellular organisms, are called **prokaryotes** and those organisms that have many cells, also known as multi-cellular organisms, are called **eukaryotes**.

Now complete Figure 6.1.2 below to show the kingdoms of organisms that have only one cell (the prokaryotes) and the kingdoms of organisms that have many cells (the eukaryotes).

![Figure 6.1.2: Classifying kingdoms of organisms as eukaryotes and prokaryotes](image-url)
Feedback to Reflection 6.1.1

Well done! As you have noticed bacteria, archaea and protists are prokaryotes, i.e. they have only one cell. They are **unicellular organisms**. On the contrary fungi, plants and animals are eukaryotes. They have many cells. They are **multi-cellular organisms**.

Most of the cells of eukaryotes have the same basic structure. We shall start by looking at a typical animal cell below to learn more about the main parts of a eukaryotic cell.

### 6.1.2 Parts of an animal cell and their function

Maybe some of you have written about the parts of a cell and possibly the functions of some parts of a cell in the Burr diagram at Figure 6.1.1 above. If you already have some knowledge of the parts and functions of a cell you have an advantage. If this topic is new to you, then here is your opportunity to learn about parts of an animal cell and the functions of each part.

Students who are doing the core objectives are only required to know the following parts and functions of the animal cell: **cytoplasm, nucleus and cell membrane**.

Students who are doing the extended objectives should also know the following parts and functions of the animal cell: **mitochondria, lysosome, rough endoplasmic reticulum, smooth endoplasmic reticulum, and Golgi apparatus**, in addition to the **cytoplasm, nucleus and cell membrane**.

We saw above that cells are the smallest building blocks of living organisms. Cells are so small that they need to be magnified many, many times for us to see them in detail.

You should therefore realize that the parts of the cell would be even tinier!! These tiny structures that form part of the cell are called **organelles**.
The main organelles of an animal cell as seen by an electron microscope are shown in Figure 6.1.3 below.

The activities below will help you learn and master the organelles of a typical animal cell. Have fun!
Computer-Based Learning 6.1.1

You should spend approximately 10 minutes on this task.

Those of you who have access to a computer go to the following website:


You will find a 3-dimentional diagram of an animal (eukaryotic) cell. On the diagram try to identify the organelles shown in Figure 6.1.3 above. Write the name of each organelle and the number representing each organelle in Table 6.1.1 below.

All students should start with the three organelles that are common for both the students doing the core objectives and those doing the extended objectives.

<table>
<thead>
<tr>
<th>Name of cell organelle</th>
<th>Corresponding number on the online diagram</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6.1.1 (a): Matching cell organelles with their number from an online diagram.

Those of you, who do not have access to a computer, work with a friend on the “Hang Man” game below.

The first 3 words are common to all students. The last 3 words are for students doing the extended objectives only; however, this does not prevent those doing the core objectives from trying.
Well done! I have provided you with the feedback for the matching exercise and the “Hang-the-man” game at the end of the topic.
Group Activity 6.1.1

You should spend around 10 minutes on this activity.

Get together with two or three friends and compose a word search game using the cell organelles that you have learnt above.

Start by writing a list of the cell organelles that you will include in your word search game in the space below.

**List of cell organelles:**

A word search game is easy to devise. All you need is to draw a grid with enough squares for you to include all the words that you want a person to look for.

In a word search, one square is for one letter. What you need to do therefore, is to write the letters for each organelle in the squares either horizontally, vertically, or diagonally. Once you have written the names of the organelles, write any other letters in the blank squares to fill all the squares in the grid.

I have started the word search for you by doing an example using the organelle *lysosome*. 
Figure 6.1.4: Word Search Game on cell organelles to be completed.

Once you have completed your word search game, exchange it with your classmates and have a class competition to see which group completes the word search faster. All your friends have to do is to highlight or circle the organelles listed once they have identified them.

I hope that the activities above have helped you to get to know the organelles of an animal cell better.
Now look back at the shape of the cell organelles in Figure 6.1.3 above. You should have noticed that the organelles have very different shapes. Each type of organelle is also different in the functions that they perform to ensure the proper functioning of the cell.

The functions of the organelles are given in Table 6.1.2 below.

**Students doing the core objectives should concentrate on the first three organelles only.**

<table>
<thead>
<tr>
<th>Name of organelle</th>
<th>Diagram</th>
<th>Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell membrane</td>
<td>![Diagram](cell membrane.png)</td>
<td>Partially permeable membrane controlling entry and exit of nutrients and waste.</td>
</tr>
<tr>
<td>Nucleus</td>
<td><img src="nucleus.png" alt="Diagram" /></td>
<td>Contains chromosomes with DNA which controls all the activities of the cell.</td>
</tr>
<tr>
<td>Cytoplasm</td>
<td><img src="cytoplasm.png" alt="Diagram" /></td>
<td>Aqueous substance containing a variety of organelles</td>
</tr>
<tr>
<td>Endoplasmic reticulum (ER)</td>
<td>![Diagram](endoplasmic reticulum.png)</td>
<td><strong>Rough ER</strong> contains ribosomes and transports proteins made by the ribosomes, <strong>Smooth ER</strong> does not have ribosomes and is the site of lipid synthesis.</td>
</tr>
<tr>
<td>Mitochondria</td>
<td><img src="mitochondria.png" alt="Diagram" /></td>
<td>Site of energy metabolism and synthesis of high-energy</td>
</tr>
<tr>
<td></td>
<td>ATP.</td>
<td></td>
</tr>
<tr>
<td>---------------------</td>
<td>----------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Golgi apparatus</td>
<td>Responsible for the secretion of waste products from the cell.</td>
<td></td>
</tr>
<tr>
<td>Lysosomes</td>
<td>Contains digestive enzymes. Concerned with breakdown of structures and molecules.</td>
<td></td>
</tr>
</tbody>
</table>

Table 6.1.2 Cell organelles and their functions

Activity 6.1.1 below will help you to learn and master the functions of the organelles in a typical animal cell.
Activity 6.1.1

You should spend no more than 10 minutes on this activity.

Come up with questions in the space below to test your colleagues’ understanding of the functions of the cell organelles in Table 6.1.2 above.

Students doing the core objectives should write three questions, and students doing the extended objectives should write four questions.

Underneath each question write the correct answer to the question.

Question 1

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

Answer to Question 1

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

Question 2

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
Answer to Question 2


Question 3


Answer to Question 3


Question 4


Answer to Question 4

2. Now find two or three friends who are also doing this course and who would be willing to answer your questions. Ask the questions one by one. Listen to your friends’ answers and together try to clarify any doubts that you or your friends might have by referring to the answers that you have written for each question as well as the notes in Table 6.1.2 above.

I am sure that this exercise was worthwhile and that it has helped you and your friends to master the functions of the cell organelles of a typical animal cell.

We shall now move on to study the parts and functions of a typical plant cell.
6.1.3 Parts of a plant cell and their function

Students who are doing the core objectives are required to know the following parts and functions of the plant cell only: **cytoplasm, nucleus, cell membrane, cell wall, vacuole and chloroplast**.

Students who are doing the extended objectives should already know the following cell organelles and their functions: **mitochondria, lysosome, rough endoplasmic reticulum, smooth endoplasmic reticulum, and Golgi apparatus**. You should note that these organelles are common to both plant and animal cells.

Please note also that these organelles have not been labelled again on the diagram of the plant cell below. Nonetheless, I expect you to be able to recognise these organelles on the plant cell diagram.

A plant cell as seen under an electron microscope is shown in Figure 6.2.4 below.

![Figure 6.2.5: Parts of a plant cell](image)

Activity 6.1.2

You should spend about 5 minutes on this activity.

Now that you have observed the picture of a plant cell, look for the similarities and the differences between the plant cell above and the animal cell shown in Figure 6.2.3, then answer the questions below.

a). Which organelles are common to both the plant cell and the animal cell?

b). What differences did you notice between the plant cell and the animal cell? Write down four of these differences below.

i.

ii.

iii.
You were right to realize that all the organelles in the animal cell are also present in the plant cell. That is, both animal and plant cells have the following parts: a nucleus, cytoplasm and cell membrane, (as well as rough endoplasmic reticulum, smooth endoplasmic reticulum, lysosomes, Golgi apparatus and mitochondria).

However, you may also have noticed that plant cells also contain chloroplasts, a cell wall and a large vacuole. Chloroplasts and cell walls are not present in the animal cells. Vacuoles, however, also exist in animal cells, but they are usually much smaller.

You might also have noted that the position of the nucleus in a plant cell is different from that in an animal cell. In the animal cell the nucleus is around the centre of the cell, whereas in the plant cell it is found at the edge of the cell. This is due to the fact that the plant cell has a large vacuole in its centre. This causes the cytoplasm to be pushed to the towards the outer walls of the cell. As such all the organelles found in the cytoplasm are found between the cell wall and the vacuole.

I am sure that you also have noticed that animal cells tend to be more circular in shape and that plant cells tend to be more rectangular in shape.

We shall now look at the functions of the three organelles that are specific to a plant cell.

What are these three organelles? List them below.
Good! I have written the functions of these three parts of the plant cell (the cell wall, chloroplast and vacuole) in Table 6.1.3 below. Study the functions of each organelle carefully.

<table>
<thead>
<tr>
<th>Name of organelle</th>
<th>Diagram</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell wall</td>
<td><img src="image" alt="Cell Wall Diagram" /></td>
<td>Provides for support and protection and allows for the movement of water and mineral salts.</td>
</tr>
<tr>
<td>Chloroplast</td>
<td><img src="image" alt="Chloroplast Diagram" /></td>
<td>Organelle in which photosynthesis takes place.</td>
</tr>
<tr>
<td>Vacuole</td>
<td><img src="image" alt="Vacuole Diagram" /></td>
<td>Usually in the centre of the cell. Mostly liquid with various substances including waste products, dissolved in it.</td>
</tr>
</tbody>
</table>

Table 6.1.3: Organelles specific to a plant cell and their function.

Activity 6.1.3

You should spend no more than 5 minutes on this activity.

Now that you know the functions of the specific organelles of a plant cell, answer the questions below.

1. Why is it important for a plant cell to have a cell wall?

2. Explain why chloroplasts are found in plant cells but not in animal cells.

3. What do vacuoles contain?
Feedback to Activity 6.1.3

I am sure that you could easily answer the three questions and that your answers were similar to the following:

1. The cell wall in a plant cell provides for support and protection of the cell and allows for the movement of water and mineral salts in and out of the cell.

2. The chloroplasts are organelles in which photosynthesis takes place. Animals do not photosynthesize and so do not need chloroplasts.

3. Vacuoles contain mostly liquid with various substances including waste products, dissolved in the liquid.

Let us now proceed to Activity 6.1.4 below. The tasks in the activity will help you to review what you have learnt about plant and animal cells above.
Activity 6.1.4

You should spend about 10 minutes on this activity.

1. Complete the Venn diagram to show the similarities and differences between animal cells and plant cells.

![Figure 6.1.6: Venn Diagram on plant and animal cells](image)

2. Draw a plant cell and an animal cell. Use the following colours in your drawing to help you identify the different organelles:

<table>
<thead>
<tr>
<th>Cell organelles</th>
<th>Colour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cytoplasm</td>
<td>grey</td>
</tr>
<tr>
<td>Mitochondria</td>
<td>red</td>
</tr>
<tr>
<td>Chloroplast</td>
<td>green</td>
</tr>
<tr>
<td>Nucleus</td>
<td>orange</td>
</tr>
<tr>
<td>Rough endoplasmic reticulum</td>
<td>dark blue</td>
</tr>
<tr>
<td>Lysosome</td>
<td>yellow</td>
</tr>
</tbody>
</table>
Table 6.1.7: Colours for the identification of cell organelles

<table>
<thead>
<tr>
<th>Cell organelles</th>
<th>Colour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Golgi apparatus</td>
<td>violet</td>
</tr>
<tr>
<td>Cell membrane</td>
<td>black</td>
</tr>
<tr>
<td>Cell wall</td>
<td>brown</td>
</tr>
<tr>
<td>Smooth endoplasmic reticulum</td>
<td>pale blue</td>
</tr>
<tr>
<td>Vacuole</td>
<td>white</td>
</tr>
</tbody>
</table>

Students doing the core objectives need to identify the following organelles only: cytoplasm, cell membrane, cell wall, nucleus, chloroplasts and vacuole.
I am sure that you have found the above activity easy and straightforward. I have provided feedback to this activity in Feedback to Activity 6.1.4 for you at the end of the topic. However, you are strongly advised to first complete the activity on your own before you refer to the feedback.

The drawings of the plant and animal cells that you have seen above are what you would see if you observe those cells under an electron microscope. You would not see as much details if you observe the cells under a light microscope.

It is now your turn to view the plant and animal cells under a light microscope.
Activity 6.1.5

You should spend around 30 minutes on this activity.

From the above activities you now have an idea of how a plant cell and an animal cell look like. You also know the different organelles of a plant cell and an animal cell, as well as the functions of the organelles.

The knowledge that you have will make it easier for you to understand the structure of a real plant cell and an animal cell under a light microscope.

So now, go to the laboratory and ask the lab technician to help you get the following equipment. Tell the technician to assist you to observe a plant cell and an animal cell under the light microscope.

- A light microscope
- 2 blank slides and cover slips
- Tweezers
- An onion
- A dropper
- Some toothpicks
- Methylene blue or iodine
- A clear ruler
- Paper towel
- A permanent slide of animal cells
- A razor blade
- A clean tile

Now start your work! We shall first look at a plant cell.

- Place a drop of water in the middle of a clean slide. Cut an onion in half. Remove one of the slices. Using the tweezers, gently remove the skin from the inside layer of the onion slice. Place the onion skin onto the tile and flatten it taking care not to damage or tear it. Carefully use the razor blade to cut a small square of the skin and place it on the slide in the drop of water. Straighten out any wrinkled skin using toothpicks.

- Carefully lower a cover slip over the sample. Remember to place the cover slip at a 45 degree angle over the specimen, with one edge touching the water drop on the slide and gently drop it.

- Set the objective lens to the scanning power lens. Place your slide on the microscope stage. Ensure that the specimen is at the centre of the glass-hole so it can get light reflected from the light sources.

- Change the objective lens to low power and adjust the coarse focus knob and the light sources until you get a clear image of the plant cells. If you need to use higher power, use it, but ensure that you use only the fine focus knob.
Make a clear diagram of the cells that you see in the space below. Try to see if you can recognize any of the organelles of a plant cell. Show these on your diagram with the appropriate labels.

Now bring the objective lens back to the scanning power. Then carefully remove the slide from the stage and put some iodine stain on one edge of the cover slip and place a piece of paper towel at the opposite end. Leave the slide aside for about 3 to 4 minutes to allow the specimen to become properly stained.

Place the stained slide back on the microscope stage. Set the slide, the objectives lens, and the light properly and focus as required.

Do you see more details of the cell organelles? Try to improve the previous diagram you made. Use the labelled diagram of the plant cell in Figure 6.1.5 above, to help you refine your own diagram. It should be possible for you to see the cell wall, nucleus, vacuole and mitochondria as well as some of the other organelles.

Under your drawing note the type of plant cell that you have looked at and the **magnification** of the cell. The magnification shows by how much the actual cell has been enlarged. You get this information from the lens power; e.g. 10x, 50x, etc.
Now that you have observed plant cells, return the objective lens of the microscope to the scanning power, and then remove the slide from the stage. Wash the slide and cover slip, dry them and put them away. Wipe the stage clean if this is needed.

Let us now have a look at an animal cell.

- Place the permanent animal cell slide that the laboratory technician has given you on the stage of the microscope. Adjust the knob and light until you see the animal cells clearly.

- Try to identify as many of the parts shown on the animal cell that you have learnt in Figure 6.1.3 above. Then draw a diagram of the animal cell that you have seen under the light microscope in the space below. Label the organelles that you see.

