11–14 years

Making ice

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The Mpemba effect

The Mpemba effect is a phenomenon named after a Tanzanian teenager, Erasto Mpemba.

Erasto was a student at Magamba Secondary School in Tanzania, where one day, he and his classmates were making ice cream. The recipe for the ice cream said the mixture should be allowed to cool down before putting in the refrigerator. However, to ensure he could get a free space, Erasto put his ice cream mixture in the fridge without letting it cool first. At the same time one of his friends, who had let his mixture cool, also put his mixture in the fridge.

Whose ice cream do you think froze quicker?

Learning objectives

1. Plan a method to investigate how quickly ice forms.
2. Make observations and accurately record them in a table.
3. Use experimental data to draw conclusions.
4. Write an investigation report.

Your task

Working in small groups (2–3 students), plan an investigation to answer the question:

'Which makes ice faster, hot or cold water?'

Use your method writing, planning and problem-solving skills to answer the question using the equipment listed on the next slide. You may be able to ask your teacher for some additional equipment.

Before you begin your planning, make a prediction and write it down. A good place to start your group discussions is to identify all the different variables.

Equipment

Materials (per group)

- Deionised water

Apparatus (per group)

- Beakers, 100 and 250 cm^3
- Thermometers, -5 to +100°C
- Access to a refrigerator and freezer
- Safety glasses (one per learner)

You will need …

Before you begin

1. Make a prediction about whether the hot or cool water will freeze fastest. Suggest a reason for your answer.
2. Identify the variables.
   a) What will you change?
   b) What will you measure?
   c) What will you keep the same?
3. Name the equipment you will use to:
   a) Measure the volume of water.
   b) Pour the water into.
   c) Measure the temperature of the water.
   d) Heat the water.
   e) Measure how long the water takes to freeze.
4. How many different water temperatures will you test? Remember to label your samples.
5. How many times will you repeat each experiment?
6. Write a method. Before you start, you will need to think carefully about the order you do things in.

Recording your results

Here are some example tables you could use to record your results.

Sample	Temperature (°C)	Notes
A		
B		

Sample	Time in the fridge/freezer (mins)	Temperature (°C)	Observations (Describe what you see)

7. Draw your own results table.

What headings will you write in each column? Don't forget to include the units.

Analysing your results

8. Interpret your results.
   a) Which sample cooled the fastest?
   b) Which sample became ice first?

9. Write a conclusion to the question:

   'Which makes ice faster, hot or cold water?'

Was your prediction correct?

Conclusion

The Mpemba effect

Remember the teenager, Erasto Mpemba, and his ice cream?

Erasto put his ice cream mixture in the fridge without letting it cool first. At the same time one of his friends, who had let his mixture cool, also put his mixture in the fridge.

To everyone's surprise, Erasto's ice cream froze first after about 1 hour, while his friend's remained liquid for longer.

This is known as the Mpemba effect.

Explanation

Explanation

Does hot water freeze more quickly than cold water?

Under some conditions, yes.

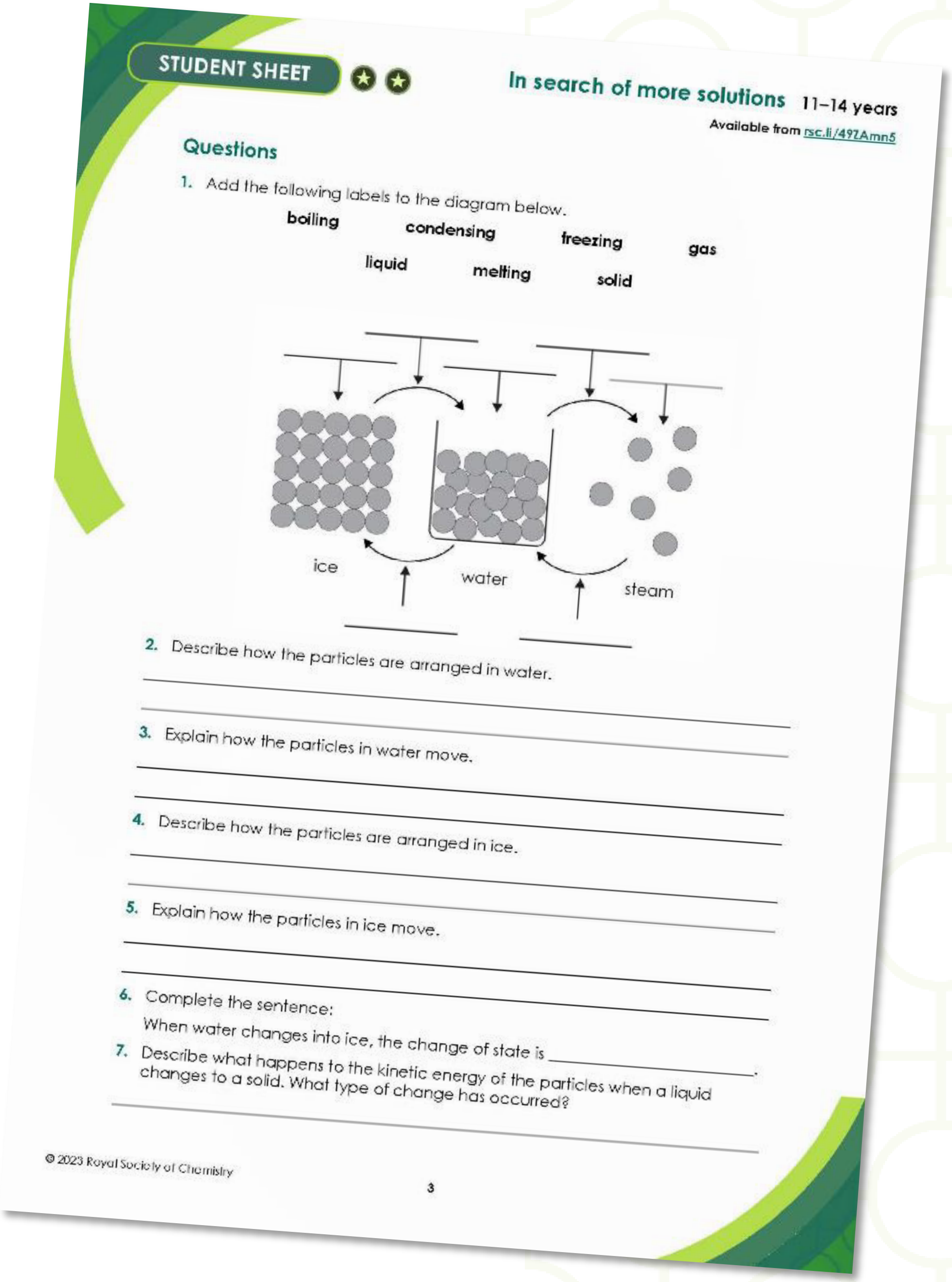
Or, more precisely, water freezes more slowly if the initial temperature is below room temperature.

