

Particle models and specific latent heat

AQA GCSE Physics 8463 and Combined Science Trilogy 8464 | Paper 1 | Foundation and Higher

Worked solutions and teaching prompts | Shared Foundation and Higher content

Specification points covered

Particle models and changes of state: 8463 4.3.1.1–4.3.1.2 / 8464 6.3.1.1–6.3.1.2 (selected content)

Internal energy: 8463 4.3.2.1 / 8464 6.3.2.1

Temperature changes and specific heat capacity: 8463 4.3.2.2 / 8464 6.3.2.2 (brief comparison)

Specific latent heat and heating or cooling graphs: 8463 4.3.2.3 / 8464 6.3.2.3

Gas temperature, particle motion and pressure: 8463 4.3.3.1 / 8464 6.3.3.1

Supporting power and time calculations: 8463 4.1.1.4 / 8464 6.1.1.4

A field team uses reusable cooling packs to protect temperature-sensitive sensor cartridges. The packs contain a material that melts at 20 °C. You will test the material and decide whether a pack can protect the cartridges for a full journey.

All questions are shared Foundation/Higher content for both routes. Accept equivalent scientific wording and sensible follow-through. Timing is suggested, not classroom-tested. These are original PhysicsUK questions, not an official AQA paper or mark scheme.

1 Starting with the cooling pack

Each calculation in this section describes a separate pack already at its melting point.

1(a) State what is meant by the internal energy of the pack material. **[1 mark]**

Answer / mark points: The total kinetic energy and potential energy of all its particles. [1]

Teacher prompt: Internal energy is not just energy supplied during this test, and not just particle kinetic energy.

1(b) Define specific latent heat of fusion. **[1 mark]**

Answer / mark points: The energy required to change 1 kg of a substance from solid to liquid with no change in temperature. [1]

1(c) Calculate the energy needed to melt all 0.240 kg of material at 20 °C. **[1 mark]**

Answer / mark points: $E = mL = 0.240 \times 90\,000 = 21\,600 \text{ J}$. [1]

1(d) In another test, only 0.080 kg melts. Calculate the energy absorbed during this melting. **[1 mark]**

Answer / mark points: $E = mL = 0.080 \times 90\,000 = 7200 \text{ J}$. [1]



2 Explaining the three states

Figure 1 shows simplified microscopic models of three states of the same material. Circles represent particles, not pieces of material. Gas separations are greatly reduced to fit the diagram; do not measure density from the drawing.

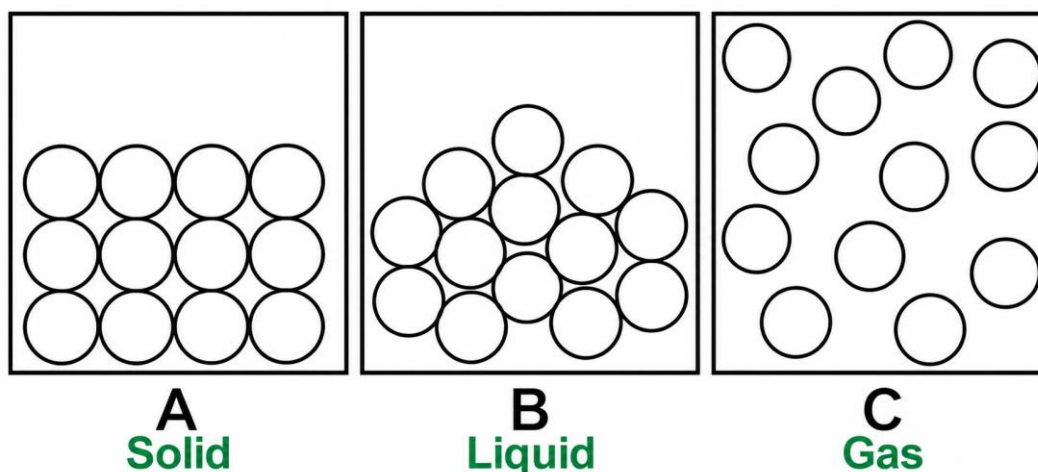


Figure 1

2(a) Identify the state represented by A, by B and by C in Figure 1. **[3 marks]**

Answer / mark points: A: solid. [1] B: liquid. [1] C: gas. [1]

2(b) Describe the movement of particles in the solid pack material and explain why the solid keeps its shape. **[2 marks]**

Answer / mark points: Particles vibrate about fixed positions. [1] They do not move freely past one another, so the solid retains its shape. [1]

Teacher prompt: Fixed positions does not mean stationary particles.