- Under your drawing note the type of the animal cell that you have looked at and the magnification of the cell.
From the activities above, you now know how a plant cell and an animal cell look like, the cell organelles that the cells contain and their functions. You have seen how a plant cell and an animal cell looks like under the light microscope and you have seen diagrams of the same cells taken from an electron microscope.

Activity 6.1.6 below will help you summarize what you have learnt in this topic.
Activity 6.1.6

You have about 5 minutes to do this activity.

Write three “Did you know?” statements in the bubbles below to show what you have learnt in Topic 6.1.

Did you know?

An example

Did you know that plant cells have a cell wall and animal cells don’t?

1.

2.

3.
That was interesting! Show your “Did you know” questions to students who have not done this course. Try to answer any comments and questions that they may have as best as you can.

Let us now see how much you have learnt in the topic.

**Self-assessment 6.1**

You need 30 minutes to do the self-assessment. The feedback is given at the end of the unit. You are, however, strongly advised to answer all questions before you refer to the feedback. This will help you learn and reflect better on areas for improvement.

1. If you are shown the picture of a cell,
   a. explain how you would decide whether it is from a plant or an animal.
b. Suppose the cell was from a plant, draw and label the cell in the space below.

<table>
<thead>
<tr>
<th>Cell organelles</th>
<th>Functions of cell organelles</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Cytoplasm</td>
<td>A. Partially permeable membrane controlling entry and exit of nutrients and waste.</td>
</tr>
<tr>
<td>2. Nucleus</td>
<td>B. Organelle in which photosynthesis takes place.</td>
</tr>
<tr>
<td>3. Cell wall</td>
<td>C. Aqueous substance containing a variety of organelles</td>
</tr>
<tr>
<td>4. Chloroplast</td>
<td>D. Contains chromosomes with DNA which controls all the</td>
</tr>
</tbody>
</table>
Cell organelles | Functions of cell organelles
---|---
activities of the cell.

5. Cell membrane | E. Provides for support and protection and allows for the movement of water and mineral salts.

Table 6.1.5a: Cell organelles and their functions for matching.

Match the numbers with the letters to show the correct functions of the five cell organelles.

<table>
<thead>
<tr>
<th>Cell organelles</th>
<th>Functions of cell organelles</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td></td>
</tr>
</tbody>
</table>

Table 6.1.5b: Matching cell organelles and their functions.

I am sure that you enjoyed the self-assessment and that you have proved that you have mastered the content of Topic 6.1. Please check your answer below at the end of this topic.

**Feedback to Computer-Based Learning 6.1.1**

The cell organelles are matched according to the numbers below.
<table>
<thead>
<tr>
<th>Cell organelle</th>
<th>Corresponding number in the online diagram</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nucleus</td>
<td>2</td>
</tr>
<tr>
<td>rough endoplasmic reticulum</td>
<td>5</td>
</tr>
<tr>
<td>Golgi apparatus</td>
<td>6</td>
</tr>
<tr>
<td>smooth endoplasmic reticulum</td>
<td>8</td>
</tr>
<tr>
<td>Mitochondria</td>
<td>9</td>
</tr>
<tr>
<td>Cytoplasm</td>
<td>11</td>
</tr>
<tr>
<td>Lysosome</td>
<td>12</td>
</tr>
</tbody>
</table>

Table 6.1.1 (b): Matching cell organelles with their number from an online diagram.

“Hang-the-man” activity

i. nucleus

ii. cytoplasm

iii. cell membrane

iv. rough endoplasmic reticulum

v. mitochondria

vi. lysosome
Feedback to Activity 6.1.4

1. Venn diagram showing similarities between plant and animal cells.

2. Organelles of plant and animal cells identified by colour.

Figure 6.1.6 Organelles in a plant cell identified by colour
Answers to Self-assessment 6.1

1.

a. To decide whether a cell comes from a plant or an animal, one has to look for the presence of a cell wall, chloroplast and a large vacuole in the centre of the cell. A cell with these organelles is a plant cell. Animal cells do not have these organelles.

b. A plant cell would look like this:
2. The organelles found in both plant and animal cells are nucleus, cytoplasm and cell membrane.

3. Cell organelles matched with their functions.

<table>
<thead>
<tr>
<th>Cell organelles</th>
<th>Functions of cell organelles</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>C</td>
</tr>
<tr>
<td>2.</td>
<td>D</td>
</tr>
<tr>
<td>3.</td>
<td>E</td>
</tr>
<tr>
<td>4.</td>
<td>B</td>
</tr>
<tr>
<td>5.</td>
<td>A</td>
</tr>
</tbody>
</table>

Table 6.1.5 (b): Matching cell organelles and their functions.

I hope now you are familiar with the components of an organism. Can you name 3 components of an organism and their function?

Let us now continue to learn further about cells in Topic 6.2 below.
You will need 2 hours and 50 minutes at the most to do the activities in this topic. It is advisable that you spend another 1 hour and 25 minutes of your own time to further practice osmosis experiments and read further about the topic.

We saw in Topic 6.1 above, that both plant and animal cells have a cell membrane.

What is the function of the cell membrane?

Good! I know that you could easily answer this question, even without referring back to Topic 6.1. Hence, we know that the cell membrane is semi-permeable. It allows useful substances such as oxygen, water and glucose, to pass into the cell and waste substances such as carbon dioxide, to pass out of the cell.

In this topic, we shall be looking at the passage of water through the cell membrane. The process by which water moves through a semi-permeable membrane is known as osmosis.

6.2.1 What is osmosis?

Read the text below to find out what osmosis is.

Osmosis is a form of diffusion. It is the movement of water from a region of high water concentration, through a semi-permeable membrane to a region of low water concentration.
In order for you to have a better grasp of osmosis, it is important that you understand each of the key words that are highlighted above, so we will now discuss each of these key words separately.

**Semi-permeable membranes** are very thin layers of material, which allow some things to pass through them but prevent others from passing through.

We saw in Topic 6.1 that cell membranes are semi-permeable. The cell membranes will allow small molecules such as oxygen, water, carbon dioxide, ammonia, glucose and amino acids to pass through, but will not allow larger molecules such as sucrose, starch and protein to pass through.

Please remember that: Osmosis is about the movement of water through the semi permeable membrane (cell membrane) and not about the movement of the other dissolved substances.

A region of **high concentration of water** is a very dilute solution of something such as dilute sucrose solution, dilute salt solution or pure water. In each case there is a lot more water molecules than molecules of the solute (sucrose or salt); i.e. there is a high concentration of water.

A region of **low concentration of water** is a very concentrated solution of something like sucrose or salt. In this case there is much less water molecules compared to molecules of sucrose or salt; i.e. there is a low water concentration.

The discussion below will help you think carefully about and understand osmosis. As you read and think about the statements in the discussion, refer to the texts above to remind you of the key terms associated with osmosis.
Discussion 6.2.1

You should spend around 10 minutes on this discussion.

Three statements which attempt to define osmosis are given below. Only one of the statements is correct.

Find a group of students who are doing this course. In your group, read and discuss each of the three statements below one at a time. You need to decide which of the three statements is correct and explain why the other two statements are not correct.

**Statement 1:** Osmosis is the movement of water molecules from a concentrated solution to a more dilute solution through a semi-permeable membrane.

**Statement 2:** Osmosis is the movement of sucrose molecules from a concentrated solution to a more dilute solution through a semi-permeable membrane.

**Statement 3:** Osmosis is the movement of water molecules from a dilute solution to a more concentrated solution through a semi-permeable membrane.

1. a) Which statement is correct about osmosis?

   __________________________

   __________________________

   __________________________

   b) Why is this statement correct?

   __________________________
2. Why are the other two statements not correct?
Feedback to Discussion 6.2.1

I am sure that you have had some interesting discussions in your group and that you have realized that statement 3 is the only statement among the three which defines osmosis properly. Let us now consider each of the three statements and try to understand what each statement means.

Statement 1 states that osmosis is the movement of water molecules from a concentrated solution to a more dilute solution through a semi-permeable membrane. First, we realize that a concentrated solution does not have much water. It has a low water concentration. As osmosis is the movement of water from a region of high water concentration to a region of low water concentration, through a semi-permeable membrane, this statement about osmosis is not true.

Statement 2 states that osmosis is the movement of sucrose molecules from a concentrated solution to a more dilute solution through a semi-permeable membrane. This statement about osmosis is also not true. This is because osmosis is about the movement of water molecules, not the movement of other types of molecules such as sucrose.

Statement 3 tells us that osmosis is the movement of water molecules from a dilute solution to a more concentrated solution through a semi-permeable membrane. In a dilute solution, the water concentration is much higher than in a concentrated solution. Hence water will move from the dilute solution, where water concentration is high, to the more concentrated one, with low water concentration, through the semi-permeable membrane. This is the same definition as the one given above. Hence, the movement of water from a dilute solution to a more concentrated solution through a semi-permeable membrane is the same as the movement of water from a region of high water concentration, through a semi-permeable membrane to a region of low water concentration.

To help you better understand osmosis, I have illustrated the idea in Figure 6.2.1 below.

In the diagram, I have showed that there is pure water outside a cell and some sugar solution inside the cell. The water molecules are shown by small blue circles and the sugar molecules are shown by larger red circles.

Use the knowledge that you have gained in the discussion activity at 6.2.1 above to help you make sense of how osmosis takes place in a cell.
Figure 6.2.1: Diagram showing osmosis taking place in the case where a cell is surrounded by pure water or a very dilute solution.

Drawn by Mariette Lucas (2009)

If you have access to the internet, try visiting the following site to take a look at an animated description of osmosis.

http://highered.mcgraw-hill.com/sites/0072495855/student_view0/chapter2/animation__how_osmosis_works.html

Please note again that we are providing this for information only and we do not endorse or recommend any links from this site.

Activity 6.2.1

You should spend approximately 5 minutes on this activity.

1. Write a short paragraph, to explain how osmosis has taken place in the diagram above. I have started the paragraph for you.

   When a cell with low water concentration content (concentrated sugar solution) is placed in ......
2. What do you think will happen if a cell that contains a very dilute sugar solution (high water concentration) is placed in a very concentrated sugar solution (low water concentration)? Circle the correct answer.

A. Water molecules will move from the dilute sugar solution inside the cell into the concentrated solution outside the cell.

B. Water molecules will move from the concentrated solution outside the cell into the dilute solution inside the cell.

C. Sugar molecules will move from the dilute sugar solution inside the cell into the concentrated solution outside the cell.

D. Sugar molecules will move from the concentrated solution outside the cell into the dilute solution inside the cell.

3. In each case below, osmosis is likely to take place. On the respective diagrams, show how this will happen by drawing solid black arrows to show the direction in which the water will move.

i) Diagram 1:

ii) Diagram 2
Feedback to Activity 6.2.1

I hope that you have had no problems realizing that in each case above, water molecules will move through the semi-permeable membrane of the cell from a region of high water concentration (dilute solutions) to a region of low water concentration (weak solutions). This is what osmosis is all about.

As such you should have shown the movement of water for diagrams 1 and 2 of Question 3 as follows:

i) Diagram 1

ii) Diagram 2
Well done!

It is now your turn to see for yourself how osmosis takes place. Get a few friends and work together on the group activity below.
Group Activity 6.2.1

You should spend around 20 minutes on this group activity.

With the help of a laboratory technician, set up the following experiment:

- Cut a piece of visking tubing and leave it to soak for a few minutes.
- Tie a knot in one end of the visking tubing and fill it with sugar solution.
- Fix the open end of the visking tubing over the end of a glass tube with some wire. The glass tube should be well inserted in the sugar solution.
- Mark the level of the liquid in the glass tube.
- Using a retort stand and clamp, completely immerse the visking tubing in a beaker of tap water.
- Over the next 10 to 15 minutes, watch the level of liquid in the glass tube.


Reflection 6.2.1

Spend 5 minutes to reflect on what happened in the experiment.

1. What did you notice about the level of liquid in the glass tube at the end of the time span (10 to 15 minutes)?
2. What do you think has caused the change in the liquid level in the glass tube?

Feedback to Reflection 6.2.1

As you should have noticed the level of liquid in the glass tube went up. This is due to the movement of water molecules from the beaker (where the water concentration is high), through the semi-permeable membrane (the visking tubing), into the sugar solution (where the water concentration is low). The experiment is a demonstration of how osmosis takes place.

Reflection 6.2.2

Spend 5 minutes to reflect further.

What do you predict will happen if you reverse the content of the visking tubing and that of the beaker (i.e. if you put pure water in the visking tubing and sugar solution in the beaker/outside the visking tubing)?

Write your prediction below.
Now try to reverse the liquids. **You need to use a new set of materials (visking tubing, sugar solution, water, glass tube and beaker) to get the best results.**

After 15 minutes, observe your set-up. Draw a diagram in the space below to show what happened. Clearly show all the observations that you made.

What evidence do you have that osmosis has taken place?
Feedback to Reflection 6.2.2

As you might have expected, the liquid moved from the inside of the visking tubing out into the beaker. This caused the level of liquid in the glass tube to decrease and the visking tubing to become flabby.

We have seen that water will either move in or out of a cell depending on the concentration of the solution inside and outside of the cell. Below we shall now look at the special terms that are used to describe the solutions involved in osmosis.

6.2.2 Hypotonic, hypertonic and isotonic solutions

We have seen in Activity 6.2.1 and in Group Activity 6.2.1 above that in osmosis, water moves from an area of high water concentration to an area of low water concentration. This tendency for water molecules to move from one area to another is known as the water potential. Pure water or a dilute solution contains more water molecules per unit volume than a concentrated solution. Therefore pure water and weak solutions are said to have greater water potentials than concentrated solutions.

A solution that has a higher water potential (a dilute solution) than another solution is a hypotonic solution. If two solutions have the same water potentials, they are said to be isotonic. A solution with a low water potential (a concentrated solution) is called a hypertonic solution.

Discussion 6.2.2

You need no more than 10 minutes for this discussion activity.

Join back together with the group of students with whom you worked on Group Activity 6.2.1 above. Refer back to the activity and study the content of the glass tube and the visking tubing for both the first and second experiment that you did.

In each case discuss and determine whether the solutions were hypotonic, hypertonic or isotonic. Then complete the table below to show the results of your discussions.
### Table 6.2.1: What happens in a visking tubing experiment

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Contents of:</th>
<th>Type of solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>First experiment</td>
<td>Visking tubing</td>
<td>Hypotonic/hypertonic/isotonic</td>
</tr>
<tr>
<td></td>
<td>Glass tube</td>
<td></td>
</tr>
<tr>
<td>Second experiment</td>
<td>Visking tubing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Glass tube</td>
<td></td>
</tr>
</tbody>
</table>

**Feedback to Discussion 6.2.2**

Well done!! You have surely realized that in the first experiment the solution in the visking tubing was hypertonic (concentrated solution), whereas the solution in the glass tube was hypotonic (dilute solution).

In the second experiment the solution in the visking tubing was hypotonic (dilute solution) whereas the solution in the glass tube was hypertonic (concentrated solution).

Let us now represent hypertonic, hypotonic and isotonic solutions with diagrams.

**Diagram 1**

Diagram 1 shows that *solution A is hypertonic* (more concentrated) and *solution B is hypotonic* (less concentrated).
Diagram 2 shows that solution B is hypertonic (more concentrated) and solution C is hypotonic (less concentrated).

Diagram 3 shows that solutions B and D are isotonic (same concentration).

Reflection 6.2.3
Take 5 minutes to reflect on this question.

In principle osmosis should happen in situations represented by diagrams 1 and 2, but not in the situation shown by diagram 3. Explain why.
Feedback to Reflection 6.2.3

That was good thinking! I am sure you realized that in situations where solutions enclosed in a semi-permeable membrane are placed in a solution with a different water concentration, water will move in if the solution inside the semi-permeable membrane is hypertonic and the solution outside is hypotonic. The reverse will happen if the solution inside the semi-permeable membrane is hypotonic and the solution outside is hypertonic.

In situations where solutions inside and outside a semi-permeable membrane are isotonic, there is no net movement of water.

We shall now look at osmosis in real life situations.