The phenomenon is still puzzling scientists but may be because a hot liquid has a 'hot top' of **mobile molecules** with **high kinetic energy**. These molecules can escape from the liquid phase more easily than colder molecules with lower kinetic energy in a cooler liquid. This is due to the hotter molecules having **more energy** to overcome the **intermolecular forces**. Therefore, the rapid cooling of the hot liquid may be due to the **evaporation** from this 'hot top'.

Read more about research into the Mpemba effect here: bit.ly/3N9qE7Q.

Questions

Now complete the worksheet questions relating to the particle model and solids, liquids and gases.


STUDENT SHEET

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Questions

1. Add the following labels to the diagram below.

boiling condensing freezing gas liquid melting solid

ice water steam

2. Describe how the particles are arranged in water.

3. Explain how the particles in water move.

4. Describe how the particles are arranged in ice.

5. Explain how the particles in ice move.

6. Complete the sentence:

When water changes into ice, the change of state is __________.

7. Describe what happens to the kinetic energy of the particles when a liquid changes to a solid. What type of change has occurred?

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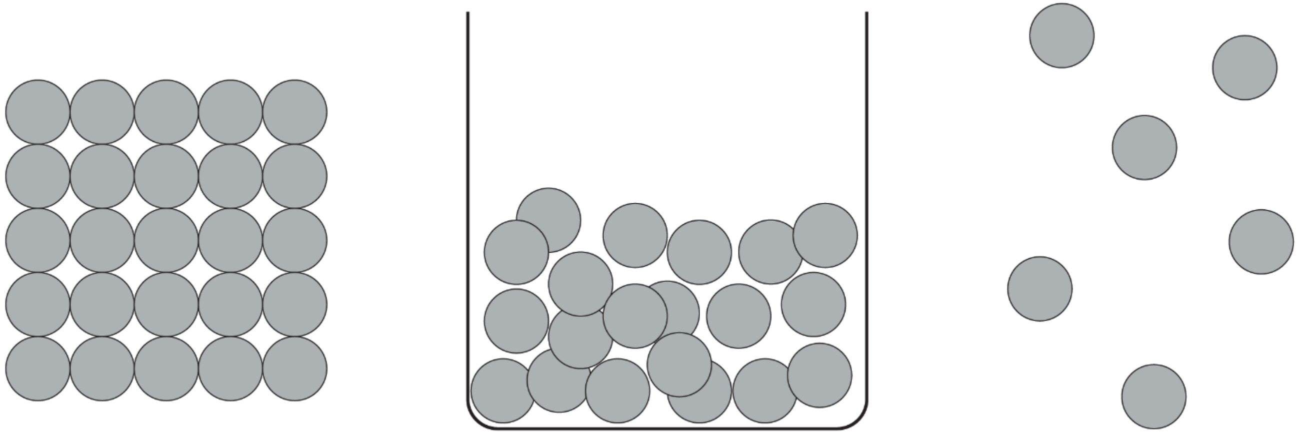
Answers (unscaffolded)

1.



