A LEVEL PHYSICS 9702 · A LEVEL · TOPIC 14 · ~5 MIN READ

Temperature

Thermal equilibrium and the direction of energy flow, the thermodynamic (kelvin) scale and absolute zero, specific heat capacity and specific latent heat, and the electrical and mixture methods for measuring them.

Thermal equilibrium | Thermodynamic scale | Absolute zero | Kelvin & Celsius | Specific heat capacity | Specific latent heat | Electrical method | Heat losses

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Paper tag = **where it is examined** DATA & FORMULAE given in the exam C1 A1 B1 how marks are awarded

highlight = comes up again and again Test yourself at the end

IN 30 SECONDS

- **Energy flows from a region of higher temperature to lower temperature.** Objects at the same temperature are in thermal equilibrium: no net energy flow.
- **The thermodynamic scale** doesn't depend on any substance. Absolute zero (0 K) is the temperature at which a substance has minimum internal energy. T/K = θ/°C + 273.15.
- **Specific heat capacity c:** the energy to raise the temperature of 1 kg by 1 K. E = mcΔθ.
- **Specific latent heat L:** the energy to change the state of 1 kg without a change of temperature. E = mL.

BY THE END YOU CAN

- Understand thermal equilibrium and that energy flows from higher to lower temperature.
- Use the thermodynamic scale and convert between kelvin and degrees Celsius.
- Define and use specific heat capacity and specific latent heat of fusion and of vaporisation.
- Describe experiments to measure c and L, including how to reduce heat losses.

1 Temperature scales

Thermal equilibrium and kelvin

Thermal equilibrium — two objects are in thermal equilibrium when there is no net transfer of energy between them, i.e. they are at the same temperature.

Absolute zero — the temperature at which a substance has minimum internal energy (0 K).

- **Converting:** T/K = θ/°C + 273.15. A temperature **change** of 1 K equals a change of 1 °C.
- **Why a thermodynamic scale?** Scales based on a property (resistance, length of mercury) only agree at their fixed points; the thermodynamic scale doesn't depend on any particular substance.

COMMON MISTAKE

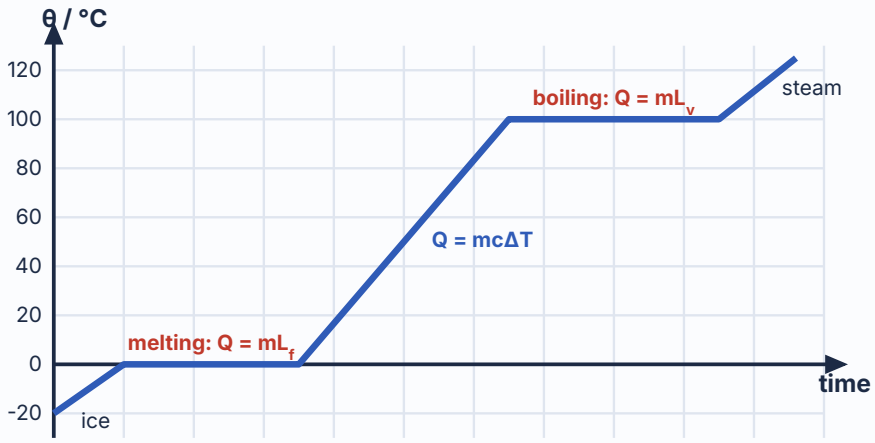
Using °C in gas or radiation formulas. $pV = nRT$ and $L = 4\pi\sigma r^2T^4$ need kelvin.

2 Heat capacity and latent heat

Definitions

Specific heat capacity — the energy required per unit mass to raise the temperature by one degree: $c = E/(m\Delta\theta)$.

Specific latent heat — the energy required per unit mass to change the state of a substance without any change in temperature: $L = E/m$. (Of fusion: solid ↔ liquid; of vaporisation: liquid ↔ gas.)



Flat parts: energy goes into breaking bonds, so temperature is constant.

Flat sections: energy goes into breaking bonds (potential energy), not into raising the temperature.

- **L_v is much larger than L_f** for the same substance: vaporising separates molecules completely, and the gas does work pushing back the atmosphere.

WORKED EXAMPLE

A 50 W heater warms a 1.2 kg aluminium block from 20.0 °C to 33.5 °C in 300 s. Find c, and say how heat loss affects your value.

1. E = Pt = 50 × 300 = 15 000 J C1
2. c = E/(mΔθ) = 15 000/(1.2 × 13.5) = **930 J kg^{-1} K^{-1}** A1
3. **heat lost to the surroundings means Δθ is too small, so the value is too high** B1

WORKED EXAMPLE

A 2.0 kW kettle boils off 0.12 kg of water in 150 s once it is boiling. Estimate the specific latent heat of vaporisation.

1. E = 2000 × 150 = 3.0 × 10^5 J C1
2. **L = E/m = 2.5 × 10^6 J kg^{-1}** A1

WORKED EXAMPLE

Find the mass of ice at 0 °C that 2.0 kg of water at 30 °C can melt, cooling to 0 °C. (c = 4200 J kg^{-1} K^{-1}, L_f = 3.34 × 10^5 J kg^{-1})

1. energy released by water = 2.0 × 4200 × 30 = 2.52 × 10^5 J C1
2. **m = 2.52 × 10^5/3.34 × 10^5 = 0.75 kg** A1

- **Reducing heat loss:** insulate the block, use a lid, start below room temperature and finish the same amount above it. **The two-power method** (two heater powers, same flow rate or same temperature) cancels the heat loss term.

COMMON MISTAKE

"Heat" for temperature, or "temperature is the energy". Temperature tells you the direction of energy flow; internal energy is in Thermodynamics.

LINKING QUESTION

Gases and the kelvin scale continue in Ideal gases; internal energy is in Thermodynamics; and IGCSE thermal physics is in the IGCSE Physics notes.

Test yourself — cover the answers first

QUICK CHECK

1. Convert 27 °C to kelvin.
2. What is absolute zero?
3. Define specific latent heat.
4. Why does temperature stay constant while ice melts?
5. Does heat loss make a measured c too high or too low?

EXAM-STYLE

6. 0.50 kg of water at 80 °C is mixed with 0.30 kg at 20 °C. Find the final temperature (no losses).
7. A 120 W heater melts 0.040 kg of ice in 2.0 min; with the heater off, 0.004 kg melts in the same time. Find L_f.
8. Explain why the thermodynamic scale is called "absolute".

Show answers

1. 300 K
2. the temperature of minimum internal energy, 0 K
3. the energy per unit mass to change state without a change of temperature
4. energy breaks bonds (raises potential energy), not kinetic energy
5. too high
6. $0.50(80 - \theta) = 0.30(\theta - 20) \Rightarrow \theta = 57.5\ °C$
7. $120 \times 120 = (0.040 - 0.004)L \Rightarrow L = 4.0 \times 10^5\ J\ kg^{-1}$
8. it doesn't depend on the property of any substance, and its zero is absolute zero

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