We saw earlier that plant and animal cells have a cell membrane which is semi-permeable. We also learnt that the cytoplasm and vacuoles of the cells contain mainly water with substances such as salts, sugar and proteins dissolved in them. Plant and animal cells are immersed in solutions. Hence osmosis is always taking place in plant and animal cells.

Water moving in or out of plant and animal cells have various consequences on the cells and hence on the organism.

In living cells, water is always moving in and out of the cell through the cell membrane, which is semi-permeable. Water molecules are free to pass in both directions through the cell membrane. However, the difference in the concentration of water inside and outside the cell causes water to move faster / more depending on the water potential of each solution. Water moves faster when the water potential either inside or outside the cell is high.

Remember that a hypotonic solution (a weak solution) has a greater water potential than a hypertonic solution (a concentrated solution).
Therefore, if an animal cell or a plant cell is placed in a liquid, one of the following three things will happen:

- If the liquid surrounding the cell is hypertonic (a concentrated solution; hence a solution with low water concentration), the cell will lose water by osmosis. That is, much more water will leave the cell compared to the amount entering the cell. As a result, the cell will shrink.

- If the liquid surrounding the cell is hypotonic (a weak solution; hence a solution with high water concentration), the cell will gain water by osmosis. That is much more water will enter the cell, compared to the amount of water leaving the cell. As a result, the cell will swell up.

- If the liquid surrounding the cell is isotonic (of the same concentration as the liquid in the cell), the cell will neither lose nor gain water. In other words osmosis will not take place. There will be the same amount of water entering the cell and leaving it. Therefore, there is no change in the size of the cell; the cell stays the same size.

6.2.3 Osmosis in plant cells

We saw earlier that one of the main differences between a plant cell and an animal cell is that plant cells have a cell wall. The cell wall is made of cellulose and is strong. It is freely permeable; that is it allows dissolved substances to move in and out of the cell freely.

Reflection 6.2.4

You will require 5 minutes for this reflection exercise.

*What do you think will happen if a plant cell is placed in a hypotonic solution? Draw and write about your idea in the space below.*
In a situation such as the one stated in the question above, there is greater water potential outside the plant cell than inside the plant cell.

**Feedback to Reflection 6.2.4**

As you realized, since there is greater water potential outside the cell, water will move from outside the cell to the inside. This will cause the cell to bulge.

Let us read the explanation below to understand better what really happens in such a situation.

When a plant cell is placed in a hypotonic solution, it takes up water and starts to swell. Because of the strong cell wall, the cell does not burst, it becomes swollen and hard. In this state the cell is said to have become **turgid**. As water continues to enter the cell, pressure builds up inside the cell until no more water can enter the cell.

I have represented this outcome in Figure 6.2.2 (a) below.

![Figure 6.2.2: Plant cell in hypotonic solution](image)

Figure 6.2.2: Plant cell in hypotonic solution

Drawn by Mariette Lucas (2009)
The turgidity of plant cells help the plants that are not composed of wood to stay upright and it also keeps the leaves firm. You will learn about the importance of turgidity in plant cells in the unit on **Support and Movement (Unit 14)**.

**Activity 6.2.2**

You should complete this activity in 5 minutes.

It should not be difficult now for you to tell what would happen when a plant cell is placed in a hypertonic solution. Complete Table 6.2.2 below to show your ideas. To help you in your thinking, I have noted on the table, what we said would happen if the cell is placed in a hypotonic solution.

<table>
<thead>
<tr>
<th>What to observe?</th>
<th>Osmosis in a plant cell placed in a hypotonic solution</th>
<th>Osmosis in a plant cell placed in a hypertonic solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>In which direction does the water move?</td>
<td>Water moves into the cell.</td>
<td>Water moves out of the cell.</td>
</tr>
<tr>
<td>What happens to the cell?</td>
<td>The cell swells and becomes turgid.</td>
<td>The cell shrinks and becomes flaccid.</td>
</tr>
<tr>
<td>Is there any pressure that is exerted on the cell?</td>
<td>Pressure builds up inside the cell until no more water can come in.</td>
<td>Pressure builds up outside the cell.</td>
</tr>
</tbody>
</table>

Table 6.2.2: Completing observations of a plant cell that is placed in a hypertonic solution.
Feedback to Activity 6.2.2

You have surely realized that if a plant cell is placed in a hypertonic solution, water will move out of the cell. This will therefore cause the cell to shrink.

I have explained the situation below and have also drawn diagrams to show what will happen.

When a plant cell is placed in a hypertonic solution, water moves out of the cell. The vacuole decreases in size and the cytoplasm shrinks and pulls away from the cell wall. The cell becomes **flaccid** and is said to be **plasmolysed**. This is illustrated in Figure 6.3.3 below.

In real life situations this is when we see plants wilting.

In the activity below you will now work with pieces of potatoes in hypertonic and hypotonic solutions in order to experience turgidity and plasmolysis yourself.
Activity 6.2.3

You will need 15 minutes to set up the experiment and a further 10 minutes to record and interpret the results.

Follow through the steps below to do your experiment. You may wish to get the assistance of a laboratory technician to get a cork borer. If you do not have cork borers, instead of potato cylinders, you can prepare potato chips of a specific dimension (6cm in length x 0.5cm in width).

**Step 1:**
Get a large potato and a cork borer of size No. 5. Wash the potato and dry it with a paper towel. Then place it on a board.

**Step 2:**
Cut off the top and bottom parts, making a flat top and bottom surface. Push a cork borer of size No. 5 into the potato and remove the potato cylinder out of the cork borer using a pencil. Place the potato cylinder in a petri dish.

**Step 3:**
Prepare a few more potato cylinders in the same way as above. Then choose the best four cylinders.

**Step 4:**
Get four clear containers such as test tubes or petri dishes and label them A1 and A2 and B1 and B2. Then place a potato cylinder in each container.
Step 5:
Cover the potato cylinder in container A1 and A2 with water and the ones in containers B1 and B2 with a concentrated sugar solution. Leave the containers for 2 to 3 hours.

Step 6:
After the time has passed, remove the potato cylinders from containers A1 and A2, feel each potato cylinder and observe carefully how they now look, then measure their lengths. Record the new length, texture and appearance of the potato cylinder that has changed the most, in the table below.

Step 7:
Repeat step 6 for the potato cylinders in test-tubes B1 and B2, but rinse them in water before measuring them. Record your observations in Table 6.2.3 below.

Experiment set-up: Louisette Bonte (2009)

<table>
<thead>
<tr>
<th></th>
<th>Length at start</th>
<th>Final length</th>
<th>Difference in length</th>
<th>Appearance and texture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potato cylinder A (in water)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potato cylinder B (in sugar solution)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6.2.3: Results of osmosis in the potato

I am sure that you have made some very interesting observations!

Now use the observations that you have recorded above to answer the following questions.
<table>
<thead>
<tr>
<th>Questions</th>
<th>Potato cylinder A</th>
<th>Potato cylinder B</th>
</tr>
</thead>
<tbody>
<tr>
<td>In which type of solution was the potato placed in? (hypertonic/hypotonic/isotonic)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>In which direction did the water move?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>What happened to the potato?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>What happened to the cells of the potato? In your explanation you are required to make reference to the terms “turgidity” and “plasmolysis”.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>How would the cells of the potato look like?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Show this by drawing one of the cells. You should also label the cell as clearly as you can.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6.2.4: Interpreting results about osmosis in the potato.

I hope you enjoyed the activity. The feedback is given at the end of the topic. You are, however, strongly advised to answer all questions first before you refer to the feedback. This will help you learn and reflect better on areas for improvement.
Reflection 6.2.5

You should spend 5 minutes on this activity.

We shall now see how osmosis takes place in animal cells. But I am sure that you already have an idea of what to expect, so I want you to share your ideas for each situation, by writing them in the solid callout shape below.

Situation 1:

What will happen to an animal cell that is placed in a hypotonic solution?

Situation 2:

What will happen to an animal cell that is placed in a hypertonic solution?
Feedback to Reflection 6.2.5

I am sure that you have expressed your ideas correctly. Did it occur to you that animal cells do not have a cell wall but that they only have a cell membrane? As a result of this animal cells would behave slightly differently when placed in hypertonic and hypotonic solutions.

Read the text below to learn more.

6.2.4 Osmosis in animal cells

You will recall that animal cells have a cell membrane, but no cell wall and that in living cells water is constantly moving in and out of the cell through the cell membrane.

We also know that if the liquid outside the cell is hypotonic, water will move in faster than it moves out and that this is due to osmosis.

Provided that there is a difference in the concentration of the liquid inside and outside the cell, osmosis will take place and this will affect the direction and speed of water in or out of the cell.

If animal cells are placed in hypertonic solutions (concentrated solutions), the water inside the cells will pass out of the cell membrane by osmosis and this will cause the cells to shrink.

Figure 6.2.4 below summarises what happens when an animal cell is put in a hypertonic solution.

![Figure 6.2.4: Animal cell in hypertonic solution](image)

Drawn by Mariette Lucas (2009)
Reflection 6.2.6

Spend 5 minutes reflecting on the question below.

From the reading that you have done above and after you have studied Figure 6.2.4, what do you think will happen if an animal cell is placed in a hypotonic solution?

Show your ideas in the space below. You are also encouraged to draw a diagram to make your ideas clearer.

Feedback to Reflection 6.2.6

I am convinced that you are not very far from the expected observation. Compare your ideas with the text below and the drawing in Figure 6.2.5.

When an animal cell is placed in a hypotonic solution, water from outside the cell will move in fast. The cell will swell up and since animal cells do not have cell walls, the cell will burst.
Were you surprised that the cell burst? Maybe you had not realised that the cell would burst, if you missed the part that an animal cell does not have a cell wall. Good try anyway!

You may have realised that in both cases above, whenever the animal cell takes in a lot of water or when it loses a lot of water, it is a problem for the animal. Hence, it is very important for animal cells to be always bathed in an isotonic solution, which is a liquid which has the same concentration as the liquid in the cytoplasm.

Water and the solvents dissolved in the animal’s body have to be regulated and kept constant. The process by which this is done is called osmoregulation. You will learn more about this in unit 21 which is about Coordination and Response.

It is now time to test your understanding about osmosis. Try Self-assessment 6.2 below to see how well you have learnt and mastered the above content.
Self-assessment 6.2

You need 30 minutes to do the self-assessment. The feedback is given at the end of the topic. You are, however, strongly advised to first answer all questions before you refer to the feedback. This will help you learn and reflect better on areas for improvement.

1. Define the term osmosis.

2. Why is the cell membrane said to be semi-permeable? Circle the best answer.

   A. It allows sugar molecules to pass through.
   B. It allows molecules to enter and leave the cell.
   C. It allows the free passage of all types of molecules.
   D. It allows some molecules to pass through, but not others.

3. If an animal cell is placed in some concentrated sugar solution, it would look like this.
a. Explain why this happens.

b. Roots of plants are usually surrounded with water. This situation is represented in the diagram below.

i. The visking tubing represents the cell membrane. It separates two solutions of different concentrations. Which solution is more concentrated?

ii. What causes the water level in the tube to rise?
iii. Explain the effect of such a situation on the leaves of a plant in real life situations.

4. Draw lines to match each term with its correct meaning.

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypotonic</td>
<td>A solution with a low water potential (concentrated solutions) than another solution.</td>
</tr>
<tr>
<td>Isotonic</td>
<td>A solution that has a higher water potential (dilute solutions) than another solution.</td>
</tr>
<tr>
<td>Hypertonic</td>
<td>Two solutions that have the same water potentials</td>
</tr>
</tbody>
</table>

Table 6.2.6 (a): Definition of hypotonic, hypertonic and isotonic

Feedback to Activity 6.2.4

Table 6.2.5 below explains what happened in potato cylinder A and potato cylinder B.
<table>
<thead>
<tr>
<th>Questions</th>
<th>Potato cylinder A</th>
<th>Potato cylinder B</th>
</tr>
</thead>
<tbody>
<tr>
<td>In which type of solution was the potato placed in? (hypertonic/hypotonic/isotonic)</td>
<td>It was placed in water. Water is a weak solution. It has a high water potential. It is a <strong>hypotonic</strong> solution.</td>
<td>It was placed in sugar solution. The sugar solution is a concentrated solution. It has a low water potential. It is a <strong>hypertonic</strong> solution.</td>
</tr>
<tr>
<td>In which direction did the water move?</td>
<td>The water moved from the outside of the potato into the potato.</td>
<td>The water moved from the inside of the potato into the sugar solution outside of the potato.</td>
</tr>
<tr>
<td>What happened to the potato?</td>
<td>The potato increased in length. It became bigger.</td>
<td>The potato decreased in length. It became smaller.</td>
</tr>
<tr>
<td>What happened to the cells of the potato? In your explanation you are required to make reference to the terms “turgidity” and “plasmolysis”</td>
<td>When a plant cell is placed in a hypotonic solution, it takes up water and starts to swell. Because of the strong cell wall, the cell does not burst, it becomes swollen and hard. In this state the cell is said to have become <strong>turgid</strong>. As water continues to enter the cell, pressure builds up inside the cell until no more water can enter the cell.</td>
<td>When a plant cell is placed in a hypertonic solution, water moves out of the cell. The vacuole decreases in size and the cytoplasm shrinks and pulls away from the cell wall. The cell becomes <strong>flaccid</strong> and is said to be <strong>plasmolysed</strong>.</td>
</tr>
<tr>
<td>How would the cells of the potato look like?</td>
<td><img src="image1" alt="Diagram of a plant cell in a hypotonic solution" /></td>
<td><img src="image2" alt="Diagram of a plant cell in a hypertonic solution" /></td>
</tr>
</tbody>
</table>

Show this by drawing one of the cells. You should also label the cell as clearly as you can.

Table 6.2.5: Interpreting results of osmosis in the potato.
Answers to Self-assessment 6.2

1. Osmosis is the passage of water molecules from a region of high water concentration, through a semi-permeable membrane to a region of low water concentration.

2. The cell membrane allows some molecules to pass through, but not others. (D).

3. The following are answers to question 3
   
   a. If animal cells are placed in hypertonic solutions (concentrated solutions), the water inside the cells will pass out of the cell membrane by osmosis and this will cause the cells to shrink.
   
   b. The following are answers to part (b) of question 3:
      
      i. The solution inside the visking tubing is more concentrated.
      
      ii. The water level rises because water from outside moves in through the visking tubing, which is semi-permeable. Hence osmosis takes place.
      
      iii. The plant cells will become turgid and plant parts such as the stem will become firm and the leaves will be held upright.

4. Matching each term with its correct meaning.

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypotonic</td>
<td>A solution that has a higher water potential (dilute solutions) than another solution.</td>
</tr>
<tr>
<td>Isotonic</td>
<td>Two solutions that have the same water potentials</td>
</tr>
<tr>
<td>Hypertonic</td>
<td>A solution with a low water potential (concentrated solutions) than another solution.</td>
</tr>
</tbody>
</table>

Table 6.2.6 (b): Definition of hypotonic, hypertonic and isotonic

Quickly reflect back on what you learned in this topic. Now that you have understood cells and osmosis, let us have a look at specialized cells.
Topic 6.3: Specialized cells

You will need 3 hours and 20 minutes at the most to do the activities in this topic. It is advisable that you spend another 1 hours 40 minutes of your own time to further learn about specialized cells, tissues, organs and body systems.

You have seen the skin and the bones of many animals. Each animal’s skin is very different from their bones. Do you have any idea of what causes this difference? Write down your idea below.

I am sure that you have realized that the skin is made up of cells that must be very different from the bones’ cells. It is these different types of cells that make our body organs different. In this topic you will learn about some of the special cells of plants and animals.

Let us start by reading the text below:

The body of eukaryotic organisms is made up of different types of cells. Most of these different types of cells have a cytoplasm, a cell membrane and a nucleus. The number of organelles in the different types of cells in one organism varies according to the special functions that the specific cells have to do in the body of the organism. This also varies from species to species, giving each organism its uniqueness.
Look carefully at the little girl and her cat. They are very different!