2(c) The melted material can be poured. Explain why this is possible even though its particles remain close together. **[1 mark]**

Answer / mark points: Its particles can move past one another, so the liquid can change shape and flow. [1]

2(d) A sealed pack contains 0.240 kg of the material before it melts. State the mass of material after it has melted and explain your answer. **[2 marks]**

Answer / mark points: 0.240 kg. [1] The same particles remain in the sealed pack; no matter enters or leaves, so mass is conserved. [1]

2(e) Some vapour forms droplets on the cooler inside surface of a sealed test container. Name the change of state and explain why it is a physical change. **[2 marks]**

Answer / mark points: Condensation. [1] No new substance is formed; reversing the change restores the original substance and properties. [1]



2 Explaining the three states continued

2(f) The vapour of the material is much less dense than its liquid. Explain this difference using the particle model. **[1 mark]**

Answer / mark points: Gas particles are much farther apart, so there is less mass in a given volume. [1]

Teacher prompt: Do not say the particles themselves become lighter or larger. Do not claim every solid is denser than its liquid.

3 Using specific latent heat

Each test below is separate. A mass given for melting or boiling is already at the temperature of that change of state. Assume all the stated energy goes into the change of state.

3(a) A spare pack contains 180 g of material at 20 °C. Calculate the energy needed to melt it completely. **[2 marks]**

Answer / mark points: $m = 180 / 1000 = 0.180$ kg. [1]
 $E = 0.180 \times 90\,000 = 16\,200$ J. [1]

Teacher prompt: Use kilograms with J kg^{-1} , not the numerical mass in grams.

3(b) A partly melting sample absorbs 13 500 J. Calculate the mass that melts. **[1 mark]**

Answer / mark points: $m = E / L = 13\,500 / 90\,000 = 0.150$ kg. [1]

3(c) A different candidate material needs 24 000 J to melt a 0.200 kg sample at its melting point. Calculate its specific latent heat of fusion. **[1 mark]**

Answer / mark points: $L = E / m = 24\,000 / 0.200 = 120\,000$ J kg^{-1} . [1]

3(d) For a separate cleaning test, 10.0 g of water at its boiling point becomes steam at the same temperature. Use $L = 2.3 \times 10^6$ J kg^{-1} to calculate the energy needed. **[2 marks]**

Answer / mark points: $m = 10.0 / 1000 = 0.0100$ kg. [1]
 $E = mL = 0.0100 \times 2.3 \times 10^6 = 23\,000$ J. [1]

Teacher prompt: This uses specific latent heat of vaporisation, not the pack material's fusion value.

3(e) All 0.240 kg of the original pack material freezes at 20 °C. Calculate the energy released during freezing. **[1 mark]**

Answer / mark points: Energy released = $mL = 0.240 \times 90\,000 = 21\,600$ J. [1] This is transferred out of the material.



4 Reading the heating curve

A 0.120 kg sample of the pack material is heated at constant pressure. Figure 2 shows an idealised test: the sample receives a constant net power of 30 W, with no energy lost from the sample. It starts solid at A, begins melting at B and finishes melting at C. No boiling occurs.

