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Joanna Haywood , Richard Harwood , Ian Lodge
Excerpt
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Chapter 1

States of matter

Solids, liquids and gases

Exercise 1.1

IN THIS EXERCISE YOU WILL:

- develop your understanding of the distinguishing properties of solids, liquids and gases
- show how the properties of each state of matter are linked to the organisation of the particles present
- use data on melting and boiling points to determine the physical state of a substance at a given temperature.

KEY WORDS

boiling: the process of change from liquid to gas at the boiling point of the substance; a condition under which gas bubbles are able to form within a liquid – gas molecules escape from the body of the liquid, not just from its surface.

evaporation: a process occurring at the surface of a liquid, involving the change of state from a liquid into a vapour at a temperature below the boiling point.

freezing point: the temperature at which a liquid turns into solid – it has the same value as the melting point; a pure substance has a sharp freezing point.

Focus

1 There are three states of matter, which have different basic physical properties. Complete the sentences by adding two properties shown by each physical state.

A solid has a fixed ____________ and ____________.

A liquid has a fixed ____________ but its ____________ changes to match that of the container in which it is placed.

A gas has no fixed ____________ or ____________. A gas completely fills the container it is in.

2 Complete the boxes below to show how the particles of a substance are arranged in the three states of matter.

solid	liquid	gas

Practice

Question 2 showed the differences in structure and organisation of the particles between the three states. The differences can also be expressed in words. Table 1.1 describes the arrangement of the particles in four different substances: A, B, C and D.

Substance	Distance between particles	Arrangement of particles	Movement of particles
A	very far apart	randomly arranged	moving about with high speed
B	very close together	regularly ordered	vibrating about fixed positions
C	very far apart	regularly ordered	vibrating about fixed positions
D	close together	irregularly arranged	moving about

Table 1.1: The arrangement and movement of particles in substances A, B, C and D.

3 Which of substances A, B, C and D is:

a a solid ....

b unlikely to be a real substance ....

c a gas ....

d a liquid? ....

4 Changing the temperature can cause a substance to change its physical state. What are the changes of state labelled A, B, C and D in Figure 1.1?

(*Note:* sublimation is not required knowledge.)

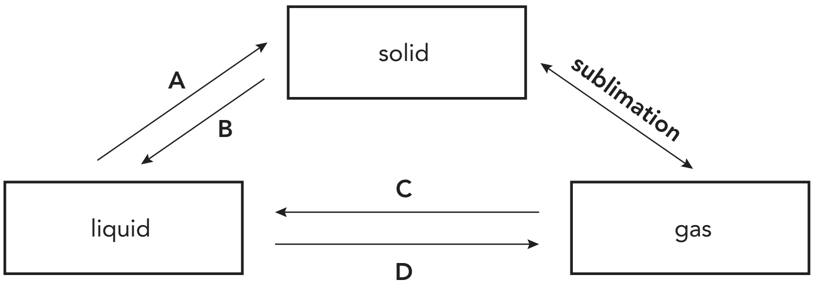

Figure 1.1: Changes of physical state.

A .... **B** ....

C .... **D** ....

KEY WORDS

kinetic particle theory: a theory which accounts for the bulk properties of the different states of matter in terms of the movement of particles (atoms or molecules) – the theory explains what happens during changes in physical state.

melting point: the temperature at which a solid turns into a liquid – it has the same value as the freezing point; a pure substance has a sharp melting point.

TIP

In a liquid, the particles are still close together. However, they are not regularly arranged and they can move around and past each other.

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Challenge

5 Table 1.2 provides data about the melting and boiling points of different substances at atmospheric pressure. Use these data to answer the questions.

Substance	Melting point / °C	Boiling point / °C
sodium	98	883
radon	−71	−62
ethanol	−117	78
cobalt	1492	2900
nitrogen	−210	−196
propane	−188	−42
ethanoic acid	16	118

Table 1.2: Melting points and boiling points of various substances at atmospheric pressure.

a Which substance is a liquid over the smallest range of temperatures?

....

b Which two substances are gaseous at −50 °C?

....

c Which substance has the lowest freezing point?

....

d Which substance is liquid at 2500 °C?

....

e A sample of ethanoic acid was found to boil at 121 °C at atmospheric pressure. Use the information in Table 1.2 to comment on this result.

....

....

TIP

Be careful when dealing with temperatures below 0 °C. Remember that −100 °C is a higher temperature than −150 °C.

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Exercise 1.2

IN THIS EXERCISE YOU WILL:

- develop your understanding of the changes in organisation and movement of particles that take place as a substance changes state
- use data from an experiment to plot a cooling curve for a substance
- link the different changes of state to the kinetic particle theory of matter and explain the changes taking place.

Focus

A student carried out a data-logging experiment as part of a project on changes of state. An organic crystalline solid was placed in a tube in a boiling water-bath, as shown in Figure 1.2. When the solid had melted, a temperature sensor was placed in the liquid.

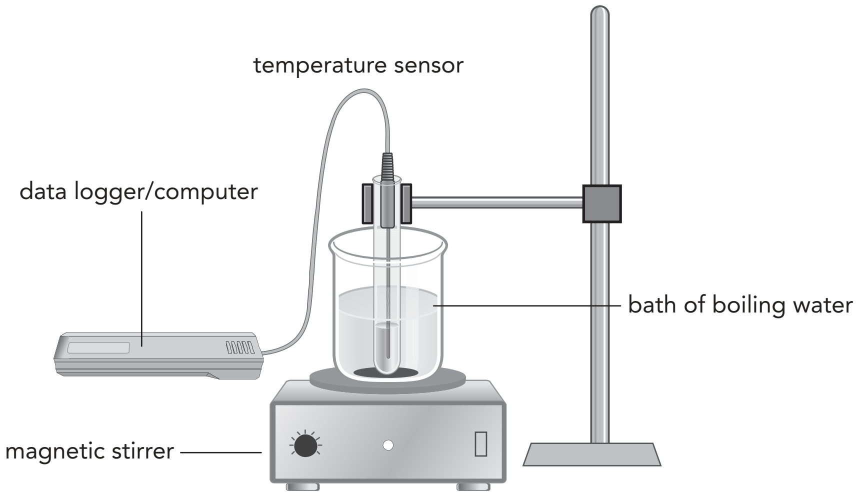

Figure 1.2: Using a temperature sensor to plot a cooling curve.