Figure 6.3.1: A little girl and her cat.
Photo taken by Mariette Lucas (2009)

Cats are hunters and agile climbers. They need to move fast to catch their prey. The number of mitochondria in the cells of the cat would therefore not be the same as in the little girl. Who do you think would have more mitochondria, the cat or the girl?

For sure the cat would have more mitochondria in its cells than the girl. This is because it needs more energy to do its day to day hunting.

Cells in the body of the same organism differ according to their special functions. They become specialized for a specific job, they have a distinct shape and special chemical changes take place in their cytoplasm. Let us start by looking at some of the specialized cells in plants.

6.3.1 Specialized cells of plants
I have shown some of the specialized cells of a plant for you below:
Plant leaves contain many different types of cells such as the **epidermal cells** on the lower and upper surface of the leaf and the **guard cells**.

- The epidermal cells prevent the leaf from excessive loss of water and protect the plant against injury.
- The guard cells contain chloroplasts with the green pigment chlorophyll, which enables the leaves to photosynthesize.

The stem contains xylem and phloem tissues. **Xylem** consists of four types of specialised cells for the transportation of water and minerals in the plant. The **phloem** consists of five cell types for the conduction of food made by the plant for use and storage. Two of these cells are **sieve tubes** and **companion cells**.

Roots consist of different types of cells, including special **root hair cells** which increase the surface area of the roots for absorption of water and nutrients.

**Activity 6.3.1**

You should spend about 5 minutes to complete the activity.

Use the information in Figure 6.3.2 above and make a table in the space below to show the specialised cells of a plant and their functions.
Feedback to Activity 6.3.1

<table>
<thead>
<tr>
<th>Specialised cell</th>
<th>Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epidermal cells</td>
<td>• Prevent the leaf from excessive loss of water.</td>
</tr>
<tr>
<td></td>
<td>• Protect the plant from injury</td>
</tr>
<tr>
<td>Guard cells</td>
<td>• Contain chloroplasts which enable the plant to photosynthesize.</td>
</tr>
<tr>
<td>Xylem</td>
<td>• Allows for the transportation of water and minerals in the plant.</td>
</tr>
<tr>
<td>Phloem</td>
<td>• Allows for the conduction of food made in the plant for storage and use.</td>
</tr>
<tr>
<td>Root hair cells</td>
<td>• Increase the surface area of roots for the absorption of water and nutrients from the soil.</td>
</tr>
</tbody>
</table>

I am sure that you had included the appropriate headings on your table and that you now know some of the specialized cells of a plant and their functions.
In Activity 6.3.2 below, we shall be looking at two of these specialised cells. These are the root hair cells in the roots of plants and the guard cells in the leaves.

Activity 6.3.2
You should complete the activity in about 20 minutes.

The texts below are about the structure and function of guard cells and root hair cells. Read the texts carefully, and then do the activities that follow.

Guard cells:
The underside of leaves contain guard cells. Guard cells contain chloroplasts, which contain chlorophyll. Guard cells are pairs of bean shaped cells that surround the stomata.

Stomata (singular: stoma) are tiny pores between each pair of guard cells.

The guard cells control the opening and closing of the stomata in response to light and heat. Carbon dioxide and oxygen moves in and out of the cell through the stomata. Water also moves out of the stomata in the form of water vapour. At night the stomata closes to conserve water in the plant.

There are more stomata on the underside of the leaf. This stops water from evaporating too quickly from the upper surface of the leaf which is exposed to the sun.

Root hair cells
Certain cells of the outer layer of roots are modified for absorption purposes. These are the root hair cells, which are long tube-like projections which anchor the roots into the soil.

Root hair cells grow from the main root and increase the surface area of the root for water intake.

The water absorbed by the root hairs is transferred to the water storage area in the root to be taken up by the plant.

1. From the descriptions of guard cells and root hair cells in the text above, you should be able to tell how each type of cell looks like.
Pictures of the cells are shown below. Write the name of each cell under their drawing.


2. Which of the sentences explain why there are more guard cells on the bottom surface of a leaf rather than on the top surface? Circle the correct answer.
   
   A. Guard cells become weak in too much light.
   B. It is easier for oxygen to get into the plant at the bottom of the leaf than on the top.
   C. The top surface of a leaf gets more sunlight and so the plant would lose too much water by evaporation.
   D. The stomata in the bottom surface of the leaf are smaller than the stomata in the top surface of the leaf.

3. Where are root hair cells found in a plant and what is their role in the plant?
Now that you know how guard cells and root hair cells look like, where they are located and what their functions are, you will be better able to identify those cells under the microscope.

You need to go to your Science teacher or a laboratory technician to get the following materials: a light microscope and a permanent slide of root hair cells and one of leaf guard cells.

Once you have got the equipment that you need:
- Observe each type of cell under the microscope.
- Make an enlarged drawing of the cells in the correct box below.
- Label any of the parts of the cell that you can see.

I have provided labelled diagrams of the root hair cell and the guard cell in the feedback to Activity 6.3.2 at the end of the topic. Use the drawings given in the feedback to improve on the drawings that you have made above.

You are, however, strongly advised to make your own drawings before you refer to the feedback. This will help you learn and reflect better on areas for improvement.

We hope that the above exercise triggered you to think of some of the specialized cells that an animal could also have. Let us now learn some of these cells.

6.3.2 Some specialized cells of animals

As you might have realized, the body of an animal also consists of many different types of specialized cells. These cells, which are located in
specific places in the body, have very specific structures that enable them to perform their very specific functions. As a result different types of chemical reactions take place in the different cells. In this unit we shall be looking at two types of animal cells: the blood cells and the muscle cells.

6.3.2.1 Blood cells

Blood consists of different types of cells: red blood cells, white blood cells and platelets, suspended in liquid called plasma. Each type of cell has a specific structure to allow them to perform their different functions. These are shown in Table 6.3.1 below.

<table>
<thead>
<tr>
<th>Blood cell</th>
<th>Drawing</th>
<th>Function</th>
</tr>
</thead>
</table>
| Red blood cell (erythrocyte) | ![Drawing](image) | • Contains haemoglobin, which takes oxygen from the lungs and carries them to all the other parts of the body.  
  • The haemoglobin gives the blood its red colour.  
  • Has no nucleus.  
  • Has a flexible cell membrane to allow it to squeeze through narrow capillaries. |
| White blood cell (leukocyte) | ![Drawing](image) | • Identifies and destroys bacteria and other disease-causing-organisms which enter the body.  
  • Has a nucleus and some have granules.  
  • Regulates the immune system of the body |
| Platelets              | ![Drawing](image) | • The smallest cells in the blood, which helps it to clot. |
Table 6.3.1: Blood cells and their functions

Group Activity 6.3.1

You will need 15 minutes to first find the answers to the quiz questions, and a further 10 minutes to do the quiz.

To help you learn the different types of blood cells and their functions, I have devised a set of questions for the quiz below. You should write the answers to each question in the space provided before you do the quiz.

Quiz: Blood cells and their functions

Instructions:

Group the participants in two groups. Ask each question for a maximum of two times. Award 2 marks for the correct answer when the question is first offered. Award 1 mark for the correct answer when the question is offered the second time.

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>What are erythrocytes?</td>
<td></td>
</tr>
<tr>
<td>What are platelets?</td>
<td></td>
</tr>
<tr>
<td>Which blood cell helps destroy bacteria and other disease causing organisms which enter the body?</td>
<td></td>
</tr>
<tr>
<td>State two functions of haemoglobin.</td>
<td></td>
</tr>
<tr>
<td>Which blood cell is shown in this diagram?</td>
<td></td>
</tr>
</tbody>
</table>
Once you have written the correct answers to the quiz questions above, find a group of about six students who are doing this course. Each time your friends have answered a question, tell them whether or not they got the correct answer. If they did not, let them know what the correct answer is.

Enjoy the game!!

Feedback to Group Activity 6.3.1

1. Erythrocytes are red blood cells. They have no nucleus and contain haemoglobin which carries oxygen. Erythrocytes have flexible membranes that enable them to squeeze through narrow capillaries.

2. Platelets are the smallest cells in the blood which help the blood to clot.

3. The white blood cell (leukocyte) helps destroy bacteria and other disease causing organisms which enter the body.

4. Haemoglobin carries oxygen from the lungs to all parts of the body and gives the blood its red colour.

5. A white blood cell (leukocyte).

6. The red blood cell (erythrocyte).

I hope that you have really enjoyed the quiz and that it has helped you and your friends to better understand the different types of blood cells and their functions.
We shall now take a closer look at some of the blood cells under the light microscope.

**Activity 6.3.3**

You will need 15 minutes to do the activities below.

1. Go to the laboratory and ask the laboratory technician for a permanent blood slide and a microscope. Look at the slide under the microscope. Make a drawing of what you see in the space below.

   Use the knowledge that you have gained above about blood cells in Table 6.3.1 above to label your drawing.

2. Using two types of blood cells, write a short paragraph, to show how cells have special structures to match their functions.
Feedback to Activity 6.3.3

1. You should have been able to see some red blood cells. Under the microscope, they look like pink discs, which are thinner in the middle and thicker on the outside, like donuts.

2. Red blood cells have flexible membranes and they contain haemoglobin. Their flexible membranes allow them to easily squeeze through the blood capillaries and their haemoglobin allow for the transportation of oxygen.

White blood cells have a nucleus and some have granules (small grains on the surface). They destroy bacteria which enter the body and regulate the immune body system.

Platelets are the smallest cells in the blood which help it to clot.

I’m sure that it was very easy for you to complete the activity. If, however, you had any problems, you should refer back to the information in Table 6.3.1 above.

We shall now look at muscle cells.
6.3.2.2 Muscle cells

Activity 6.3.4

Take 5 minutes to do the activity.

Move your lower arm up and down and feel your upper arm muscles.

Do you have any idea what these muscles look like?

Discuss with a friend and make a rough sketch of your ideas below.

I am sure that you are not far from reality. Once you have learnt about muscle cells, return to this drawing and assess how close your drawing is to the structure of muscle cells.

There are three main types of muscle cells in the body of vertebrates. These are the skeletal muscle cells, the smooth muscle cells and the cardiac muscle cells. We shall be looking more specifically at skeletal muscle cells in this unit as skeletal muscles are one type of muscle that we are more familiar with.
Reflection 6.3.1

You need to spend 5 minutes on this reflection.

What does the word muscle remind you of?

Feedback to Reflection 6.3.1

Of course you may have thought of the muscles in your upper arm and in your upper and lower leg or even muscles in the flesh of animals that we eat. Some of you may have thought of the muscles in the upper arms of body builders.

When you eat drumsticks, you are eating muscles in the lower half of the leg of the chicken.

Let us now learn about the cells that make up skeletal muscles and their functions

A skeletal muscle is linked to a bone by tendons. A skeletal muscle consists of multiple bundles of muscle fibres held together by connective tissue. Skeletal muscle fibres contain long sausage shaped cells, with many nuclei. The cells contain special proteins that are necessary for muscle contraction. Contraction of the skeletal muscles causes the bones of the body to move. The flesh of vertebrates underneath the skin is mostly skeletal muscle.
Reflection 6.3.2
Spend 5 minutes on this reflection activity.

Let us now reflect on the above text.

1. Copy the sentence in the text above that tells us about the function of the skeletal muscle. Then underline the function of the skeletal muscle in the sentence.

2. Describe the cells of the skeletal muscle.

3. In which part of the body are skeletal muscles found?
1. Contraction of the skeletal muscles causes the bones of the body to move.

2. Skeletal muscle fibres contain long sausage shaped cells, with many nuclei. The cells contain special proteins that are necessary for muscle contraction.

3. Skeletal muscles are found underneath the skin. The flesh underneath the skin is mostly skeletal muscle.

Feedback to Reflection 6.3.2

1. Contraction of the skeletal muscles causes the bones of the body to move.

2. Skeletal muscle fibres contain long sausage shaped cells, with many nuclei. The cells contain special proteins that are necessary for muscle contraction.

3. Skeletal muscles are found underneath the skin. The flesh underneath the skin is mostly skeletal muscle.

Well done! By now you must be conscious of the two major skeletal muscles in our upper arm. These muscles are the biceps and the triceps. To lift your lower arm, the biceps muscle contracts. When the triceps muscles contract the lower arm is lowered.

Try moving your lower arm up and down and you will feel the contraction of the biceps muscles.

You will learn more about these skeletal muscles in the topic Support and Movement in Unit 14.

We saw above in the example of the skeletal muscle, that it is made up of many muscle fibres. Each fibre contains long sausage shaped cells. This shows that cells group together to do specific jobs.

We shall see how cells work together below.

6.3.3 Tissues

Groups of cells working together to perform a particular function are known as tissues. A tissue may contain cells of only one type of cell, or a mixture of different types of cells. Muscle tissue, for example, contains only one type of cell, known as muscle fibre, whereas the xylem tissue contains four different types of cells. Below we shall be looking more
closely at bone tissues and epithelial tissues in animals, and xylem, phloem and mesophyll tissues in plants.

6.3.3.1 Sample animal tissues

6.3.3.1.1 Bone tissues

We have all seen the bones of animals and have also probably eaten or crushed bones that have been cooked.

Activity 6.3.5

You should complete this activity in 10 minutes.

Find the bone of a chicken or that of an animal that we use as food. With a hand lens and a toothpick study the outside and the inside of the bone carefully. Then complete the table below to show the differences in the inside and outside of the bone. Include a drawing of the bone in the table.

<table>
<thead>
<tr>
<th>Bone of……………………………</th>
<th>Bone Properties</th>
<th>Inside of bone</th>
<th>Outside of bone</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Texture</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Colour</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Other observations</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6.3.2: The inside and outside of a bone

Below is a text on bone cells. Read the text and compare the information with what you have written in Table 6.3.2 above.
Bones consist of compact bone tissue in the outer layer and spongy bone tissue filling the interior of the bone. They are covered by a layer of dense connective tissue.

The different tissues are made of different types of cells. The compact bone tissue facilitates the passage of nutrients, metabolic waste and respiratory gases towards and away from the cells and produces a structure of great strength.

The spongy bone tissue is the site of production of the blood cells and fat cells. It enables the bone to withstand tension and compression forces effectively, whilst at the same time keeping the weight of the bone to a minimum.

Figure 6.3.4 below is part of the femur bone, showing the bone tissues.

![Figure 6.3.4: Femur bone showing bone tissues](http://simple.wikipedia.org/wiki/Bone_marrow)

1. *In what ways was your drawing similar to the drawing of the femur bone drawing above?*
Try discussing your results with your peers and your teacher.

Now that you have some good knowledge about bone tissues, let us learn about epithelial tissues.

### 6.3.3.1.2 Epithelial tissues

The epithelium is a thin layer of tissue which forms the lining of the mouth cavity and other organs such as the windpipe and food canals. Epithelial tissues protect the organs from physical and chemical damage.

**Summary 6.3.1**

You should take about 5 minutes to do this activity

In a short paragraph of no more than 100 words, write a summary of what you have learnt about animal tissues. Use the notes above to help you.
Show your summary to your teacher. I am sure that you will get some very positive feedback.

Now, let us proceed to learn about some plant tissues.

**6.3.3.2 Sample plant tissues**

**6.3.3.2.1 Xylem and phloem**

We saw earlier that plants have phloem and xylem tissues which help with the conduction of materials in the plant. The cells of the xylem tissue are different from those of the phloem tissue. This is because they conduct different types of materials.

![Figure 6.3.5: Xylem and phloem tissues](http://en.wikipedia.org/wiki/Xylem)

**Activity 6.3.6**

You have about 5 minutes to do this activity.

What do the xylem and the phloem tissues conduct? If you are not sure, go back to our section on specialized cells to find the answer.
Feedback to Activity 6.3.6

Good! You noticed that the xylem tissue conducts water and minerals from the soil to the leaves to allow the plant to photosynthesise. The phloem tissue is responsible for the transportation of food made in the leaves to the other parts of the plant.

