Exercise walk-through

3.4
Specific latent heat (4.3.2.3)

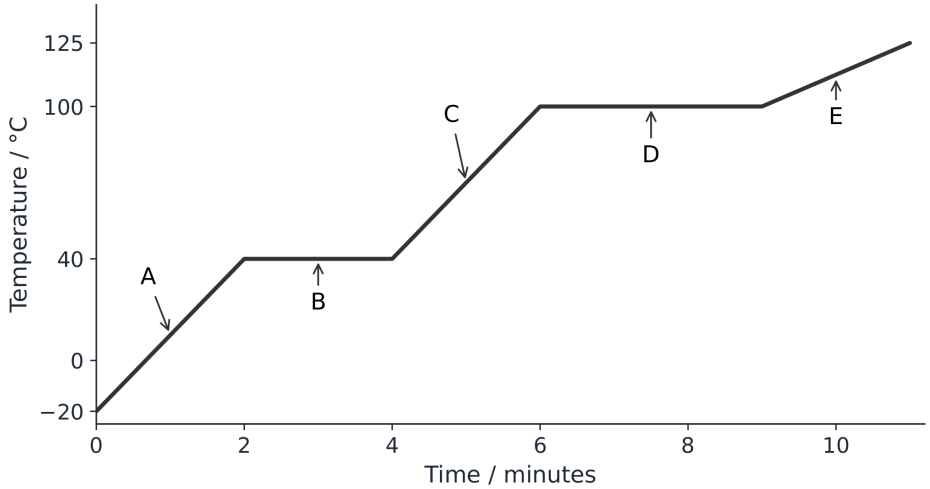
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Specific latent heat and heating graphs

- The **specific latent heat** of **fusion** is for changing from solid to liquid.
- The specific latent heat of **vaporisation** is for changing from liquid to vapour.
- on the sloping parts, its temperature rises and the particles gain kinetic energy ($\Delta E = mc\Delta\theta$);
- on the flat parts, it is changing state and the particles gain potential energy ($E = mL$).

$$E = mL$$

Figure: Specific latent heat and heating graphs



- A heating graph: the substance warms in sections A, C and E, melts in B and boils in D.
- Read the axes and units first.

Exercises 2.1·2.2

2.1 Ice at 0 °C has $L_f = 3.34 \times 10^5$ J/kg. Calculate the energy to melt 0.030 kg. [2]



2.2 A heater supplies 45 000 J and vaporises 0.020 kg of a liquid already at its boiling point. Calculate L. [2]



Exercises 2.1–2.2

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2.1

$$E = mL = 0.030 \times 3.34 \times 10^5 = \mathbf{1.0 \times 10^4}\ \text{J}$$

(substitution 1, answer with unit 1.)

2.2 A heater supplies 45 000 J and vaporises 0.020 kg of a liquid already at its boiling point. Calculate L. [2]



2.2

$$L = \frac{E}{m} = \frac{45\,000}{0.020} = \mathbf{2.25 \times 10^6}\ \text{J/kg}$$

(rearrangement 1, answer 1.)

Exercise 2.3

2.3 State the difference between specific heat capacity and specific latent heat. [2]

specific heat capacity

specific latent heat

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specific heat capacity | specific latent heat

2.3 Specific heat capacity is the energy to raise the temperature of one kilogram by one degree Celsius – a temperature **change**; specific latent heat is the energy to change the state of one kilogram with **no** temperature change.

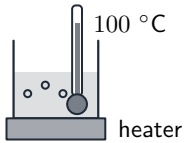
Exercise 3.1

3.1 A student boils water in an open beaker.

(a) The water's temperature stays at 100 °C while it boils. Explain why, using internal energy. [2]

(b) 0.030 kg of water turns to steam; $L_v = 2.26 \times 10^6$ J/kg. Calculate the energy needed for this change of state. [2]

(c) Some water evaporated before reaching 100 °C. Explain how this affects the student's value for the specific latent heat. [2]



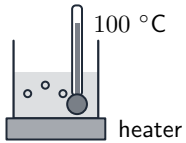
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3.1 (a) The supplied energy increases the particles' potential energy as they break free of the liquid; their average kinetic energy – and so the temperature – stays constant until all the water has boiled. (b)

$$E = mL_v = 0.030 \times 2.26 \times 10^6 = \mathbf{6.8 \times 10^4}\ \text{J}$$

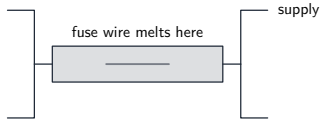
(c) If water already left by evaporation, less than 0.030 kg actually boiled at 100 °C for the measured energy; with the full 0.030 kg in the calculation, L comes out too **small**.

Exercise 3.2

3.2 A heater supplies 1.02 J while a fuse wire melts at its melting point. The specific latent heat of fusion of the wire is 60 kJ/kg.

(a) Assuming all supplied energy melts the wire, calculate its mass. [3]

(b) Energy is also transferred to the surroundings while the wire melts. Explain whether the true mass is larger or smaller than your answer. [2]



$E = 1.02$ J at melting point; $L_f = 60$ kJ/kg

3.3 A freezer freezes 1.5 kg of water at 0 °C in 50 minutes. Assume the net rate of energy removal is the same during freezing and subsequent cooling. $L_f = 3.34 \times 10^5$ J/kg.



(a) Calculate the energy the freezer removes from the water. [2]

(b) Calculate the freezer's power output to the water's thermal store. [3]

(c) The ice then cools from 0 °C to −18 °C; ice has $c = 2100$ J/kg °C. Calculate the energy removed in this stage. [2]

(d) Explain why the second stage is quicker than the first. [2]

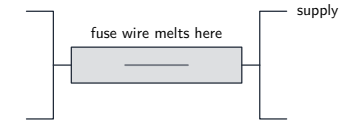
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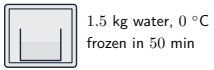
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3.2 (a) Convert: $L = 60$ kJ/kg $= 60\,000$ J/kg (C1).

$$m = \frac{E}{L} = \frac{1.02}{60\,000} = \mathbf{1.7 \times 10^{-5}}\ \text{kg}$$

(rearrangement C1, answer A1.) (b) Some of the 1.02 J input is transferred to the

Full solution on next slide

Full solution 3.2 (1/2)

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(rearrangement C1, answer A1.) (b) Some of the 1.02 J input is transferred to the surroundings, so less than 1.02 J melts the wire; with $m = E_{\text{melting}}/L$ and the same L, the true melted mass is **smaller** than the no-loss estimate.

3.3 (a)

$$E = mL_f = 1.5 \times 3.34 \times 10^5 = \mathbf{5.0 \times 10^5}\ \text{J}$$

Full solution 3.2 (2/2)

(b) Convert: 50 min = 3000 s (C1).

$$P = \frac{E}{t} = \frac{5.01 \times 10^5}{3000} = \mathbf{170}\ \text{W}\ (2\ \text{s.f.})$$

(C1, A1.) (c)

$$\Delta E = mc\Delta\theta = 1.5 \times 2100 \times 18 = \mathbf{56\,700}\ \text{J} \approx 5.7 \times 10^4\ \text{J}$$

(C1, A1.) (d) Cooling the ice needs only 5.7×10^4 J against 5.0×10^5 J for freezing – about a ninth of the energy; freezing releases energy as the particle arrangement changes and potential energy decreases; cooling the solid lowers average kinetic energy.