

Temperature

A-Level Physics 9702 · Topic 14 revision notes · A2

Thermal equilibrium, the thermodynamic (kelvin) scale, practical thermometers, and the energy needed to heat a substance or change its state.

9 definitions to learn word for word, 7 equations in their own column, 8 diagrams and graphs. Read it, cover it, test yourself.

1. 14.1 Thermal equilibrium
2. 14.2 Temperature scales
3. 14.3a Specific heat capacity
4. 14.3b Specific latent heat

Definitions (mark-scheme wording) Equations Exam traps

14.1 Thermal equilibrium

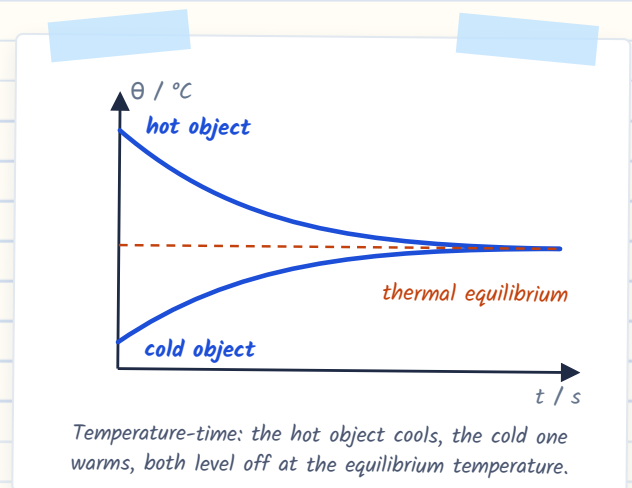
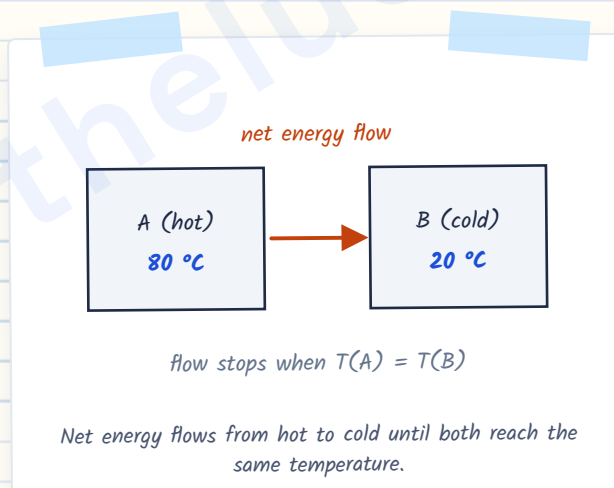
Definitions

Thermal equilibrium: the state in which two regions are at the same temperature, so there is no net transfer of thermal energy between them.

Temperature: a measure of the average random kinetic energy of the particles; it determines the direction of net thermal energy transfer.

Key points

- ✓ Net thermal energy flows from a region of **higher temperature** to a region of **lower temperature**.
- ✓ Energy still passes both ways at equilibrium; the **net** transfer is zero.
- ✓ Temperature, not energy stored, sets the direction of flow: a hot spark is hotter than a warm bath.
- ✓ Two objects each in equilibrium with a third are in equilibrium with each other: the basis of a **thermometer**.



Watch out!

- ! Equal **temperature** means equilibrium, not equal internal energy: a bath and a cup at 40 °C are in equilibrium.
- ! At equilibrium energy transfer has not stopped; the **net** transfer is zero.

14.2 Temperature scales

Definitions

Thermodynamic (kelvin) scale: a temperature scale that does not depend on the property of any particular substance.

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

Kelvin: the SI unit of thermodynamic temperature; a temperature change of 1 K equals a change of 1 °C.

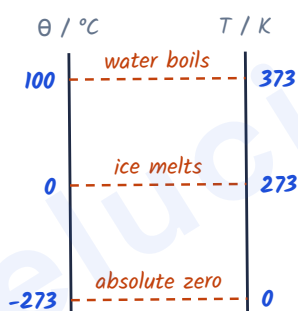
Equations

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

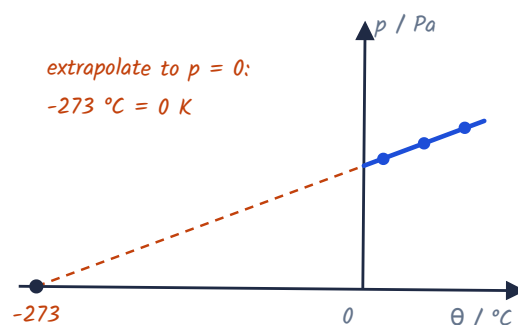
kelvin from Celsius (273 is usually enough)
K

Key points

- ✓ Any **physical property that varies with temperature** can be used to measure it.
- ✓ Examples: **density of a liquid, volume of a gas at constant pressure, resistance of a metal, e.m.f. of a thermocouple.**
- ✓ Scales based on different properties agree only at the calibration points, since the properties do not vary linearly.
- ✓ The kelvin scale is **absolute**: no substance-dependent calibration; its zero is absolute zero.
- ✓ Gas thermometer: p against θ extrapolates to $p = 0$ at **$-273.15\text{ }^\circ\text{C} = 0\text{ K}$** .
- ✓ A **temperature difference** has the same numerical value in K and $^\circ\text{C}$.



Celsius and kelvin scales: the same size of degree, zero shifted by 273.



Constant-volume gas thermometer: extrapolating p to zero locates absolute zero at $-273\text{ }^\circ\text{C}$.