We shall now look at some tissues found in the leaves of plants.

A leaf has three main groups of tissues. These are the epidermal tissue, which covers the upper and lower surfaces of the leaf, the mesophyll tissue which forms part of the interior of the leaf, and the vascular bundle tissues which consist of xylem and phloem.

The epidermal tissue and each of the mesophyll tissues consist of only one type of cell, whereas the xylem tissue and the phloem tissue consist of more than one type of cell.

We shall have a look at the mesophyll tissues in the next section.

6.3.3.2.2 Mesophyll tissues

The mesophyll tissues in the leaves of plants comprise of the palisade mesophyll and the spongy mesophyll.

The palisade mesophyll is directly below the upper epidermis of leaves. These are tightly packed, vertically elongated cells, regularly arranged in one to five rows.

The cells in the spongy mesophyll are more rounded and not so tightly packed, with large intercellular air spaces.

The cells in the palisade mesophyll contain a lot more chloroplasts than the cells in the spongy mesophyll, which is just beneath the palisade layer (see diagram below).

Most photosynthesis takes place in the palisade mesophyll, whereas the large air spaces in the spongy mesophyll allows for efficient gaseous exchange.
The main tissues in a leaf

Figure 6.3.6: Mesophyll tissues in a leaf
Source: http://en.wikipedia.org/wiki/Epidermis_(botany)

Summary 6.3.2

You should spend about 5 minutes on this activity.

Draw a table in the space below. In the table list all the plant tissues and the animal tissues that you have learnt about in the sections above.

Make sure that you give a title to your table to show the type of information that it contains.
### Feedback to Summary 6.3.2

<table>
<thead>
<tr>
<th>Plant tissues</th>
<th>Animal tissues</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Epidermal tissue</td>
<td>• Bone tissue</td>
</tr>
<tr>
<td>• Mesophyll tissues</td>
<td>• Epithelial tissue</td>
</tr>
<tr>
<td>o Palisade mesophyll</td>
<td></td>
</tr>
<tr>
<td>o Spongy mesophyll</td>
<td></td>
</tr>
<tr>
<td>• Vascular bundle tissues</td>
<td></td>
</tr>
<tr>
<td>o Xylem tissue</td>
<td></td>
</tr>
<tr>
<td>o Phloem tissue</td>
<td></td>
</tr>
</tbody>
</table>
It is now your turn to view some of the tissues that you have learnt about under the microscope. You will do this by doing the activity below.

**Activity 6.3.7**

You should spend at least 15 minutes on this activity.

You will observe at least **one plant tissue** and **one animal tissue**.

Ask the laboratory technician for permanent slides of epithelial tissues of the skin or bone tissues, and the xylem or phloem tissues of plants or the epidermis of a leaf.

Observe the tissues under the light microscope. Draw and label what you see below.

**Do not forget to write the type of tissue that you have observed next to the drawing.**

**An animal tissue**

**A plant tissue**
Use the diagrams of the various tissues that you have learnt above to improve on your drawings.

**Feedback to Activity 6.3.7**

I hope that you have been able to see first-hand some animal and plant tissues and that you have been able to represent what you saw under the light microscope clearly. Show your drawings to your teacher and ask for any comments or for ways you to improve on your work.

Below, I have provided you with sample microscopic views of an animal tissue and plant tissues.

- **Animal epithelial tissue.**
  ![Human cheek cells](http://en.wikipedia.org/wiki/Epithelium)

  Human cheek cells (Nonkeratinized stratified squamous epithelium) 500x


- **Plant tissues (epidermal, mesophyll and vascular bundle tissues)**
  ![Plant tissues](http://kentsimmons.uwinnipeg.ca/16cm05/16labman05/lb4pg5.htm)

  [http://kentsimmons.uwinnipeg.ca/16cm05/16labman05/lb4pg5.htm](http://kentsimmons.uwinnipeg.ca/16cm05/16labman05/lb4pg5.htm)

We saw above that cells group together to form tissues. Below we shall look at how the different tissues together, form organs in plants and animals.
6.3.4 Organs and systems

An organism’s body is made up of various systems. These systems consist of different organs. We will now look at some organs and systems of plants and animals below.

6.3.4.1 Organs in plants

6.3.4.1.1 The leaf

You have seen above that each of the different tissues has a particular function for the organism (the plant or the animal). For example, we saw the specific functions of the mesophyll tissues and the xylem and phloem tissues of a plant.

Even though each of these tissues does a different job, they all contribute to help the leaf make food for the plant. Hence, the leaf is made up of many different tissues, and together it is called an organ. An organ is made up of different tissues.

Some other organs in the plant are the roots, and the stem (the vegetative organs) and the flower, seeds and fruits (the reproductive organs).

In this unit we shall focus on the leaf as an organ.

Activity 6.3.8

You need 5 minutes to do this activity.

Take some time to think of how the epidermal tissue, the mesophyll tissue and the xylem and the phloem tissues in the leaf could work together to make food for the plant. Then complete the passage below using your own words.
The leaf is an example of an ....................
An organ is a group of different .................... working together to perform a particular function.
The main function of the .................... is to make food for the plant.
To make food, the plant needs to take .................... from the air, water from the .................... and use light energy to convert these into food.
The .................... in the spongy mesophyll provide for air to reach the chloroplasts in the ...................., and the xylem brings the water needed.
The .................... conducts the food that is made in the leaf to the other parts of the plant.
The different tissues make up the ..................., and by working together the tissues contribute to the specific job of the leaf.

Good! I am sure that you now understand how tissues work together to form organs.

The feedback to Activity 6.3.8 is given at the end of this topic. You are, however, strongly advised to first complete the activity above before you refer to the feedback. This will help you learn and reflect better on areas for improvement.

6.3.4.2 Organs in animals

As we saw above, the various tissues in animals make up organs, which do specific jobs for the body. Think about some organs that are found in our bodies.
Activity 6.3.9

You should spend 5 minutes on this activity.

1. List three organs of the human body in the boxes below.

   Three organs in the human body
   [ ] [ ] [ ]

   Each of these organs comprise of different tissues working together for one common purpose.

2. What is the purpose (function) of each of the organs that you have listed above? Write the function of each in their respective boxes.

Feedback to Activity 6.3.9

1. That was not difficult was it! I have no doubt that you have mentioned organs such as the stomach and the heart as an example! The eyes, lungs, heart and skin are some of the other organs in the human body.

2. You surely know the main functions of many of our body organs already. The stomach is one of the organs for digestion, the heart pumps blood to ensure that it is circulated around the body, the eyes allows us to see, the lungs allows us to exchange the gases that our body needs and the skin is the organ for touch.

Each of these organs is made up of different types of tissues, each of which contributes in a very specific way to the proper functioning of the organ. The stomach for example, is an organ which is made up of muscle tissues, gland tissues, and epithelial tissues amongst others.
Below, we shall now look at how organs also work together to make it possible for the plant or the animal to work properly.

### 6.3.5 Systems

Organs in the body do not work independently. Groups of organs work together to perform several related functions in a **system**. I have described some of the body systems for you below.

#### 6.3.5.1 The digestive system

The **digestive system** comprises of organs such as the oesophagus, the stomach, the small and large intestine, the pancreas. All these different organs contribute to the digestion of food in the body.

#### 6.3.5.2 The circulatory system

The **circulatory system** comprises of organs such as the veins, arteries and the heart. These organs transport food, gases, hormones and waste products to and from the cells of the body. There are two types of fluids that move in the circulatory system; **blood** and a clear fluid called **lymph**. Lymph flows in separate lymph vessels as part of an independent lymphatic system, which eventually links up with the bloodstream. The lymphatic system has three interrelated functions: it is responsible for the removal of interstitial fluid from tissues, it absorbs and transports fatty acids to the circulatory system and transports immune cells to and from the lymph **nodes**.

#### 6.3.5.3 The nervous system

The **nervous system** comprises of organs such as the brain, spinal cord, and the sense organs. The sense organs provide the nervous system with information of what goes on inside and outside the body. This information known as impulses travel to the brain and spinal cord, where the body activities are controlled and monitored.

#### 6.3.4.5 The endocrine system

The **endocrine system** comprises of glands which are organs that produce and secrete hormones. The hormones regulate growth, metabolism, and sexual development and function.
Activity 6.3.10

You should spend approximately 5 minutes on this activity.

I have mentioned four of the main systems of the body above. Look for any Biology book and make a list of three other body systems in the space below.

____________________________________________________

____________________________________________________

____________________________________________________

____________________________________________________

____________________________________________________

Feedback to Activity 6.3.10

I am sure that you have mentioned systems such as the skeletal system, respiratory system, immune system, excretory system, muscular system and reproductive system.

You will learn about each of the different systems mentioned above in other related units as you go through the course.
With the study on body systems, we have come to the end of this Topic. To test how much you have learnt, you should now do the Self-assessment 6.3 below.

**Self-assessment 6.3**

You need 30 minutes to do the self-assessment. The answers to Self-assessment 6.3 are given at the end of this topic. You are, however, strongly advised to first answer the questions before you refer to the feedback. This will help you learn and reflect better on areas for improvement.

1. Draw a table in the space below, and classify the following as cells, tissues or organs:
   - erythrocyte, xylem, root hair, phloem, leukocyte, bone, and muscle.

2. With the help of diagrams, differentiate between a specialized cell and a tissue.
3. In Table 6.3.3 (a) below, write the name of the cell next to its function.

<table>
<thead>
<tr>
<th>Function</th>
<th>Cell</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controls the water loss in a plant and the exchange of oxygen and carbon dioxide in the leaf, by regulating the opening and closing of the stomata.</td>
<td></td>
</tr>
<tr>
<td>Helps fight invading organisms that enter the body</td>
<td></td>
</tr>
<tr>
<td>Absorbs water for the plant</td>
<td></td>
</tr>
</tbody>
</table>

Table 6.3.3 (a): Completing a table to show cell types and function

4. Draw any two specialized animal cells in the space below and state their functions.
5. Name two plant tissues and describe their functions.


6. To which system would you associate the following groups of organs? Write the correct system next to its corresponding group of organs.

<table>
<thead>
<tr>
<th>Group of organs</th>
<th>System</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Heart, veins and arteries</td>
<td></td>
</tr>
<tr>
<td>b. Stomach, intestine, and oesophagus</td>
<td></td>
</tr>
<tr>
<td>c. Brain, neurons and spinal cord</td>
<td></td>
</tr>
<tr>
<td>d. Flower, seeds, and fruits</td>
<td></td>
</tr>
</tbody>
</table>

7. Discuss the relationship between cells, tissues and organs in a system.
Feedback to Activity 6.3.2

Please note that:

Answers (a) and (b) below serve as feedback to Question 1 as well as the observation of root hair cells and guard cells under the microscope.

1. Root hair cells growing from a root.

![Root hair cells](image)

Guard cells

2. C. The top surface of a leaf gets more sunlight and so the plant would lose too much water by evaporation.

3. Root hairs are found on the main roots of plants. They help absorb water for the plant.
Feedback to Activity 6.3.8

The leaf is an example of an organ.
An organ is a group of different tissues working together to perform a particular function.
The main function of the leaf is to make food for the plant.
To make food, the plant needs to take carbon dioxide from the air, water from the soil and use light energy to convert these into food.
The air spaces in the spongy mesophyll provide for air to reach the chloroplasts in the palisade mesophyll, and the xylem brings the water needed.
The phloem conducts the food that is made in the leaf to the other parts of the plant.
The different tissues make up the (leaf) organ, and by working together the tissues contribute to the specific job of the leaf.

Answers to Self-assessment 6.3

1. Erythrocyte, leukocyte and root hair are cells, xylem, phloem and muscle are tissues, and bone is an organ.

2. 

<table>
<thead>
<tr>
<th>Specialized cells</th>
<th>Tissues</th>
</tr>
</thead>
<tbody>
<tr>
<td>A specialized cell has a distinct shape, location and function.</td>
<td>A tissue is a group of similar cells working together to perform a particular function.</td>
</tr>
<tr>
<td>Any of the following specialised cells can be drawn:</td>
<td>Any of the following tissues can be drawn:</td>
</tr>
<tr>
<td>• a root hair cell,</td>
<td>• Bone tissues (compact bone tissue and spongy bone tissue</td>
</tr>
<tr>
<td>• a guard cell,</td>
<td>• Mesophyll tissues (palisade</td>
</tr>
<tr>
<td>• a muscle cell</td>
<td></td>
</tr>
</tbody>
</table>
3. **Cells and their functions**

<table>
<thead>
<tr>
<th>Function</th>
<th>Cell</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controls the water loss in a plant and the exchange of oxygen and carbon dioxide in the leaf, by regulating the opening and closing of the stomata.</td>
<td>Guard cell</td>
</tr>
<tr>
<td>Helps fight invading organisms that enter the body</td>
<td>White blood cell</td>
</tr>
<tr>
<td>Absorbs water for the plant</td>
<td>Root hair cell</td>
</tr>
</tbody>
</table>

Table 6.3.3 (b): Cell types and function

4. Any two cells shown below is accepted:

<table>
<thead>
<tr>
<th>Blood cell</th>
<th>Drawing</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red blood cell (erythrocyte)</td>
<td><img src="image" alt="Image" /></td>
<td>Contains haemoglobin, which takes oxygen from the lungs and carries them to all the other parts of the body.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The haemoglobin gives the blood its red colour.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Has no nucleus.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Has a flexible cell membrane to allow it to squeeze through narrow capillaries.</td>
</tr>
</tbody>
</table>
### White blood cell (leukocyte)
- Identifies and destroys bacteria and other disease-causing organisms which enter the body.
- Has a nucleus and some have granules.
- Regulates the immune system of the body

### Platelets
- The smallest cells in the blood, which helps it to clot.

---

Muscle cells. They help bones of the body to move.

---

5. Some plant tissues and their functions are as follows:

The mesophyll tissues consist of the **palisade mesophyll** which is directly below the upper epidermis and the **spongy mesophyll**.

The **palisade mesophyll** consists of tightly packed, vertically elongated cells, regularly arranged in one to five rows. The cells contain a lot more chloroplasts than the cells in the spongy mesophyll.

The **spongy mesophyll**, which is just beneath the palisade layer contain cells that are more rounded and not so tightly packed, with large intercellular air spaces.

The xylem and phloem tissues are both conducting tissues in the plant. The **xylem tissue** conducts water and minerals from the soil to all parts of the plant.
The **phloem tissue** conducts food from the leaves where food is made to all other parts of the plant for energy production and storage.

6. The table below shows organs and their related systems.

<table>
<thead>
<tr>
<th>Organs</th>
<th>Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart, veins and arteries</td>
<td>Circulatory system</td>
</tr>
<tr>
<td>Stomach, intestine, and oesophagus</td>
<td>Digestive system</td>
</tr>
<tr>
<td>Brain, neurons and spinal cord</td>
<td>Nervous system</td>
</tr>
<tr>
<td>Flower, seeds, and fruits</td>
<td>Reproductive system</td>
</tr>
</tbody>
</table>

7. The relationship between cells, tissues and organs in a system is that cells make up tissues, tissues make up organs and organs form part of different systems.
We have come to the end of the unit. I hope that you have enjoyed doing the activities and that you have really mastered the concepts on cells, osmosis, specialised cells, tissues, organs and systems.

Good luck and Bon courage for the remaining units that you will study to complete the course. I know that you will persevere until you have completed the remaining units.

Unit summary

In this unit you learned about the structure of the cell and differentiated between plant cells and animal cells. You learnt about the functions of organelles found in plant and animal cells and had opportunities to view animal and plant cells under the microscope.

You learnt about osmosis and its importance for living organisms.

