LESSON 5.1.1

Specific Heat Capacity and Specific Latent Heat

Energy transfer can change temperature or change state. Choose the equation by asking what happens to the substance, not just whether a heater is switched on.

1. TEMPERATURE CHANGES, WITH NO CHANGE OF STATE

$$\Delta E = mc\Delta\theta$$

Specific heat capacity c is the energy required per kilogram for a temperature rise of 1 K, without a change of state. Here m is the mass heated and Δθ is the temperature change.

Unit of c: J kg^{-1} K^{-1}

A rise of 1 °C equals a rise of 1 K. Use the change, not the final temperature.

2. STATE CHANGES AT CONSTANT TEMPERATURE

$$\Delta E = L\Delta m$$

Specific latent heat L is the energy required per kilogram to change state without changing temperature. Δm is the mass that changes state, not necessarily all the mass present.

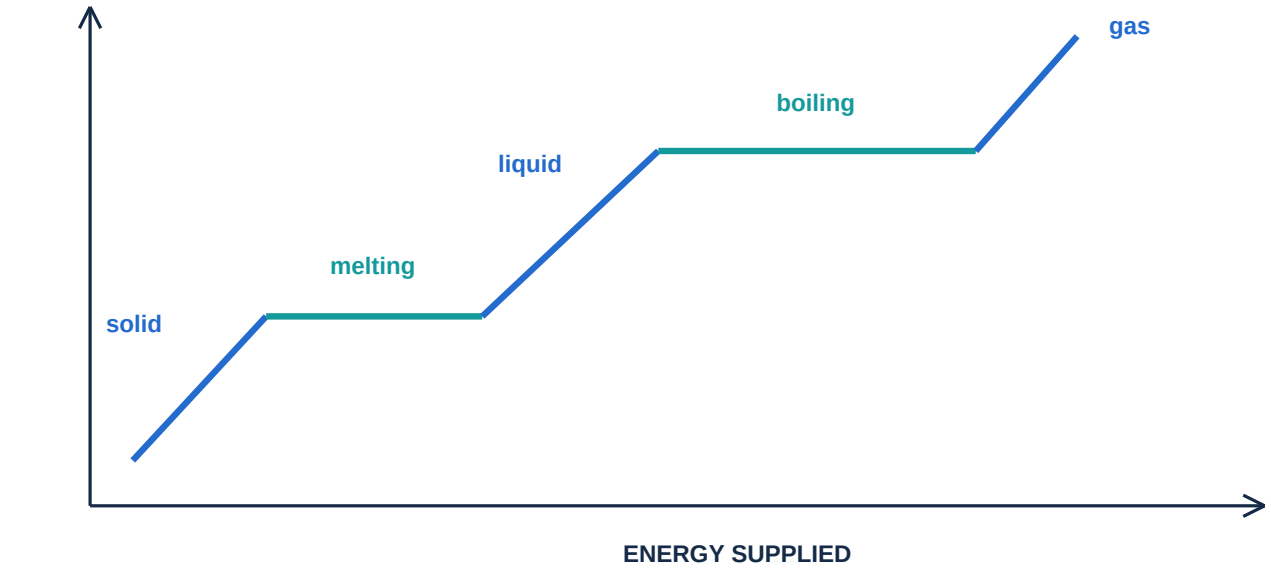
Unit of L: J kg^{-1}

Fusion: solid ↔ liquid. Vaporisation: liquid ↔ gas.

Melting and vaporisation absorb energy; freezing and condensation release it. The positive values c and L describe the material under the stated conditions.

1 Read a heating curve

Idealised pure substance at constant pressure; horizontal distance represents energy supplied to the sample.



Schematic: phase widths and slopes are not to scale.

SLOPING SECTIONS

For fixed mass and constant c, temperature rise per joule is 1/(mc). A larger c gives a gentler slope.

FLAT SECTIONS

Energy changes the particle arrangement, not the temperature. A plateau is not evidence of zero energy transfer.

WORKED EXAMPLE: MELT ICE, THEN WARM THE WATER

Convert 0.100 kg of ice at 0 °C to water at 20.0 °C. Use L = 334 000 J/kg and c = 4200 J/(kg K). Ignore energy losses and the container.

$$E_{melt} = (0.100)(334\,000) = 33\,400 \text{ J}$$

$$E_{warm} = (0.100)(4200)(20.0) = 8400 \text{ J}$$

$$E_{total} = 41\,800 \text{ J} = 41.8 \text{ kJ}$$

With a 200 W heater transferring all its energy to the sample, t = E/P = 209 s. If ice starts below 0 °C, first add a separate mcΔθ term using the heat capacity of ice.

2 Measure the energy transfer

Electrical input is E = VIt for steady voltage and current. Only the energy reaching the sample belongs in the thermal equation.

A. SPECIFIC HEAT CAPACITY: ELECTRICAL HEATING

Measure the mass of an insulated metal block. Fit a heater and thermometer with good thermal contact. Record V, I and the temperature rise during a measured time; allow for temperature lag.

$$c \approx \frac{VIt}{m\Delta\theta}$$

$$c = \frac{7200}{0.500 \times 16.0} = 900 \text{ J kg}^{-1} \text{ K}^{-1}$$

Here V = 12.0 V, I = 2.00 A and t = 300 s. Losses are neglected.

B. CORE PRACTICAL 13: SPECIFIC LATENT HEAT

One fusion method uses crushed ice already melting at 0 °C. Put a low-voltage heater in the ice and collect the meltwater. Use an equivalent unheated control to estimate melting caused by the surroundings.

After steady melting is established, collect both samples for the same time. Subtract the control mass from the heated mass; this estimates the mass melted by the heater alone.

$$L \approx \frac{VIt}{\Delta m_{heated} - \Delta m_{control}}$$

Example: 10.0 W for 300 s; collected masses 0.0140 kg and 0.0050 kg.

$$L = \frac{3000}{0.0090} = 3.33 \times 10^5 \text{ J kg}^{-1}$$

Check the assumptions: insulate the sample, use stable conditions and repeat readings. Uncorrected heat loss makes the simple c estimate too high. Ignoring background melting makes the ice-method L estimate too low.

Safety: use a supervised low-voltage supply; keep connections dry. Switch off before a heater becomes uncovered, and handle hot apparatus carefully.

Sources: Pearson IAL Physics, Unit 5 p. 33 (125, 127); Practical Guide, CP13.

Course lesson numbering. Worked values are illustrative; apparatus losses need evaluation.