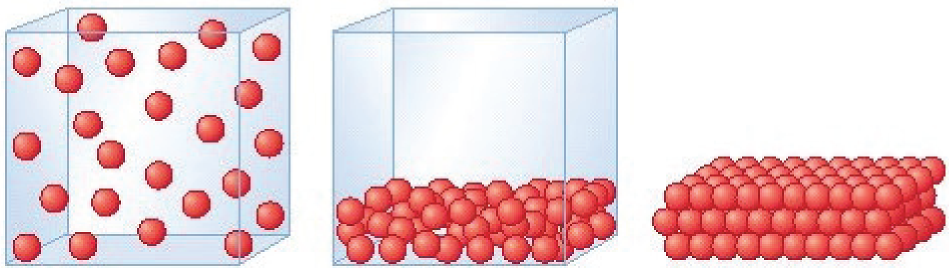
SENIOR ONE

CHAPTER 3
States and Changes of States of Matter



Key words :

- matter
- states of matter
- particle theory
- diffusion
- kinetic theory

By the end of this chapter, you should be able to:

- *understand that matter is anything which occupies space and has mass and can exist in a solid, liquid, gas and plasma form (u)*
- *understand that solids, liquids and gases have different properties including shape, pouring and compressing (u, s)*
- *know the kinetic theory of matter and use it to explain particle arrangement, inter-particle forces, movement of particles and the properties of solids, liquids and gases (k, u)*
- *understand that a change from one state to another involves either heat gain or heat loss (u, s)*
- *appreciate the cooling effect of evaporation and how this contributes to maintaining constant body temperature (k, u, s)*

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

Introduction

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

Fig 3.1: Heaps of sand at the lake shores

What do you think is the scientific term/name given to the grains of sand and anything else around you?
In this chapter, you will use knowledge o f the a rrangement and motion o f particles to explain the properties of solids, liquids and gases in everyday life.

3.1: What is Matter?

Everything you see, hear, smell, touch, and taste is matter. Matter is anything that has mass and takes up space. Matter exists in many shapes, colours, textures, and forms. Water, rocks, living things, and stars are all made of matter.
By studying matter, we learn to understand how and why some things work. After that, we can manage and control those things to make new things that improve our lives. The study of matter is important because it guides us in classifying substances.
To understand matter, you need to take a c loser look a t i t. As you observe o r examine matter more closely, more of its parts are revealed. Now that the term 'matter' has been introduced, we can use it to say there are three states of matter; solids, liquids and gases.

Assignment 3.1

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

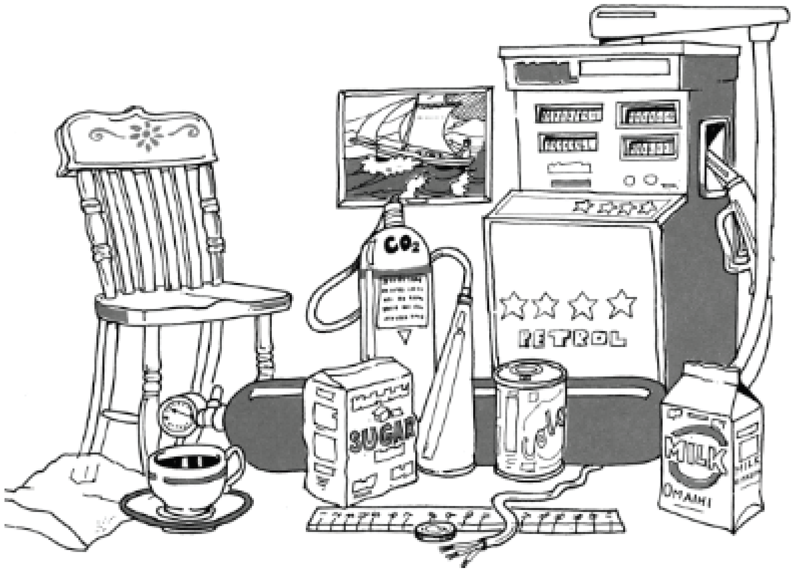


Fig. 3.2: Group of assorted items

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

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

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

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

The Particle Theory of Matter

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

There are things we experience in our daily life situations which can also explain that solids, liquids and gases are made of small particles which we cannot see with our naked eyes. For example, when your clothes are drying or when sugar mixes (dissolves) in water,

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we cannot see what is happening. Scientists use the idea of **particles** to explain what is happening. The particles are so small that we cannot see them.
What do you think happens to the water particles when clothes dry and to the sugar particles when they dissolve in the water?
When wet clothes dry, the water from the clothes gets evaporated and the water vapour formed from it goes into the atmosphere. When wet clothes are kept in the sunlight, Due to the sun's hot rays, the molecules of water which present in the clothes gain energy andevaporate.
Sugar gets disappeared once added to water. The molecules have broken down into atoms and dispersed in the water. The sugar molecules cannot go away but they can disperse in the water. They will s till be sugar molecules just not a ttached to any o ther molecules of sugar. The water and the sugar particles will be mix together and form a newsubstance.