You also acquired information about special types of cells and how their shape and location relate to their functions. Added to that, you learnt how to differentiate between cells, tissues, organs and organ systems, and you saw the relationship between cells, tissues, organs and systems for the proper functioning of an organism.
## Contents

**Unit 7**

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<td>Unit summary</td>
<td>48</td>
</tr>
</tbody>
</table>


Unit 7

Classifying elements

Introduction

Classification is an important activity in our everyday life. For instance, looking for a word in the dictionary is easy because the words are classified in alphabetical order. Classification is also very crucial in science. In Unit 1: Biological classification, you learned how to classify living organisms according to specific characteristics. Unit 2: The elements of chemistry, we classified matter (anything that has a mass and occupies space) as either solids, liquids or gases based on their properties. In Unit 4: Atoms, Bonding and the Periodic Table, Topic 4.1, we learned that the elements of the Periodic Table are arranged into: (i) Periods according to their number of shells; and (ii) Groups according to the number of electrons in their outermost shells and their chemical properties. As promised in Unit 4, Topic 4.1, in this unit we are going to learn more about the properties of elements.

To start of this unit, we will classify the elements of the Periodic Table as metals and non-metals and identify the differences between them in terms of their physical and chemical properties. In this unit you will also learn about the properties of the elements in Group I and Group VII of the Periodic Table. As a result you will also be able to predict the trends in the properties of elements in other Groups.
Upon completion of this unit you will be able to:

- **differentiate** between metals and non-metals on the basis of their physical properties, in particular, density, malleability, electrical and thermal conductivity.
- **state** that some metals form oxides through the reaction with oxygen.
- **state** that some metals form basic oxides and some non-metals form acidic oxides.
- **explain** that elements can be arranged in groups with similar chemical properties and may also form compounds with similar chemical properties.
- **describe** the trends in physical properties of the alkali metals, in particular, density, hardness and melting point.
- **state** that the reactivity of the alkali metals increases down Group I.
- **describe** the trends in physical properties of the halogens, in particular, colour, physical state, density and melting point.
- **state** that the reactivity of the halogens decreases down Group VII.
- **predict** the properties of elements from their position in the Periodic Table, given relevant information, and identify trends in other groups of elements.
- **describe** what is meant by a periodic pattern, exemplified by electronic structure of atoms and melting point of elements (qualitative treatment only required).

**Terminology**

- **Alkali metals:** Elements in Group I of the Periodic Table
- **Combustion:** Also known as burning, is a chemical reaction in which a substance reacts with oxygen to produce heat and light.
- **Halides:** A compound resulting from the reaction of a halogen with a positively charged ion.
- **Halogens:** Halogens are elements in group VII.
- **Oxides:** The main product formed during combustion or burning (reaction of metals or non-metals with oxygen).
Table 7.0 below shows the number of formal study hours needed for you to complete this unit and the number of hours that you need to devote for self-study.

<table>
<thead>
<tr>
<th>Category of students</th>
<th>Number of formal study hours needed</th>
<th>Number of hours for self-study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full-time student outside the conventional school setting</td>
<td>5 hours</td>
<td>2 hours and 30 minutes</td>
</tr>
<tr>
<td>Full-time student within the conventional school setting</td>
<td>5 hours</td>
<td>2 hours and 30 minutes</td>
</tr>
<tr>
<td>OR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Part-time student</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 7.0: The time needed for you to work on this unit

**Topic 7.1: Metals and non-metals**

You will need 1 hour 40 minutes to complete this topic. It is advisable that you spend another 50 minutes of your own time to further review the topic.

As it was mentioned in Unit 4, Topic 4.1, the metallic properties of the elements gradually decrease as we move from left to right across the Periodic Table. In this unit, we are going to learn about the positions of metals and non-metals on the Periodic Table. You are also going to learn about the differences in physical and chemical properties between metals and non-metals.
7.1.1 The position of metals and non-metals on the Periodic Table

The elements of the Periodic Table exist as metals, metalloids, and non-metals. With reference to Figure 7.1.1 below, we are now going to describe the position of metals, metalloids and non-metals on the Periodic Table.

If you have access to the internet, try taking a look at this youtube video. It is called the “chemistry element song.” http://youtu.be/DYW50F42ss8

Please note again that we are providing this only for reference and we do not recommend or endorse any links from this site.

The elements found on the left-hand side and the middle parts of the Periodic Table (the pink part) are the metals whereas those found on the right-hand side of the Periodic Table (the yellow part) are the non-metals. The small number of elements in between the metals and non-metals (the blue part) are called metalloids.

Figure 7.1.1: The Periodic Table of elements showing the positions of the metals (the pink part), the metalloids (the blue section) and the non-metals (the yellow section)

Source: Unit 2: The elements of chemistry, Topic 2.3, Figure 2.3.1
Take a look at the following link to get a visual idea of what each element looks like. [http://www.rsc.org/periodic-table/](http://www.rsc.org/periodic-table/)

Please note again that we are providing this only for reference and we do not recommend or endorse any links from this site.

Now that you know the positions of metals and non-metals on the Periodic Table, we are going to look at the physical and chemical properties on metals and non-metals.

To start off, let us learn about the physical properties of metals and non-metals.

### 7.1.2 The physical properties of metals and non-metals

Metals and non-metals exhibit different physical properties. Metalloids exhibit some properties of metals and non-metals. Before we talk about the difference in physical properties between metals and non-metals, you are going to carry out a short activity in groups to try to identify some physical differences between metals and non-metals.
**Group Activity 7.1.1**

You should spend about 25 minutes on this activity.

You are advised to carry this activity in the science laboratory in groups of 4 or 5.

**Equipment:**

In your group, you will be provided with a small sample of: iron nails, copper turnings, sulphur, carbon, zinc, bromine, magnesium and iodine crystals.

**Instruction:**

1. You are required to observe those substances and group them as metals and non-metals.

<table>
<thead>
<tr>
<th>Metals</th>
<th>Non-metals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Briefly state why you have grouped the materials as metals and non-metals in terms of the differences in physical properties (physical state, appearance, ability to produce sound when hit, etc.). You may want to present these in a table.
I hope that you have found the task interesting. Please refer to the Feedback to Group Activity 7.1.1 for the possible observations.
Feedback to Group Activity 7.1.1

1. From your observation, you should have classified those elements as shown in the table below.

<table>
<thead>
<tr>
<th>Metals</th>
<th>Non-metals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron</td>
<td>Sulphur</td>
</tr>
<tr>
<td>(iron nails)</td>
<td>(yellow powder)</td>
</tr>
<tr>
<td>Copper turnings</td>
<td>Carbon (graphite)</td>
</tr>
<tr>
<td>Zinc</td>
<td>Bromine</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Iodine crystals</td>
</tr>
</tbody>
</table>

Photo of sulphur and carbon adapted from: [http://en.wikipedia.org](http://en.wikipedia.org)

All other photos by: Rosianna Jules, January 2011

Prepared by: Louisette Bonte, January 2011
2. Some possible observations between the physical properties of metals and non-metals are listed below.

<table>
<thead>
<tr>
<th>Metals</th>
<th>Non-metals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are solids</td>
<td>Can be solids, liquids or gas (the brownish vapour in the bromine reagent bottle)</td>
</tr>
<tr>
<td>Are shiny</td>
<td>Are not shiny</td>
</tr>
<tr>
<td>Are hard</td>
<td>Are soft, not hard</td>
</tr>
<tr>
<td>Produce sounds when hit</td>
<td>Do not produce sounds when hit</td>
</tr>
</tbody>
</table>

I hope that you have managed to make those observations. If you did not, please go back and observe those elements again.

Apart from the physical difference mentioned above, there are more physical differences between metals and non-metals. We are now going to learn more about the difference in physical properties between metals and non-metals. The differences in physical properties of metals and non-metals are summarised in Table 7.1 below.

<table>
<thead>
<tr>
<th>Physical Properties</th>
<th>Metals</th>
<th>Non-metals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical state at room temperature</td>
<td>Solid (except mercury which is semi solid)</td>
<td>Solid (e.g. sulphur, carbon, iodine &amp; silicon); Liquid (bromine is the only liquid); or Gas (e.g. oxygen, nitrogen, &amp; helium).</td>
</tr>
<tr>
<td>Appearance</td>
<td>Shiny / lustrous and can be polished</td>
<td>Non-shiny / have no lustre and cannot be polished</td>
</tr>
</tbody>
</table>
So far we have seen the physical differences between metals and non-metals. Next, we are going to learn about the chemical differences between metals and non-metals.

### 7.1.3 Chemical properties of metals and non-metals

In Unit 4: *Atoms, bonding and the Periodic Table*, we saw that when metals and non-metals react together, ionic (electrovalent) bonds are formed and the metals and non-metals acquire opposite charges. Before we continue, let us see how much you can recall regarding ionic bonds.
Activity 7.1.1

You should spend about 5 minutes on this activity.

Please answer the questions below in the space provided.

1. What happens during the formation of ionic bonds?

2. During ionic bond formation, what charge is acquired by:
   a. the metal
   b. the non-metals?

I hope that you still remember the answers to the questions above. Please refer to the Feedback to Activity 7.1.1 for the answers.
Feedback to Activity 7.1.1

1. Yes, you are right! During ionic bond formation, there is the complete transfer of electrons. The metals lose (donate) their outer electrons to the non-metals while the non-metals gain (accept) the electrons.

2. a. During ionic bonds formation, the metals become positively charged

b. During ionic bonds formation, the non-metals become negatively charged.

I bet that this activity has brought back some memories of Unit 4 and I hope that you have managed to get the correct answers. If you did not, please devote some more time to review Unit 4.

From the Feedback to Activity 7.1.1 above, we saw that there is a difference in the charge that metals and non-metals acquire during ionic bond formation. Metals and non-metals exhibit other differences in chemical properties. The main differences in chemical properties between metals and non-metals are summarised in Table 7.1.2.

<table>
<thead>
<tr>
<th>Chemical Properties</th>
<th>Metals</th>
<th>Non-metals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formation of ions</td>
<td>Metals react by losing electrons to become positively charged ions. E.g. Ca – 2e → Ca^{2+}</td>
<td>Non-metals react by gaining electrons or sharing its electrons to become negatively charged ions. E.g. Br + e → Br^-</td>
</tr>
<tr>
<td>Ability to displace hydrogen from dilute acids</td>
<td>Metals above hydrogen in the activity series displace (can release) hydrogen from dilute acids. E.g. Mg^{2+} + H_2SO_4 → H_2 + MgSO_4</td>
<td>Non-metals cannot displace hydrogen from dilute acids.</td>
</tr>
<tr>
<td>Combustion (reaction with oxygen)</td>
<td>Metals burn in oxygen to form basic oxides. E.g. Ca^{2+} + O_2 → 2CaO Soluble basic oxides are</td>
<td>Non-metals burn in oxygen to form either acidic oxides or neutral oxides. E.g. 2C + O_2 → 2CO (neutral oxide)</td>
</tr>
</tbody>
</table>
### Chemical Properties

<table>
<thead>
<tr>
<th></th>
<th>Metals</th>
<th>Non-metals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>called alkalis. E.g. CaO + H₂O → Ca(OH)₂</td>
<td>E.g. C + O₂ → CO₂ (acidic oxide)</td>
</tr>
<tr>
<td></td>
<td>(You will learn about the terms bases, alkali, acids and neutral later in the course.)</td>
<td>Soluble acidic oxides form acids. E.g. CO₂ + H₂O → H₂CO₃</td>
</tr>
<tr>
<td>Reaction with halogens</td>
<td>Metals react with halogens to form electrovalent halides. E.g. 2Na⁺ + Cl₂ → 2NaCl⁻</td>
<td>Non-metals react with halogens to form covalent halides. E.g. P₄ + 6Cl₂ → 2P₂Cl₆</td>
</tr>
<tr>
<td>(group VII elements)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reaction with hydrogen</td>
<td>Metals react with hydrogen to form electrovalent hydrides. 2Na⁺ + H₂ → 2NaH⁻</td>
<td>Non-metals react with hydrogen to form numerous covalent hydrides. E.g. C + 2H₂ → CH₄ (methane) Other examples include: C₂H₂ – ethyne C₂H₄ – ethene NH₃ – ammonia HCl – hydrogen chloride</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ability to reduce or</td>
<td>Metals are reducing agents. E.g. 2Mg²⁺ + CO₂ → 2MgO + C</td>
<td>Non-metals may be either (i) reducing agents E.g. 2C + 2CuO → 2Cu + 2CO₂</td>
</tr>
<tr>
<td>oxidise</td>
<td></td>
<td>OR (ii) oxidising agents E.g. 2NaI + Cl₂ → 2NaCl + I₂</td>
</tr>
</tbody>
</table>

Table 7.1.2: The differences in the chemical properties of metals and non-metals
Please note that you will learn about alkalis, bases, acids, reduction and oxidation later in the course.

Now before we move on to the next topic, let us see how much you have learned through this self-assessment.

**Self-Assessment 7.1**

You should spend no more than 20 minutes on this self-assessment. This self-assessment is based on Topic 7.1. The answers are given at the end of the topic. You are strongly advised to answer all questions before you refer to the Answers to Self-assessment 7.1. This will help you learn and reflect better on areas for improvement.

You are required to answer the questions below in the space provided.

1. Write TRUE or FALSE next to each statement regarding the physical properties of metals and non-metals.

<table>
<thead>
<tr>
<th>Statements</th>
<th>TRUE / FALSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A All metals form covalent bonds.</td>
<td></td>
</tr>
<tr>
<td>B Non-metals form negatively charged ions.</td>
<td></td>
</tr>
<tr>
<td>C Metals are shiny when cut while non-metals are not shiny.</td>
<td></td>
</tr>
<tr>
<td>D Metals have relatively high density just like non-metals.</td>
<td></td>
</tr>
<tr>
<td>E Metals and non-metals are good conductors of electricity and heat.</td>
<td></td>
</tr>
<tr>
<td>F Non-metals have low boiling points and melting points.</td>
<td></td>
</tr>
</tbody>
</table>
2. Complete the statements with the most appropriate word or chemical symbol or chemical formula.

a. Metals burn in __________ to form __________ oxides.
   \[ \text{__O} + \text{H}_2\text{O} \rightarrow \text{Mg(OH)}_2 \]

b. Non-metals burn in oxygen to form either __________ oxides (\(\text{C} + \text{O}_2 \rightarrow \) \_) or neutral oxides (\(2\text{C} + \text{O}_2 \rightarrow \) \_).

c. __________ above hydrogen in the activity series can displace __________ from dilute acids.

d. __________ cannot displace __________ from dilute acids.

e. Non-metals react by __________ __________ or __________ __________ to form __________ charged ions.

f. Metals react by losing electrons to become __________ charged ions.

g. Metals react with __________ to form __________ halides. \(\text{__} + \text{__} \rightarrow 2\text{K}^+\text{Br}^-\)

I hope that the assessment was easy for you. Once, you have completed the self-assessment, please refer to the Answers to Self-Assessment 7.1 at the end of this topic for the correct answers.
## Answers to Self-assessment 7.1

### 1. TRUE or FALSE

<table>
<thead>
<tr>
<th></th>
<th>Statements</th>
<th>TRUE / FALSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>All metals form covalent bonds.</td>
<td>FALSE: metals form electrovalent or ionic bonds.</td>
</tr>
<tr>
<td>B</td>
<td>Non-metals for negatively charged ions.</td>
<td>TRUE</td>
</tr>
<tr>
<td>C</td>
<td>Metals are shiny when cut while non-metals are not.</td>
<td>TRUE</td>
</tr>
<tr>
<td>D</td>
<td>Metals have relatively high density just like non-metals.</td>
<td>FALSE: true for metals but non-metals have relatively low density</td>
</tr>
<tr>
<td>E</td>
<td>Metals and non-metals are good conductors of electricity and heat.</td>
<td>FALSE: true for metals, non-metals are poor conductors of heat and electricity</td>
</tr>
<tr>
<td>F</td>
<td>Non-metals have low boiling points and melting points.</td>
<td>TRUE</td>
</tr>
<tr>
<td>G</td>
<td>Apart from mercury, all metals are solids at room temperature.</td>
<td>TRUE: mercury is semi-solid</td>
</tr>
<tr>
<td>H</td>
<td>Silicon is an example of metals</td>
<td>FALSE: silicon is a non-metal</td>
</tr>
</tbody>
</table>

### 2. Filling the blanks

a. Metals burn in oxygen to form basic oxides.

\[ \text{MgO} + \text{H}_2\text{O} \rightarrow \text{Mg(OH)}_2 \]

b. Non-metals burn in oxygen to form either acidic oxides

\[(\text{C} + \text{O}_2 \rightarrow \text{CO}_2)\] or neutral oxides \((2\text{C} + \text{O}_2 \rightarrow 2\text{CO})\)
c. **Metals** above hydrogen in the activity series can displace hydrogen from dilute acids.

d. **Non-metals** cannot displace hydrogen from dilute acids.

e. Non-metals react by losing electrons or sharing electrons to form negatively charged ions.

f. Metals react by losing electrons to become positively charged ions.

g. Metals react with halogens to form electrovalent / ionic halides. \( 2K^+ + Br_2 \rightarrow 2K^+Br^- \)

I hope that you have got all the answers correct. If you did not, please review Topic 7.1 before moving on.

