4.1 Kinetic theory and latent heat

Name: _____ Class: _____ Date: _____ **Total: 25 marks**

KEY WORDS specific heat capacity • specific latent heat

Objective

Build the skills to answer exam questions on **particles, heating and changes of state** : the particle model, internal energy, specific heat capacity, specific latent heat and cooling curves.

You must be able to:

- describe solids, liquids and gases with the particle model
- use $E = mc\Delta\theta$
- use $E = mL$ for melting and boiling
- explain heating and cooling curves and describe the cooling-curve practical

1 Key knowledge and worked examples

Particles and heating

idea	equation or rule
particles	solid: fixed positions, vibrating; liquid: close, moving past each other; gas: far apart, fast and random
internal energy	the total kinetic and potential energy of the particles
specific heat capacity	$E = mc\Delta\theta$ (c in J/kg °C)
specific latent heat	$E = mL$ for melting (fusion) or boiling (vaporisation); the temperature stays the same while the state changes
cooling curve	the flat part is the change of state; an impurity lowers the melting point

Worked example 1: heating water. Find the energy to heat 2.0 kg of water from 20 °C to 70 °C. ($c = 4200$ J/kg °C)

1. Known: $m = 2.0$ kg, $\Delta\theta = 50$ °C.
2. Rule: $E = mc\Delta\theta$.
3. Numbers: $2.0 \times 4200 \times 50$.
4. Result: $E = 420\,000$ **J**.

Worked example 2: melting ice. Find the energy to melt 0.50 kg of ice at 0 °C. ($L = 3.34 \times 10^5$ J/kg)

1. Known: $m = 0.50$ kg.
2. Rule: $E = mL$.
3. Numbers: $0.50 \times 3.34 \times 10^5$.
4. Result: $E = 1.67 \times 10^5$ **J**.

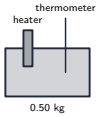
Answer shapes: use $E = mc\Delta\theta$ when the temperature changes and $E = mL$ when the state changes.

2 Practice

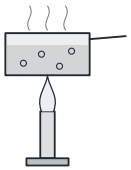
2.1 The boxes show the particles in three states of matter. Name the state in each box. [2]



2.2 A 0.50 kg aluminium block is heated by 20 °C. Aluminium has $c = 900$ J/kg °C. Calculate the energy supplied. [2]

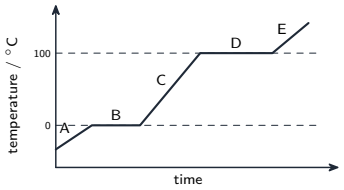


2.3 Calculate the energy needed to boil away 0.20 kg of water at 100 °C. ($L = 2.26 \times 10^6$ J/kg) [2]

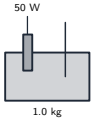


3 Exam-style questions

3.1 The graph shows the temperature of some ice as it is heated at a steady rate. Explain what happens in parts B and D, and why the temperature does not change there. [3]

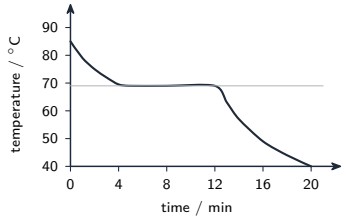


3.2 A 50 W heater warms a 1.0 kg metal block for 600 s. The temperature rises from 20 °C to 53 °C. Calculate the specific heat capacity of the metal. [3]



3.3 A student melts 0.050 kg of stearic acid in a water bath. Then she lets it cool and records its temperature every 30 s. The graph shows her results.

(a) Use the graph to find the melting point of stearic acid. Give a reason. [2]



(b) What is the state of the stearic acid at 2 minutes and at 14 minutes? [2]

(c) The specific latent heat of fusion of stearic acid is 2.0×10^5 J/kg. Calculate the energy released while it freezes. Calculate the average rate at which it loses energy during freezing. [3]

(d) Describe how the student did this practical. Explain the shape of the graph. [6]

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Solutions

Marking: **M1** a correct method, **A1** the correct answer, **B1** an independent mark.

Each answer shows the steps, then the **result**.

2.1

- two correct
- X **solid**, Y **liquid**, Z **gas**

2.2

- $E = 0.50 \times 900 \times 20$
- $=$ **9000** J

2.3

- $E = mL = 0.20 \times 2.26 \times 10^6$
- $=$ **452 000** J

3.1

- B: the ice is melting at 0 °C
- D: the water is boiling at 100 °C
- the energy breaks bonds between particles (increases their potential energy), not their kinetic energy, so the temperature stays the same

3.2

- $E = Pt = 50 \times 600 = 30\,000$ J
- $c = \frac{E}{m\Delta\theta} = \frac{30\,000}{1.0 \times 33}$
- $=$ **910** J/kg °C

3.3

(a) **69** °C; the temperature stays constant there while it changes state

(b) 2 min: **liquid**; 14 min: **solid**

(c) $E = mL = 0.050 \times 2.0 \times 10^5 =$ **10 000** J; freezing lasts 8 min = 480 s, so about **21** W

(d) points to include:

- melt it in a boiling tube in hot water, with a thermometer in it; then stand the tube in a rack
- record the temperature every 30 s, reading the thermometer at eye level
- plot temperature against time
- the liquid cools, then the temperature stays at 69 °C while it freezes
- bonds form during freezing and release energy, so the temperature does not fall

Levels: **5–6** a full, logical answer with correct physics and correct terms; **3–4** several correct points, partly linked; **1–2** one or two relevant points.