Fig. 3.3: A vehicle raising a lot of dust on marram road

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

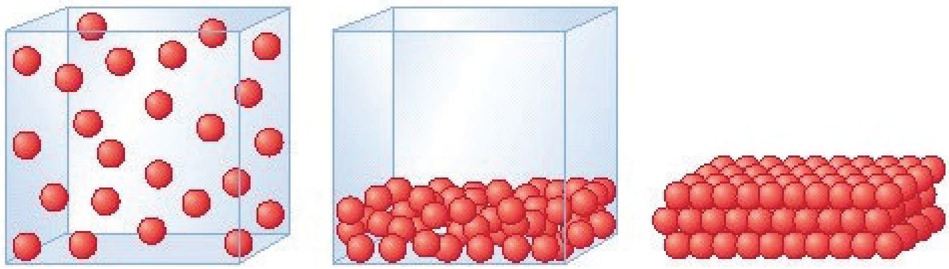
Think about Air

We cannot see air particles because they are very much smaller than grains of dust.
We know that they exist because we breathe in air particles. We also feel the wind when many air particles are moving and hitting us.

3.3. Investigating Properties of Solids, Liquids and Gas

The properties of substances depend on how the particles in these substances are arranged, and how they are held together. To investigate the properties of solids, liquids and gases including shape, pouring a nd c ompressing, i t i s important t o s tudy t he arrangement, the forces between the particles and movement of the particles.

Forces between Particles



Gas Liquid Solid

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

It is easier to run fast on land than it is to swim fast. Why is this? Particles are held together by forces. The forces holding water particles together are much greater than the forces which hold air particles together.

Therefore, when you swim you have to use more force to break the water particles apart. Fig. 3.4 shows how particles are held together in solids, liquids and gases.

Particles in Solids

The particles in solids are very close to one another and are in fixed positions. The forcesofattraction between particles are strong. The particles can vibrate but cannot move pasteach other. They are close together, touching each other.

Particles in Liquids

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

Particles in Gases

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

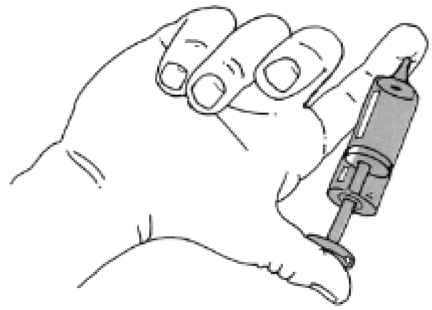
The next activity compares a liquid with a gas. It provides *evidence* for the idea that particles are close together in a liquid and far apart in a gas.

Activity 3.1: Finding out if gas or liquid can be compressed.

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

What you need

- a syringe
- water



What to do1 Draw some air into a syringe.
2 Close the opening with your finger so the air cannot get out.
3 Press down on the plunger (piston) as shown in the picture. Observe what happens.
4 Do the same with a syringe containing water.
Observe what happens.
You w ill have found that it was easy to compress (squeeze) the syringe full o f air, but impossible to compress the water.

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

What Evidence is there for Particles?
We cannot see particles; they are too small. But scientists believe they exist. This is a **scientific theory**. Scientists think up theories to explain their observations.
Then they look for **evidence** that their theory is correct. Evidence is something that you can see or hear or touch that can be explained by the theory.
The next activity provides some *evidence* for particles. You will make an observation thatcan be explained by the theory of particles.

Activity 3.2: Investigating Evidence of Particles using Balloon Filled with Air.

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

What you need

a balloon string

What to do

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

Results

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

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

Here is an explanation that uses the theory of particles. The balloon going down is *evidence*for the theory of particles.

Look at the picture. It shows the rubber skin of the balloon. The skin is made of rubber particles packed closely together. But there are places where the air particles can get out through holes between the rubber particles. The air particles inside the balloon are constantly moving around and hitting the skin of the balloon. A few manage to get out of the balloon.