So far we have seen that the difference in the properties of metals and non-metals. Take a moment now to reflect back on what you have learned.

In the next topic we are going to look at the properties of a group of metal and a group of non-metals.

**Topic 7.2: Properties of Group I elements**

You will need 1 hour 40 minutes to complete this topic. It is advisable that you spend another 50 minutes of your own time to further review the topic.
Before you carry on with this topic, you are advised to contact the laboratory technician at your school or centre so that you can place a booking for group demonstration to illustrate the reaction of two alkali metals with water (sub-topic 7.2.3.1).

Please note that for economical purposes, a minimum of five students is required per demonstration.

You will remember that in Unit 4, Topic 4.1, we saw that a group is the vertical column of elements in the Periodic Table and that all groups (except the groups of transition metals) are numbered using Roman numerals (I, II, III, IV, V, VI, VII, and VIII). We also saw that the elements in Group VIII / Group 0 (zero) are stable gases and do not undergo chemical reactions. In other words, they are inert gases. Similarly, all groups of elements exhibit certain specific characteristics.

In this topic you are going to learn about the trends in the physical and chemical properties of elements in Group I (the alkali metals). We will start off with the physical properties of the elements in Group I.

### 7.2.1 Group I elements

As mentioned previously, Group I elements are also known as the alkali metals. The most common Group I elements are: lithium, sodium and potassium. Table 7.2.1 shows the common elements in Group I, their proton number, period and electronic configuration.

<table>
<thead>
<tr>
<th>Group I Elements</th>
<th>Symbol</th>
<th>Proton number</th>
<th>Period</th>
<th>Electron configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lithium</td>
<td>Li</td>
<td>3</td>
<td>2</td>
<td>2,1</td>
</tr>
<tr>
<td>Sodium</td>
<td>Na</td>
<td>11</td>
<td>3</td>
<td>2,8,1</td>
</tr>
<tr>
<td>Potassium</td>
<td>K</td>
<td>19</td>
<td>4</td>
<td>2,8,8,1</td>
</tr>
</tbody>
</table>

Table 7.2.1: Group I elements, their proton number, period and electronic configuration
With one electron in their outermost (valence) shell, Group I elements are a group of **very reactive metals**. We are now going to learn about the physical and chemical properties of Group I elements. We will start with the physical properties of the alkali metals.

### 7.2.2 Physical properties of Group I elements

We have seen earlier that metals exhibit certain physical properties. We are now going to look at the properties of Group 1 elements. Table 7.2.2 shows some of the physical properties of these elements.

<table>
<thead>
<tr>
<th>Group I Elements</th>
<th>Appearance</th>
<th>Melting point in °C</th>
<th>Boiling point in °C</th>
<th>Density in g/cm³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lithium</td>
<td>Soft grey metal (has a shiny metallic surface when freshly cut)</td>
<td>181</td>
<td>1342</td>
<td>0.54</td>
</tr>
<tr>
<td>Sodium</td>
<td>Soft light grey metal (has a shiny metallic surface when freshly cut)</td>
<td>98</td>
<td>883</td>
<td>0.97</td>
</tr>
<tr>
<td>Potassium</td>
<td>Very soft blue/grey metal (shiny when cut)</td>
<td>63</td>
<td>759</td>
<td>0.86</td>
</tr>
</tbody>
</table>

Table 7.2.2: Some physical properties of Group I elements

The melting points and boiling points of the most common alkali metals (Group I elements) can also be displayed graphically as shown in Figure 7.2.1 below.
Now that you know the physical properties of the Group I elements, let us look at the trend (pattern) in these physical properties. You will do this through a short group discussion.

**Group Discussion 7.2.1**

You should spend about 10 minutes on this discussion.

With one or two colleagues, with reference to Figure 7.2.1 and Table 7.2.2, discuss the trend in the physical properties of the elements in Group I.
I hope that you have enjoyed this discussion. In the information that follows, you will find out the pattern or trend in the physical properties of the elements in Group I.

From Figure 7.2.1 and Table 7.2.2, we can conclude that as we go down the group, there is a progressive change in the physical properties of the elements in Group I. These progressive changes are as follows:

a. the hardness of the metals decreases (in other words, the metals become softer);

b. the melting point decreases;

c. the boiling point decreases; and

d. the density decreases.

Please note that all the previous properties of metals discussed in Topic 7.1.2 also apply to the elements in Group I. This means that the elements in Group I are also:

a. solids;

b. good conductor of electricity;

c. malleable and ductile.

So far you have learned about the trend in the physical properties of Group I elements; now we are going to look at their chemical properties.

### 7.2.3 Chemical properties of Group I elements

Previously, we learned that metals lose their valence electron(s) to form positively charged ions. From Table 7.2.1, we saw that the elements in Group I have only one electron in their outermost (valence) shell. Since a small amount of energy is required to lose their single valence electron, Group I elements are a group of very reactive metals: they react immediately with water. Consequently, alkali metals are stored under paraffin oil to exclude humidity (moisture).
All the members of the alkali family exhibit similar chemical properties. You are now going to learn about the three common chemical properties of the alkali metals.

### 7.2.3.1 Reaction of alkali metals with water

To illustrate the reaction of alkali metals with water, you are required to follow the group demonstration which you should have booked with the laboratory technician at the start of Topic 7.2.

However, if you did not place a booking, please check with the laboratory technician for the next demonstration session. Alternatively, you could watch the video clips on CD ROM which can be borrowed from your school or centre.
Group Activity 7.2.1

You should spend no more than 25 minutes to follow this demonstration performed by the laboratory technician and to answer the questions involved.

You are required to stand to watch this demonstration. Please take heed to the lab technician’s advice as to the distance you should be from the set up. Make sure that you should read all the instructions before the demonstration starts.

Instructions:

1. The laboratory technician will cut a small piece of sodium and a small piece of potassium. Observe the cut surface of the metals. What do you notice?

2. The lab technician will now fill a trough half full with tap water. What is the temperature of the water?

3. When it is time for the live demonstration, you should back away. Respect the technician’s advice.

4. The lab technician will now repeat steps 2 to 4 but this time using the small piece of potassium. Observe what happens. (You may want to take the temperature of the water in the trough after the reaction.)
5. Which of the two elements reacted faster or more vigorously?

6. You should have noticed that sodium and potassium floated on water. Why do you think this happens?

I hope that you have found this demonstration interesting. Please refer to the Feedback to Group activity 7.2.1 for the expected observations.
**Feedback to Group activity 7.2.1**

Expected observations.

1. The cut surfaces of sodium and potassium were shiny (silvery in colour).

2. The temperature of the tap water in the trough (before adding the metal) was around room temperature (30°C).

3. When the small piece of sodium was placed in the trough of water, you should have observed that:
   a. the piece of sodium floated and skidded on the water surface as it reacted;
   b. the piece of sodium ignited and burned with an orange flame;
   c. after the metal has reacted, the water become warm: the temperature of water has increased (it was more than 30°C);
   d. the piece of sodium melted.

4. When the small piece of potassium was placed in the trough of water, you should have observed that:
   a. the piece of potassium floated and skidded on the water surface as it reacted;
   b. the piece of potassium ignited and burned with a pink or lilac flame;
   c. after the metal has reacted, the water became warm: the temperature of water has increased (it was more than 30°C);
   d. the piece of potassium melted.

5. Potassium acted faster and more vigorously than sodium.

6. The reason why sodium and potassium float on water is because they are less dense than water. The density of water is 1 g/cm³ and the density of sodium and potassium are 0.97 g/cm³ and 0.86 g/cm³ respectively.
You are now going to talk more about the reaction of alkali metals with water.

When an alkali metal is added to cold water, it reacts immediately to produce an alkali (a hydroxide solution of the respective metal) and hydrogen gas. The heat produced when sodium and potassium react with water is enough to melt the metal.

The chemical equations for the reactions of lithium, sodium and potassium with water are given below.

Word equation

lithium + water → lithium hydroxide + hydrogen

\[ 2\text{Li}^+ (s) + 2\text{H}_2\text{O} (l) \rightarrow 2\text{LiOH(aq)} + \text{H}_2 (g) \]

sodium + water → sodium hydroxide + hydrogen

\[ 2\text{Na}^{2+} (s) + 2\text{H}_2\text{O} (l) \rightarrow 2\text{NaOH(aq)} + \text{H}_2 (g) \]

potassium + water → potassium hydroxide + hydrogen

\[ 2\text{K}^+ (s) + 2\text{H}_2\text{O} (l) \rightarrow 2\text{KOH(aq)} + \text{H}_2 (g) \]

You should have noticed from the equations, that the three metals react in the same ration and they all produce an alkali (base) and hydrogen gas. So, if the alkali metals were represented by the letters ‘Am’, then the general chemical equation would be:

Alkali metal + water → alkali metal hydroxide + hydrogen

\[ 2\text{Am} (s) + 2\text{H}_2\text{O} (l) \rightarrow 2\text{AmOH(aq)} + \text{H}_2 (g) \]
Please note that there are two ways of writing chemical equations. We can write them as *word equations* or *symbol equations*.

- **In a word equation**, the chemicals are represented by their names.

  An example of word equation is:

  potassium + water → potassium hydroxide + hydrogen

- **In a symbol equation**, the chemicals are represented by their chemical symbols.

  An example of symbol equation is:

  \[ 2K^+ (s) + 2H_2O (l) \rightarrow 2KOH(aq) + H_2 (g) \]

When writing a symbol equation, the equation needs to be balanced. This means that, the number of atoms of each of the element in the reactants (chemical reacting on the left hand side) should be equal to the number of atoms of each of the element in the product (the chemical produced on the right hand side).

You will learn more about balancing equation later in the course.

Now let us move on to the reaction of Group I elements with oxygen.

### 7.2.3.2 Reaction of alkali metals with oxygen

When heated, the alkali metals burn in oxygen (air) to form a white solid oxide. Each alkali metal burns with distinct coloured flames. In Group activity 7.2.1, we saw that sodium burned with an orange flame and potassium burned with a pink/lilac flame. So when the alkali metals react with oxygen, the colour of the flames produced is as follows:

- a. lithium burns with a red flame;
- b. sodium burns with an orange flame; and
- c. potassium burns with a pink/lilac flame.

The colour of the flame is a unique characteristic of each of the alkali metals.
The chemical equation for the reaction of lithium with oxygen is given below.

\[
\text{Lithium + oxygen} \rightarrow \text{lithium oxide} \\
4\text{Li}^+(s) + \text{O}_2(g) \rightarrow 2\text{Li}_2\text{O}(s)
\]

The equation for the reaction of any Group I elements with oxygen is the same as that for lithium. So, the general equation for the reaction of any alkali metal (represented by the letters ‘Am’) with oxygen is as follows:

\[
\text{Alkali metal + oxygen} \rightarrow \text{alkali metal oxide} \\
4\text{Am}^+(s) + \text{O}_2(g) \rightarrow 2\text{Am}_2\text{O}(s)
\]

We are now going to look at another characteristic reaction of Group I elements.

### 7.2.3.3 Reaction of alkali metals with chlorine

Alkali metals react readily with chlorine. When a piece of burning alkali metal is lowered into a gas jar of chlorine, the alkali metal continues to burn forming a white smoke of the alkali metal chloride.

The reaction of an alkali metal with chlorine is illustrated below.

\[
\text{Lithium + chlorine} \rightarrow \text{Lithium chloride} \\
2\text{Li}^+(s) + \text{Cl}_2(g) \rightarrow 2\text{LiCl}(s)
\]

The reaction of any Group I elements with chlorine is similar to that of lithium. Hence, the general equation for the reaction of any alkali metal (represented by the letters ‘Am’) with chlorine is as follows:

\[
\text{Alkali metal + chlorine} \rightarrow \text{alkali metal chloride} \\
2\text{Am}^+(s) + \text{Cl}_2(g) \rightarrow 2\text{AmCl}(s)
\]
We have seen three different reactions involving the three most common alkali metals. Now let us see if there is a trend in the reaction of the alkali metals with water.

From the Group activity 7.2.1, you learned that potassium react faster and more vigorously than sodium. This is a fact: as you go down the group, the reactivity of the alkali metals increases. This implies that sodium reacts faster than lithium and potassium reacts faster than sodium. So, among the three elements, lithium is the least reactive alkali metal and potassium is the most reactive.

There are three more members of the alkali metals family: rubidium (Rb) in Period 5, caesium (Cs) in Period 6 and francium (Fr) in Period 7. These three alkali metals are all more reactive than potassium.

**Reflection 7.2.1**

Now take 10 minutes to reflect on what you have learned about the properties of the elements in Group I.

1. Among the seven alkali metals, which do you think:
   
   a. has the highest boiling and melting points? __________

   b. has the lowest boiling and melting points? __________

   c. is the most reactive metal? ________________

   d. is the least reactive metal? _________________

2. Put these elements in order of decreasing reactivity: caesium, lithium, potassium, francium, sodium and rubidium.

   ________________________________________________
You are right!

1. 
   a. The alkali metal with the highest boiling and melting points is lithium.
   b. The alkali metal with the lowest boiling and melting points is francium.
   c. The most reactive metal is francium.
   d. The least reactive metal is lithium.

2. In order of decreasing reactivity, the elements are: francium, caesium, rubidium, potassium, sodium and lithium.

To conclude this section regarding the properties of the alkali metals, Figure 7.2.2 below provides the relative reactivity of the alkali metals as we move down the group.

![Reactivity Diagram](image)

Figure 7.2.2: The relative reactivity of the alkali metals as we move down the group

This brings us to the end of topic 7.2 but what did you learn about the properties of Group I elements? How are these elements unique? What is it about them that give them these characteristics? Briefly think about their reactivity going down the table. Why don’t they all have the same reactivity?

In the topic below, we are going to learn about the properties of the elements in Group VII. Judging from what you learned about Group I elements, can you make any predictions on the reactivity of Group VII elements? Let’s move on to find out.
Topic 7.3 Properties of Group VII elements

You will need 1 hour 40 minutes to complete this topic. It is advisable that you spend another 50 minutes of your own time to further review the topic.

In this topic you are going to learn about the trends in the physical and chemical properties of elements in Group VII (the halogens). We will start off with the physical properties of the elements in Group VII.

7.3.1 Group VII elements

The elements in Group VII are also known as the **halogens**. The halogens are a family of reactive non-metals. The most common halogens are fluorine, chlorine, bromine and iodine. Table 7.3.1 shows the common elements in Group VII, their proton number, period and electronic configuration.

<table>
<thead>
<tr>
<th>Group VII Elements</th>
<th>Proton number</th>
<th>Period</th>
<th>Electron configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluorine</td>
<td>9</td>
<td>2</td>
<td>2, 7</td>
</tr>
<tr>
<td>Chlorine</td>
<td>17</td>
<td>3</td>
<td>2,8,7</td>
</tr>
<tr>
<td>Bromine</td>
<td>35</td>
<td>4</td>
<td>2,8,18,7</td>
</tr>
<tr>
<td>Iodine</td>
<td>53</td>
<td>5</td>
<td>2,8,18,18,7</td>
</tr>
</tbody>
</table>

Table 7.3.1: Group VII elements, their proton number, period and electronic configuration
Like in the case of metals, non-metals display certain physical and chemical properties as we saw earlier. We are now going to look more closely at the properties of Group VII elements. We will start with their physical properties.