Watch out!

- ! Every gas-law and kinetic-theory formula needs **kelvin**; never substitute $^\circ\text{C}$ for T .
- ! Absolute zero is minimum internal energy, not "all motion stops" in the mark scheme wording.

14.3a Specific heat capacity

Definitions

Specific heat capacity (c): the energy required per unit mass to raise the temperature by one kelvin (or one degree Celsius).

Heat capacity: the energy required to raise the temperature of an object by one kelvin.

Key points

- ✓ Electrical method: heater of known power in a **lagged** block (or liquid); measure V , I , t and the temperature rise.
- ✓ Energy supplied = VIt (or read a joulemeter); then $c = VIt / m\Delta\theta$.
- ✓ Plot θ against t : **gradient** = P / mc , so $c = P / (m \times \text{gradient})$.
- ✓ Heat loss to the surroundings makes the measured c **too large**; lag, and start below room temperature and end the same amount above.
- ✓ Continuous-flow method: repeat at two flow rates with the same $\Delta\theta$ to cancel the heat loss.
- ✓ Water has a **high c** ($4200 \text{ J kg}^{-1} \text{ K}^{-1}$): it heats and cools slowly.

Equations

$$E = mc\Delta\theta$$

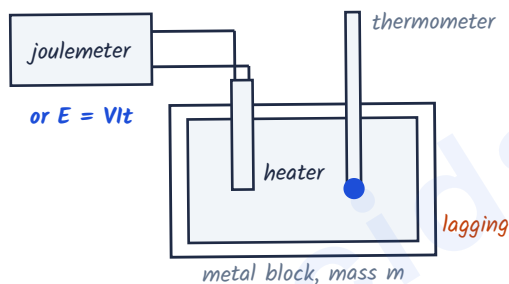
energy to change temperature
J

$$E = VIt$$

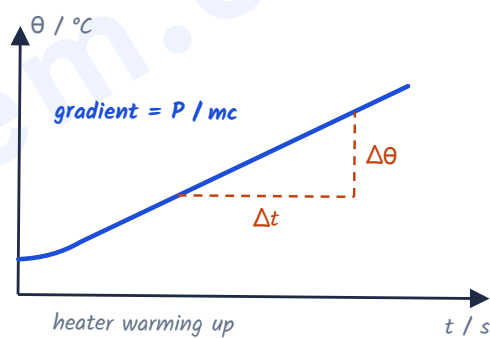
electrical energy supplied by the heater
J

$$c = P / (m \times \text{gradient})$$

from the θ - t graph, gradient = $d\theta/dt$
 $\text{J kg}^{-1} \text{ K}^{-1}$



Electrical method: a heater and thermometer in a lagged metal block; energy from a joulemeter (or V , I and t).



θ - t graph for a constant heater power: the steady gradient gives c .

Watch out!

- ! Use the **temperature change** $\Delta\theta$, not the final temperature.
- ! Heat losses make the **energy supplied** larger than the energy gained, so c comes out too high, not too low.

14.36 Specific latent heat

Definitions

Specific latent heat of fusion: the energy required per unit mass to change a substance from solid to liquid without a change of temperature.

Specific latent heat of vaporisation: the energy required per unit mass to change a substance from liquid to gas without a change of temperature.

Equations

$$E = mL$$

energy to change state at constant temperature

J

$$L = P\Delta t / \Delta m$$

heater power $\times$ time / mass changed

J kg⁻¹

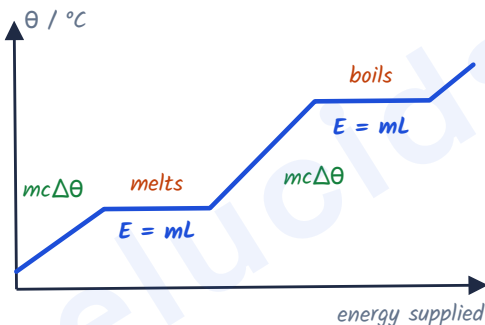
$$(P_1 - P_2)t = (m_1 - m_2)L$$

two-power method: heat loss cancels

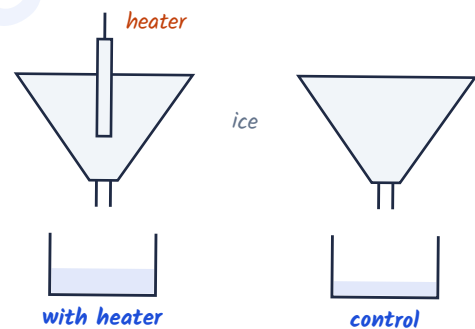
J

Key points

- ✓ During a change of state the temperature is **constant**: energy increases the **potential energy** of the molecules, not their kinetic energy.
- ✓ L_v is much larger than L_f : molecules must be **completely separated** and the gas must do work pushing back the atmosphere.
- ✓ Measuring L_v : boil liquid with a heater of power P on a balance; $L = P\Delta t / \Delta m$.
- ✓ Measuring L_f : heater in a funnel of ice, collect melt water; a **control** funnel with no heater corrects for melting by the room.
- ✓ Repeat at two powers and subtract to cancel heat losses: $(P_1 - P_2)t = (m_1 - m_2)L$.



Heating curve at constant power: sloping parts use $mc\Delta\theta$; flat plateaus (state changes) use mL .



Measuring L_f : the control funnel measures ice melted by the room alone.

Watch out!

- ! On a plateau energy is supplied but the **temperature does not rise**: use $E = mL$, never $mc\Delta\theta$.
- ! Subtract the control mass before calculating L_f .