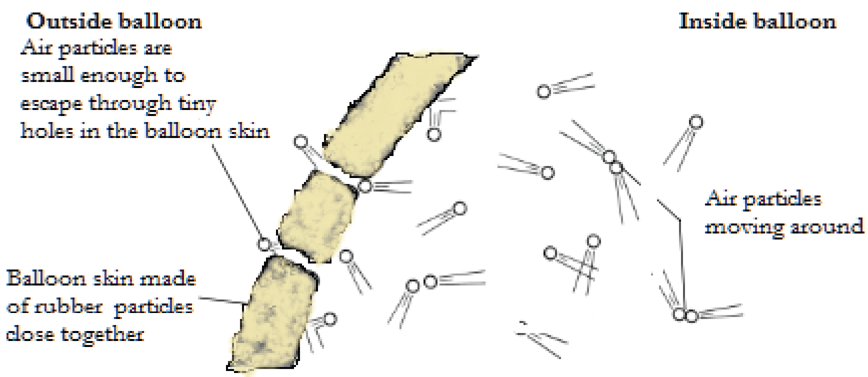


Fig. 3.6: Balloon filled with air

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

Activity 3.3: Investigating Evidence of Particles using Liquid

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

What you need

A crystal of potassiumpermanganate
a drop of ink
water
two small containers (tops fromjam jars are suitable)

What to do

1 Fill the containers with water.

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

What happened to the crystal of potassium permanganate? Did you see that the crystal of potassium permanganate changed the colour of the water? This can be explained by the idea of particles. Each particle that leaves the crystal moves in between the particles of water and spread.

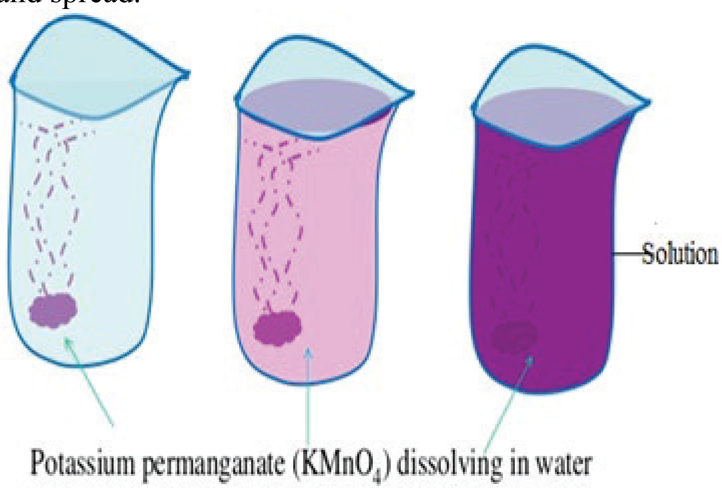


Fig. 3.7: Showing difussion in liquids

You cannot see each particle of water because the particles are very, very small. When particles of a substance spread from one region of higher concentration to another of lower concentration, the process is called **diffusion**. After some time, all the particles fromthe potassium permanganate crystal have spread evenly throughout the water to form a**solution**. This is why the crystal cannot be seen any more. It has **dissolved**.
Think of coloured liquid like ink. What would happen to the colour of water if a drop of theink is put into the glass of water?
The particles in the ink (which is a liquid) will also diffuse (spread) throughout the water until the colour becomes the same throughout the solution.

Diffusion in Gases

If someone is cooking in the kitchen, it doesn't take long for the smell to travel around thehouse to other rooms. This is because of diffusion. Gas particles from car exhaust fumes,perfumes or flowers diffuse through the atmosphere. Our nose detects the small particles.
This is how we smell things around us.
You don't have to mix the gases by waving your arms around - it mixes on its own.
You can easily show this with a gas that has a smell such as butane in a burner. One person should turn on the burner for a few seconds in the front of the classroom.
Are you able to smell anything?

Activity 3.4: Investigating Particles in Gases

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

What you need

- Gas of bromine vapour
- Two empty gas jars
- Cover plate

What to do

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

Results and Discussion

The difference between the two jars can be explained by the idea of particles. Each particle that leaves bromine vapour moves in between the particles of air in the jar on top. The bromine gas spreads (diffuses) rapidly into the air to produce a uniform pale brown colour in both jars. You cannot see each particle because the particles are very, very small.But you see the brown colour spreading throughout the two jars.

