Temperature

Thermal equilibrium, thermometric properties, the thermodynamic scale and absolute zero, converting kelvin and Celsius, specific heat capacity, and specific latent heat of fusion and vaporisation.

14.1 Thermal equilibrium

Thermal energy is transferred from a region of **higher temperature** to a region of **lower temperature**. Regions at the same temperature are in **thermal equilibrium**: there is no net transfer of thermal energy between them.

14.2 Temperature scales

Thermometric properties

Any physical property that varies with temperature can be used to measure temperature. Examples are:

- the density of a liquid (a liquid-in-glass thermometer works by expansion),
- the volume of a gas at constant pressure,
- the resistance of a metal,
- the e.m.f. of a thermocouple.

These properties do not all change at a steady rate with temperature, so two thermometers may disagree between their calibration points.

The thermodynamic scale

The **thermodynamic temperature scale** does not depend on the property of any particular substance. Its unit is the kelvin.

The lowest possible temperature is **absolute zero**, 0 K. At absolute zero, a substance has its minimum possible internal energy.

$$T/\mathrm{K} = \theta/^{\circ}\mathrm{C} + 273.15$$

A **change** of 1 K equals a change of 1 °C. So a temperature difference has the same number in both units, and only absolute temperatures must be converted.

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14.3 Specific heat capacity and specific latent heat

Specific heat capacity

The **specific heat capacity** c of a substance is the energy needed per unit mass per unit temperature rise, with no change of state.

$$Q = mc\Delta\theta$$

The unit is J kg^{-1} K^{-1}. Water has $c \approx 4200$ J kg^{-1} K^{-1}.

> **TRY IT**
>
> **How much energy is needed to heat 0.50 kg of water from 20 °C to 100 °C?** $Q = 0.50 \times 4200 \times 80 = 1.7 \times 10^5$ J.

Measuring specific heat capacity

Heat a block of known mass with an electrical heater, measuring the current, p.d. and time. Then the energy input is VIt, and $c = VIt/(m\Delta\theta)$. Insulate the block to reduce heat loss, which otherwise makes c come out too high. A graph of temperature against time gives the rise over the straight part.

Specific latent heat

The **specific latent heat** L is the energy needed per unit mass to change the state of a substance, with no change of temperature.

$$Q = mL$$

- **Fusion** is melting, from solid to liquid. For ice, $L_f \approx 3.3 \times 10^5$ J/kg.
- **Vaporisation** is boiling, from liquid to gas. For water, $L_v \approx 2.3 \times 10^6$ J/kg.

Vaporisation needs much more energy than fusion, for two reasons. The molecules must be separated completely, which is a much larger increase in potential energy than melting gives. Work must also be done pushing back the atmosphere as the volume expands.

During a change of state, the energy goes into increasing the potential energy of the molecules, and the mean kinetic energy stays constant. So the temperature does not change.

> **TRY IT**

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How much energy turns 0.20 kg of ice at 0 °C into water at 20 °C? Melting: $0.20 \times 3.3 \times 10^5 = 66$ kJ. Warming: $0.20 \times 4200 \times 20 = 17$ kJ. Total: 83 kJ.

NOTE

Exam tip: on a heating curve, the flat sections are where the state changes. For a constant power P, the steeper the slope, the smaller mc is. The ratio of the lengths of the flat sections gives the ratio of the latent heats.

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