### 7.3.2 Physical properties of Group VII elements

Table 7.3.2 shows some of the appearances of these elements at room temperature.

<table>
<thead>
<tr>
<th>Group I Elements</th>
<th>Appearance at room temperature</th>
<th>Melting point in °C</th>
<th>Boiling point in °C</th>
<th>Density in g/cm³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluorine</td>
<td>Pale yellow gas</td>
<td>-220</td>
<td>-188</td>
<td>1.7</td>
</tr>
<tr>
<td>Chlorine</td>
<td>Yellow/green gas</td>
<td>-101</td>
<td>-35</td>
<td>3.2</td>
</tr>
<tr>
<td>Bromine</td>
<td>Red/brown volatile liquid</td>
<td>-7</td>
<td>58</td>
<td>3.1</td>
</tr>
<tr>
<td>Iodine</td>
<td>Dark grey crystalline solid</td>
<td>114</td>
<td>184</td>
<td>4.94</td>
</tr>
</tbody>
</table>

Table 7.3.2: Some of the physical properties of Group VII elements

Now to help us discuss the trend in the physical properties of the halogens (Group VII elements), you are required to carry out this short activity.
Activity 7.3.1

You are advised to spend about 15 minutes on this activity.

1. Use the information from Table 7.3.2 to draw a graph to show the melting points and boiling points on Group I elements on the graph paper (Figure 7.3.1a) provided.

![Figure 7.3.1a: Graph paper to show the melting points and boiling points of Group VII elements](image)

2. From Table 7.3.2 and your graph (Figure 7.3.1a), what trend do you notice regarding the melting points and boiling points of Group VII elements?
3. What other conclusion can you draw from Table 7.3.2?

I hope that you have found the activity easy. Once you have completed the activity, please refer to the Feedback to Activity 7.3.1 below for the expected answers.
Feedback to Activity 7.3.1

1. Figure 7.3.1b shows the melting points and boiling points of Group VII elements.

![The melting points and boiling points of Group VII elements](image)

Figure 7.3.1b: The melting points and boiling points of Group VII elements

2. You should have noticed from your graph (Figure 7.3.1a, as illustrated by Figure 7.3.1b above) and Table 7.3.2 that:

   As we move down Group VII:
   
   a. the melting point of the elements increases; and
   
   b. the boiling point of the elements increases.

3. From Table 7.3.2 you can also conclude that as we move down the group:

   a. the particles in the halogens becomes more closely packed. Hence, the state of the halogens change from gas (fluorine and chlorine) to liquid (bromine) then to solid (iodine); and
   
   b. the density of the halogens increases.
I believe that you have found this activity interesting and easy, and that you have managed to get all the correct answers.

Please note that all the previous properties of non-metals discussed in Topic 7.1.2 also apply to the elements in Group VII. This means that the elements in Group VII:

a. can be in the gaseous, liquid or solid state;

b. are bad conductor of electricity;

c. are not malleable and ductile.

Now we are going to learn about the trend in the chemical properties of the elements in Group VII.

7.3.3 Chemical properties of Group VII elements

Being in Group VII, the halogens have seven electrons in their outermost shells as shown in Table 7.3.1 above. Hence, the halogens are very reactive non-metals as they require a small amount of energy to acquire a full/stable octet. The halogens (like all non-metals, apart from the elements in Group VIII) can acquire a full octet either:

1. by forming ionic bonds with metals. During ionic bond formation, the halogen gains an electron from the metal to become a negatively charged ion; OR

2. by forming covalent bonds with non-metals. During covalent bond formation, the halogen shares an electron with another non-metal.

Please note that although the elements in the halogen family have different physical appearances (different state of matter as shown in Table 7.3.2 above), they are in the same family because they exhibit similar chemical properties.

We are now going to look at some characteristic chemical properties of the elements in Group VII.
Please note that because fluorine is a very reactive gas and too reactive to handle in a normal laboratory, it will not be addressed in the reaction examples below. Hence, we will focus on chlorine, bromine and iodine.

7.3.3.1 Solubility of the halogens in water (a polar solvent)

None of the halogens are very soluble in water (a polar solvent) because halogens are made of molecules. The halogen which is the most soluble in cold water is chlorine. Iodine does not dissolve much in cold water and it only dissolves slightly in hot water.

*Chlorine solution* (also known as chlorine water) has a very pale green colour. Chlorine water is acidic, so it turns a universal indicator red. Chlorine solution also bleaches the indicator quickly.

*Bromine solution* (also called bromine water) is orange in colour. It is a very weak acid and it also serves as bleach.

*Iodine solution* is also a very weak acid and it also slightly acts as bleach.

7.3.3.2 Reaction of the halogens with hexane (a non-polar solvent)

The halogens dissolve readily in hexane (a non-polar solvent) to give the following distinctive coloured solutions.

*Chlorine* dissolves in hexane to give a colourless solution.

*Bromine* dissolves in hexane to give an orange solution.

*Iodine* dissolves in hexane to give a purple solution.
Please be aware that you will learn about polar and non-polar molecules later in the course. For now, you simply need to know that the distribution of electrons due to the arrangement or geometry of the atoms in a molecule can cause a molecule to be polar or non-polar.

A polar molecule (like water, alcohol, ammonia and sulphur dioxide) has a positive electrical charge on one side and a negative electrical charge on the other side due to the unsymmetrical distribution of electrons.

A non-polar molecule (like hexane, carbon dioxide, nitrogen and oxygen gases) is one where the electrons are distributed more symmetrically and hence, there is no abundance of charges on either side.

7.3.3.3 Displacement reaction of the halogens

When chlorine is bubbled into a solution of potassium bromide, the colourless solution turns orange. This is because chlorine displaces the less reactive bromine. The orange colour results from the free bromine in the solution.

The equation for the displacement is shown below.

Potassium bromide + chlorine → potassium chloride + bromine

\[ 2\text{KBr(aq)} + \text{Cl}_2(g) \rightarrow 2\text{KCl(aq)} + \text{Br}_2(aq) \]

If iodine solution was added to potassium bromide, no reaction will take place because iodine is less reactive than bromine.

So, based on the information above, what can we conclude about the displacement of a halogen by another halogen? Jot down your conclusion in the space provided.

You’re right! We can conclude that a more reactive halogen can displace a less reactive halogen from its compound.
Now, based on what you have learnt about the chemical properties of the halogens, what can we conclude about their reactivity as we move down the group? Write your thoughts in the space below.

Now let us see if your conclusion is correct. We can conclude that as we move down the group, the reactivity of the halogen decreases. Astatine which is radioactive and a very rare element, is the last member of the halogen family. Astatine is the least reactive halogen. Figure 7.2.4 below shows the relative reactivity of the halogens as we move down the group.

Fluorine (F)  \textit{most reactive}
Chlorine (Cl)
Bromine (Br)
Iodine (I)
Astatine (At)  \textit{least reactive}

Figure 7.3.2: The relative reactivity of the halogens as we move down the group

We have now come to the end of Unit 7. I hope that you have found the content of this unit easy to master. If you feel that you need to review certain parts again, please do so before you attempt the self-assessment which follows.
Self-Assessment 7.2

You should spend around 40 minutes on this self-assessment. This self-assessment is based on Topics 7.2 and 7.3. The answers are given at the end of this topic. You are strongly advised to answer all questions before you refer to the Answers to Self-assessment 7.2. This will help you learn and reflect better on areas for improvement.

1. The table below provides a summary of the trend in the physical properties of Group I elements and Group VII elements. Complete the table with the word *increases* or *decreases*.

<table>
<thead>
<tr>
<th>As we move down</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Group I elements</td>
</tr>
<tr>
<td>Boiling points</td>
</tr>
<tr>
<td>Melting points</td>
</tr>
<tr>
<td>Density</td>
</tr>
</tbody>
</table>

2. The melting points and boiling points of some elements are given in the table below. Use the information to answer the following questions.

<table>
<thead>
<tr>
<th>Group I Elements</th>
<th>State at 30°C</th>
<th>State at 100°C</th>
<th>Melting point in ºC</th>
<th>Boiling point in ºC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lithium</td>
<td>Solid</td>
<td>Solid</td>
<td>181</td>
<td>1342</td>
</tr>
<tr>
<td>Bromine</td>
<td>______</td>
<td>______</td>
<td>-7</td>
<td>58</td>
</tr>
<tr>
<td>Chlorine</td>
<td>______</td>
<td>______</td>
<td>-101</td>
<td>-35</td>
</tr>
<tr>
<td>Fluorine</td>
<td>______</td>
<td>______</td>
<td>-220</td>
<td>-188</td>
</tr>
<tr>
<td>Iodine</td>
<td>______</td>
<td>______</td>
<td>114</td>
<td>184</td>
</tr>
<tr>
<td>Potassium</td>
<td>______</td>
<td>______</td>
<td>63</td>
<td>759</td>
</tr>
</tbody>
</table>
**Table 7.2.5a:** Table to be completed to show the state of the elements based on their melting points and boiling points.

<table>
<thead>
<tr>
<th>Group I Elements</th>
<th>State at 30°C</th>
<th>State at 100°C</th>
<th>Melting point in °C</th>
<th>Boiling point in °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium</td>
<td>______</td>
<td>______</td>
<td>98</td>
<td>883</td>
</tr>
</tbody>
</table>

a. Complete Table 7.2.5a to show the state of the elements (as in the example of lithium) at:

i. 30°C; and

ii. 100°C

b. Separate the 7 elements in table 7.2.5a above into two groups in Table 7.2.6a and also do the following:

i. Name the two groups of elements.

ii. Classify the elements in order of their increasing reactivity.

**Table 7.2.6a:** Table to classify the elements into their respective group in order of increasing reactivity

3. Use the table below to summarise the results of the reaction when chlorine, bromine and iodine are added to potassium halides.
Solutions of

<table>
<thead>
<tr>
<th>Element added</th>
<th>Potassium chloride</th>
<th>Potassium bromide</th>
<th>Potassium iodide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorine</td>
<td>X</td>
<td></td>
<td>/</td>
</tr>
<tr>
<td>Bromine</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iodine</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a. Complete the table using a cross (X) to indicate when no reaction takes place and a tick (√) to indicate when a reaction occurs. Two examples have been done for you.

b. What type of reaction is taking place when potassium iodide reacts with chlorine?

c. For the reaction of potassium iodide with chlorine, write
   i. the word equation;

   ii. the symbol equations

4. One chemical property of the alkali metals is their reaction with oxygen.

   a. What is the name given to the reaction of alkali metals with oxygen?
b. What type of oxide is formed by the reaction?


c. For the reaction of sodium with oxygen, write:
   i. the word equation for the reaction

   ii. the chemical equation for the reaction

   iii. what colour of flame is produced during the reaction?

I am sure that you have found the self-assessment quite easy to tackle. Please refer to the Answers to Self-assessment 7.2 at the end of the topic below for the correct answers.
### Answers to Self-assessment 7.2

1. As we move down

<table>
<thead>
<tr>
<th></th>
<th>Group I elements</th>
<th>Group VII elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiling points</td>
<td>Increases</td>
<td>Increases</td>
</tr>
<tr>
<td>Melting points</td>
<td>Increases</td>
<td>Increases</td>
</tr>
<tr>
<td>Density</td>
<td>Increases</td>
<td>Increases</td>
</tr>
</tbody>
</table>

2. a. i & a. ii

<table>
<thead>
<tr>
<th>Group I Elements</th>
<th>State at 30°C</th>
<th>State at 100°C</th>
<th>Melting point in °C</th>
<th>Boiling point in °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lithium</td>
<td>Solid</td>
<td>Solid</td>
<td>181</td>
<td>1342</td>
</tr>
<tr>
<td>Bromine</td>
<td>liquid</td>
<td>gas</td>
<td>-7</td>
<td>58</td>
</tr>
<tr>
<td>Chlorine</td>
<td>gas</td>
<td>gas</td>
<td>-101</td>
<td>-35</td>
</tr>
<tr>
<td>Fluorine</td>
<td>gas</td>
<td>gas</td>
<td>-220</td>
<td>-188</td>
</tr>
<tr>
<td>Iodine</td>
<td>solid</td>
<td>solid</td>
<td>114</td>
<td>184</td>
</tr>
<tr>
<td>Potassium</td>
<td>solid</td>
<td>solid</td>
<td>63</td>
<td>759</td>
</tr>
<tr>
<td>Sodium</td>
<td>solid</td>
<td>solid</td>
<td>98</td>
<td>883</td>
</tr>
</tbody>
</table>

Table 7.2.5b: The state of the elements based on their melting point and boiling points

b. i. & b. ii

<table>
<thead>
<tr>
<th>Name of the two groups of elements</th>
<th>Group I / Alkali metals</th>
<th>Group VII / Halogens</th>
</tr>
</thead>
</table>
Name of the two groups of elements

<table>
<thead>
<tr>
<th>Least reactive</th>
<th>Group I / Alkali metals</th>
<th>Group VII / Halogens</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lithium</td>
<td>Iodine</td>
</tr>
<tr>
<td>Increasing order of reactivity</td>
<td>Sodium</td>
<td>Bromine</td>
</tr>
<tr>
<td>most reactive</td>
<td>Potassium</td>
<td>Chlorine</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fluorine</td>
</tr>
</tbody>
</table>

Table 7.2.6b: The elements classified into their respective group in order of increasing reactivity

3. a.

<table>
<thead>
<tr>
<th>Solutions of</th>
<th>Element added</th>
<th>Potassium chloride</th>
<th>Potassium bromide</th>
<th>Potassium iodide</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Chlorine</td>
<td>X</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Bromine</td>
<td>X</td>
<td>X</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Iodine</td>
<td>X</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

b. The type of reaction is: displacement reaction

c. For the reaction of potassium iodide with chlorine,

   i. the word equation is:

   Potassium iodide + chlorine → potassium chloride + iodine

   ii. the symbol equation is:

   \[ 2\text{KI(aq)} + \text{Cl}_2(\text{g}) \rightarrow 2\text{KCl(aq)} + \text{I}_2(\text{aq}) \]
4.

a. Combustion

b. Basic oxide

c.

i. sodium + oxygen → sodium oxide

ii. $4\text{Na}^+(s) + \text{O}_2(g) \rightarrow 2\text{Na}_2\text{O}(s)$

iii. Sodium burns in oxygen with an orange flame.

How well did you do? I hope that you are satisfied with your performance. If you are not, please review the topic before moving on to Unit 8.

All the best with the remaining units!

---

**Unit summary**

In this unit you learned that elements can be categorised as metals and non-metals. You learned that the metals are situated in Groups I, II, III (on the left hand side) and the lower part of the Periodic Table (known as the transition elements) while the non-metals are in Groups: IV, V, VI and VII (on the right hand) of the Periodic Table.

You also learned about the chemical and physical properties of metals and non-metals. You learned that, at room temperature, all metals (except for mercury) are solids while the non-metals can be solid, liquid or gas. You learned about the different types of chemical reactions that metals and non-metals undergo.

You also learned about the physical and chemical properties of the elements in Group I (also known as alkali metals) and the elements in Group VII (also known as the halogens). You saw that elements are put in a particular group because they exhibit similar properties. You established that as we go down Group I the melting point and the boiling point of the elements decreases. You also established that the melting point and boiling point of the elements in Group VII increases as we go
down the group.

You learned about the trend in the reactivity of the alkali metals and that of the halogens. You learned that the reactivity of the alkali metals increases as we go down Group I. Hence, among lithium, sodium and potassium, potassium is the most reactive while lithium is the least reactive. By contrast, we saw that the reactivity of the halogens decreases as we move down the Group VII. So, among fluorine, chlorine, bromine and iodine, fluorine is the most reactive while iodine the least reactive.