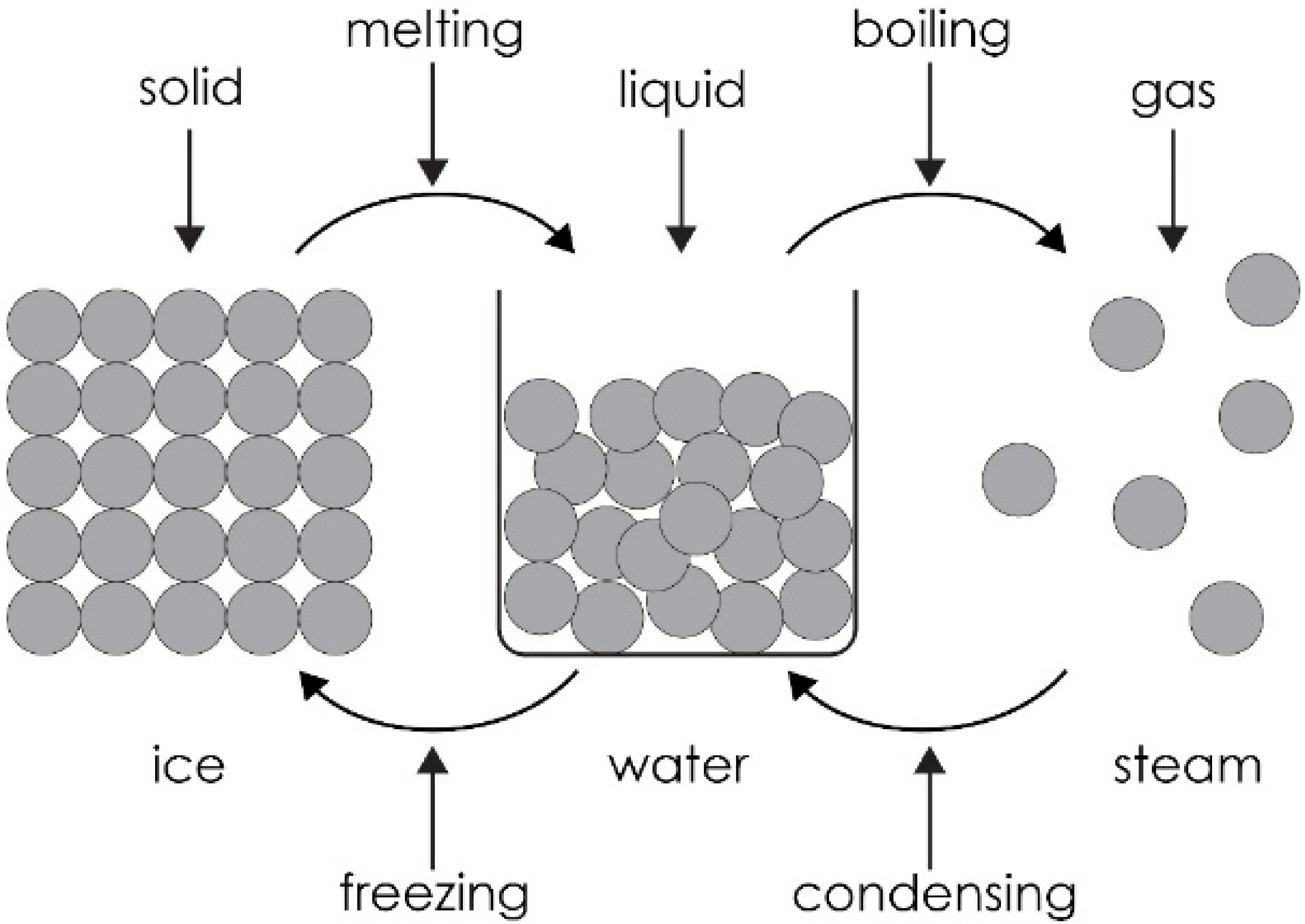
solid liquid gas

Answers (scaffolded)

2. In ice, the particles are very close together in a regular pattern. The particles vibrate around a fixed position. Solids have a fixed shape. Solids cannot be easily compressed because their particles are close together with no space to move into.
3. In water, the particles are very close together and are **randomly** arranged, but still touching. The particles move around each other and have **more** energy than in a solid but **less** than in a gas. Liquids do not have a fixed **shape**. Liquids can **flow** and take the shape of their container, because their **particles** can move around each other. Liquids cannot be easily **compressed** because their particles are close together with little space to move into.
4. Freezing.
5. Decreases, exothermic.

Answers (scaffolded)

1.



Answers (unscaffolded)

2. The particles in water are close together and randomly arranged with most touching.
3. Particles move randomly and can flow around each other because they enough have kinetic energy.
4. The particles in ice are close together and touching.
5. The particles in ice vibrate around a fixed point because they don't have enough kinetic energy to flow over each other.
6. Freezing.
7. It decreases. Exothermic change.
8. In solid iron the particles are very close together giving it a higher density than liquid iron where the particles randomly flow over each other. The density of ice must be lower than the density of water otherwise it would sink. Therefore, the particles in ice must have strong forces between the particles, giving a more open structure.
9. Accept any reasonable suggestion here including ideas that the particles must lose their kinetic energy more quickly if the water is hotter.