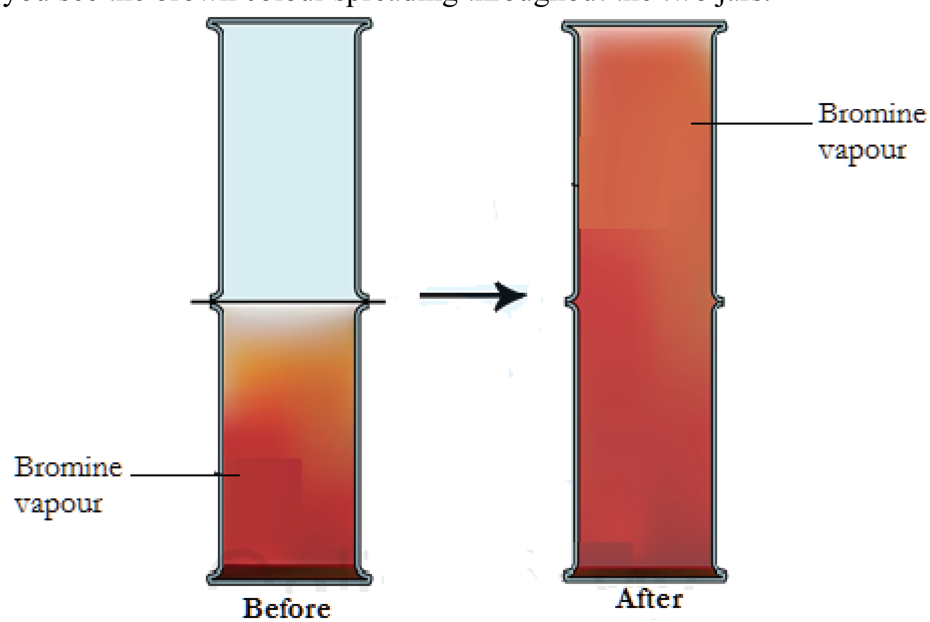


Fig. 3.8: showing diffusion in gases

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

Exercise/Assessment
Using suitable examples explain what the following terms mean;
Kinetic theory of matter
Brownian motion
Diffusion
a) Describe two ways in which properties of;
a liquid is similar to that of a solid
a gas is similar to that of a liquid
b) Give reasons for each of the similarities you have stated in (a) above
c) Why is gas compressible while a liquid is incompressible, yet particles of the two states undergo Brownian motion in a similar pattern?

3.4: The Kinetic Theory of Matter

Activities 2.3 (particles in liquids) and 2.4 (particle in gases) can be used to explain kinetictheory of matter.
These activities demonstrated that particles in liquid and gases are constantly moving freely and randomly in all directions, and keep colliding with each other. The particles in liquids and gases move freely because forces of attraction between particles in liquids areweak, while forces between particles in gases are negligible
The particles in solid also do move but the movement of the particles in solid differs fromthat in l iquids and gases in that they do not move f reely, they v ibrate about a certainaverage/mean position.
Therefore, the kinetic theory matter states; all matter is made up of small particles that are in continuous state of motion.

3.5: Changes of State by Heat gain or Heat loss

Many of the uses of the d ifferent states of matter rely on their changing f rom one s tate matter to another. For example, purifying water relies on a change of state from liquid to gas and back again, as does the formation of rain. The burning of candle relies on the waxchanging from a solid to a liquid and then to a gas.
Understanding that when things change from one state to another requires energy (heat)gain or loss is very important. Substances can move from one state to another whenspecific **physical conditions** change. For example, when the temperature of a substancegoes up, the particles in the substance becomes more excited and active. If enough energyis placed in a substance, a change of state may occur as the matter moves to a more activestate.
In this section, the particle model will help you to explain how substances change from one state to another. An example of this is the changing of ice water to water (liquid) to watervapour (gas) during boiling of water.
Can you give example of substances which are always in a solid form but you change theminto a liquid form before use? How do you do it?
What happens when you put drinking water in fridge? Why do you put other drinks in fridge?