The data logger recorded the temperature of the liquid as it cooled to room temperature. Some of the data is shown in Table 1.3.

Time / minutes	0	0.5	1.0	1.5	2.0	2.2	2.4	2.6	2.8	3.0	3.5	4.0	4.5	5.0
Temperature / °C	96.1	89.2	85.2	82.0	80.9	80.7	80.6	80.6	80.5	80.3	78.4	74.2	64.6	47.0

Table 1.3: Results for a cooling curve experiment.

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1 On the grid provided, plot a graph of the temperature change that took place in this experiment.

2 The student decided to repeat the experiment using a compound with a melting point greater than 100 °C. What change would she need to make to carry out the experiment?

3 What change is taking place between minutes 2 and 3 of the experiment?

Practice

4 Why does the temperature remain almost constant during the third minute of the experiment? When giving your answer, think about changes to the organisation of the molecules in the substance.

....

....

....

....

....

....

> **TIP**
>
> Pure substances have definite, precise melting points and boiling points. When a substance contains impurities, the melting and boiling points change and become less precise (spread over a range of temperatures).

5 Another student carried out a similar experiment to demonstrate the cooling curve for paraffin wax.

a In the space provided, sketch the shape of the graph you would expect the student to produce.

b Explain why you chose this shape for the curve you drew in part **a**.

....

....

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Challenge

6 Cooling curve experiments can be reversed, allowing students to plot a heating curve instead. Figure 1.3 shows the heating curve for a pure substance. The temperature rises over time as the substance is heated.

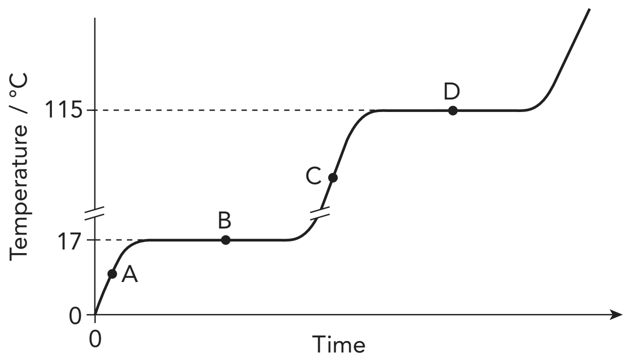

Figure 1.3: A heating curve for a pure substance.

a In what physical state(s) is the substance at points A, B, C and D?

A ....

B ....

C ....

D ....

b What is the melting point of the substance?

....

c What is the boiling point of the substance?

....

d How does the temperature change while the substance is changing state?

....

e The substance is not water. How do you know this from the graph?

....

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7 The solid form of carbon dioxide is known as dry ice. Dry ice is used in commercial refrigeration and to create spectacular and misty stage effects. The surface of dry ice at atmospheric pressure is different from the surface of ordinary water ice: there is no liquid film on it.

a If you gently shake a fire extinguisher filled with carbon dioxide (Figure 1.4), you will feel the presence of liquid within the extinguisher. What conditions within the extinguisher allow the carbon dioxide to exist as a liquid?

....

....

Figure 1.4: A carbon dioxide fire extinguisher.

b Frost is ice crystals that form on surfaces when conditions are very cold. Using the words provided, complete the following paragraph about a particular type of frost known as hoar frost.

colder **crystals** **humid** **ice**

liquid **surrounding** **white**

Hoar frost is a powdery ____________ frost caused when solid ____________ forms from ____________ air.

The solid surface on which it is formed must be ____________ than the ____________ air.

Water vapour is deposited on a surface as fine ice ____________ without going through the ____________ phase.

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c For most substances, the change from a solid to a gas involves a liquid phase. The change from liquid to gas takes place by evaporation and/or boiling. Use the ideas of kinetic particle theory to explain the difference between these two processes.

evaporation: ....

....

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....

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boiling: ....

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....

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SELF ASSESSMENT

Use this checklist to give yourself a mark for the graph you drew in question 1.
For each point, award yourself:

2 marks if you did it really well

1 mark if you made a good attempt and partly succeeded

0 marks if you did not try to do it, or did not succeed.

Then ask your teacher to mark you on the skills as well.

Checklist	Marks awarded	
	You	Your teacher
Have you drawn the axes with a ruler, using most of the width and height of the grid?		
Have you used a sensible scale for the *x*-axis and the *y*-axis, which goes up in easily managed units (1 minute, 2 minutes, etc.)? (*Note:* the axes do not necessarily need to start at the origin (0, 0).)		
Have you labelled the axes correctly? Have you given the correct units for the scales on both axes?		
Have you plotted each point precisely and correctly?		
Have you used a small neat cross or encircled dot for each point?		
Have you drawn a single, clear best-fit line through each set of points?		
Have you ignored any anomalous (unexpected) results when drawing the line through each set of points?		
Total (out of 14):		

Your total score will reflect how clear and well-presented your graph is. You should be able to deduce reliable information from your graph.

Look at the scores in the table. What did you do well? What aspects will you focus on next time? Talk with your teacher and ask for advice to help you improve your presentation of graphical data.