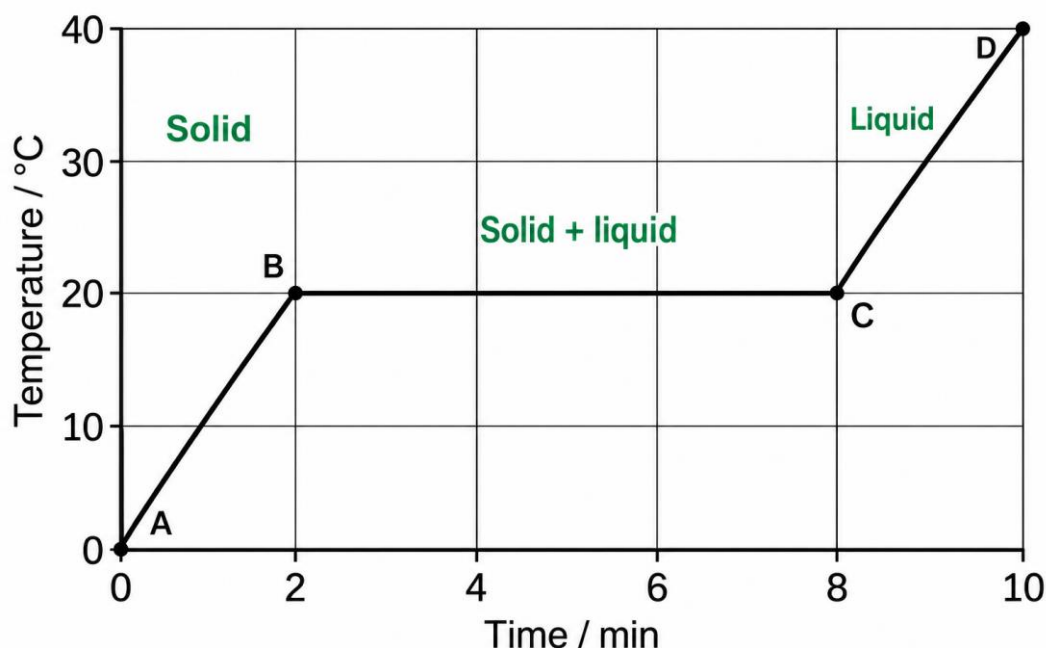


Figure 2

4(a) Use Figure 2 to find the temperature at a time of 1.0 minute. [1 mark]

Answer / mark points: 10 °C. [1] Read halfway along the straight segment A–B.

4(b) Use the graph to state the melting temperature of the material. [1 mark]

Answer / mark points: 20 °C. [1]

4(c) Determine the duration of the melting stage B–C, in seconds. [1 mark]

Answer / mark points: $8 - 2 = 6$ minutes = 360 s. [1]

Teacher prompt: Use the interval, not the time at C; convert minutes to seconds.



4 Reading the heating curve continued

4(d) Calculate the energy transferred to the sample during B–C. **[2 marks]**

Answer / mark points: $t = (8 - 2) \times 60 = 360 \text{ s}$. [1]
 $E = Pt = 30 \times 360 = 10\,800 \text{ J}$. [1]

4(e) Use your answer to part (d) and the 0.120 kg sample mass to calculate its specific latent heat of fusion. Use 10 800 J if needed. **[1 mark]**

Answer / mark points: $L = E / m = 10\,800 / 0.120 = 90\,000 \text{ J kg}^{-1}$. [1]

4(f) Energy continues to enter the sample during B–C, but its temperature stays constant. Explain what happens to internal energy, average particle kinetic energy and particle potential energy. **[3 marks]**

Answer / mark points: Internal energy increases as energy enters. [1]
 Average particle kinetic energy stays constant because temperature stays constant. [1]
 Particle potential energy increases as the arrangement changes and attractions are overcome during melting. [1]

Teacher prompt: Particles keep moving. Do not say energy is destroyed, particles stop, or bonds within individual molecules break.

4(g) During C–D the liquid warms from 20 °C to 40 °C. Its specific heat capacity is 1500 J kg⁻¹ °C⁻¹. Calculate the increase in its internal energy during C–D. **[1 mark]**

Answer / mark points: $\Delta E = mc\Delta\theta = 0.120 \times 1500 \times (40 - 20) = 3600 \text{ J}$. [1] This agrees with 30 W $\times$ 120 s.