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

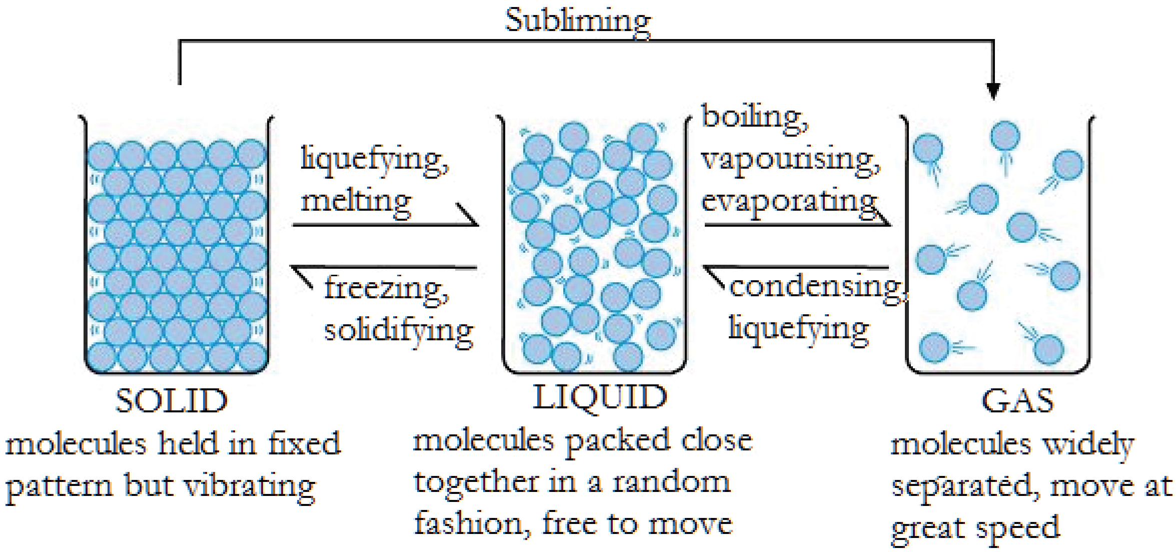


Fig. 3.9: Showing changes of states

This can be explained by the idea of the movement of particles due to increase or decrease of heat energy.
When matter is heated, the particles absorb heat energy; move faster, thus an increase inthe kinetic energy.
When matter is cooled, the particles will release heat energy, move slower, thus a decrease in kinetic energy.

Activity 3.5: Investigating the changes taking place when water is heated.

What you need

- source of heat
- ice cubes (100ml)
- Celsius thermometer
- stirring rod
- 250ml beaker
- stop watch or wall clock

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

What to do

1 Put150ml of water and 100ml of ice into a beaker and place the beaker on the hot plate.
2 Put the thermometer into the ice/water mixture. Do not stir with the thermometer or allow it to rest on the bottom of the beaker.
3 Record the temperature of the ice/water mixture.
4 Put the ice water on a source of heat and record the temperature every minute in the table below including the physical state of the water.
5 Continue doing this until water begins to boil.
6 NOTE: Before making each temperature measurement, stir the ice/water mixture with the stirring rod.
7 Use your data to plot a graph of temperature (oC) vs. time (sec).

Data Table:

Time (min)	Temperature ($_0$C)	Physical state
0		
1		
2		
3		

3.5. Energy Changes during Heating and Cooling

When you heated a beaker of ice, you noticed that the temperature stayed at 0$_0$C until allthe ice had melted. Only after this does the temperature rise. So, what happens to theheat energy that you put into the ice if it does not make the ice warmer? The answer isthat energy is needed to pull apart the particles in the ice so that they are no longer in regular rows but are moving around. This energy has a name; it is called the latent heat ofmelting of ice.

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

Activity 3.6: Investigating the changes of state that occur when ice is heated

What you need

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

- beaker (250ml)
- stop watch or wall clock

What to do

1 Put 150 cm^3 of water and 100 cm^3 of ice into a beaker and place the beaker on the hot plate.
2 Put the thermometer into the ice/water mixture. Do not stir with the thermometer or allow it to rest on the bottom of the beaker.
3 Record the temperature of the ice/water mixture.
4 Put the ice water on a source of heat and record the temperature every minute in the table below including the physical state of the water.
5 Continue doing this until water begins to boil.
6 Before making each temperature measurement, stir the ice/water mixture with the stirring rod.
7 Use your data to plot a graph of temperature (°C) against time (seconds).

Table 4: Results of temperatures of ice on cooling

Time (min)	Temperature (^oC)	Physical state
1		
2		
3		
4		
5		
6		
7		

3.6: Cooling Effect of Evaporation

Activity 3.5: Investigating the Effect of Evaporation.

What you need

- ether or acetone
- a spatula

What to do

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

Results and Discussion

What did you feel on your skin as the drop was evaporating?
1. What conclusion can you draw about the effect of evaporation on the back of your hand?
2. Explain how this effect is an important aspect in the life of living organisms.

Activity of Integration

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