4(h) Explain why $E = mL$ is appropriate for B–C but $\Delta E = mc\Delta\theta$ is appropriate for C–D. **[2 marks]**

Answer / mark points: B–C is a change of state at constant temperature, so use specific latent heat. [1]
 C–D has no change of state; energy raises the liquid's temperature, so use specific heat capacity. [1]



5 Will the pack protect the cartridges

For a journey, a pack contains 0.240 kg of solid material already at 20 °C. Energy enters the material at a constant rate of 0.60 W for 8.0 hours. While solid and liquid coexist, the material stays at 20 °C. The design passes only if some solid remains at arrival. Ignore energy absorbed by the container or cartridges.

5(a) Calculate the energy entering the material during the full 8.0-hour journey. **[2 marks]**

Answer / mark points: $t = 8.0 \times 3600 = 28\,800$ s. [1]

$E = Pt = 0.60 \times 28\,800 = 17\,280$ J. [1]

5(b) Calculate the mass that melts during the journey and then the mass of solid remaining. **[2 marks]**

Answer / mark points: Mass melted = $E / L = 17\,280 / 90\,000 = 0.192$ kg. [1]

Solid remaining = $0.240 - 0.192 = 0.048$ kg (48 g). [1]

5(c) Does the pack pass the design requirement? Justify your answer using the remaining solid and explain why the melting process is useful for the cartridges. **[2 marks]**

Answer / mark points: Yes: 0.048 kg of solid remains at arrival, so the pack has not finished melting. [1]

The material absorbs energy during melting without its temperature increasing, helping keep the cartridges near 20 °C. [1]

Teacher prompt: The finite energy capacity matters. A pack cannot absorb energy indefinitely at constant temperature once all the solid has melted.

5(d) For a longer journey, the team considers the same mass of another material with the same melting point but a larger specific latent heat of fusion. Explain the benefit, assuming the same energy input rate. **[2 marks]**

Answer / mark points: For the same mass, a larger L means more energy is required for complete melting, from $E = mL$. [1]

At the same input rate, melting therefore takes longer and the material can stay at its melting temperature for longer. [1]



6 Cooling the material and warming a gas

The team refreezes the pack for reuse. It also tests a separate rigid, sealed gas canister. The canister's volume and the amount of gas stay constant during warming.

6(a) During recharging, the liquid material freezes at 20 °C. Explain why its temperature can remain constant even though energy is being removed. **[2 marks]**

Answer / mark points: Energy removal decreases particle potential energy as the solid arrangement forms. [1]
Average particle kinetic energy, and therefore temperature, stays constant during the change of state. [1]

6(b) The gas canister is initially at room temperature. Describe the motion of its molecules. **[1 mark]**

Answer / mark points: The molecules move constantly and randomly in all directions. [1]

6(c) The sealed gas canister warms, with no change in volume. Explain why its pressure increases using molecular motion and collisions with the walls. **[3 marks]**

Answer / mark points: Higher temperature gives molecules greater average kinetic energy, so they move faster on average. [1]
They collide with the walls more frequently and each collision produces a larger average force contribution. [1]
The total force on the same wall area increases, so pressure increases. [1]

Teacher prompt: Accept larger force per collision or greater momentum change per collision, without requiring momentum vocabulary. Molecules do not grow or push continuously on a wall.

6(d) A trainee says that the pressure increases because the gas molecules grow larger when warmed. Correct this claim. **[1 mark]**

Answer / mark points: The molecules do not grow larger; their average kinetic energy and speed increase. [1]

6(e) A different container leaks and the balance reading decreases. Does this show that mass has been destroyed? Explain your answer. **[1 mark]**

Answer / mark points: No: gas particles have left the container and entered the surroundings; mass has not been destroyed. [1]

Review and improve

During melting, internal energy increases while temperature remains constant. Distinguish particle potential energy from average kinetic energy. Individual particles do not melt or expand. A sealed system conserves mass, and a cooling pack has a finite capacity to absorb energy during melting.

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