IGCSE PHYSICS • EXERCISE SHEET

2.2 Thermal properties and temperature

Name: ____________ Class: ________ Date: __________ **Total: 26 marks**

KEY WORDS specific heat capacity 比热容 • evaporation 蒸发 • thermal expansion 热膨胀 • thermal properties 热学
• boiling 沸腾 • specific heat capacity 比热容 • evaporation 蒸发 • thermal expansion 热膨胀 • thermal properties 热学
• melting 熔化

Objective

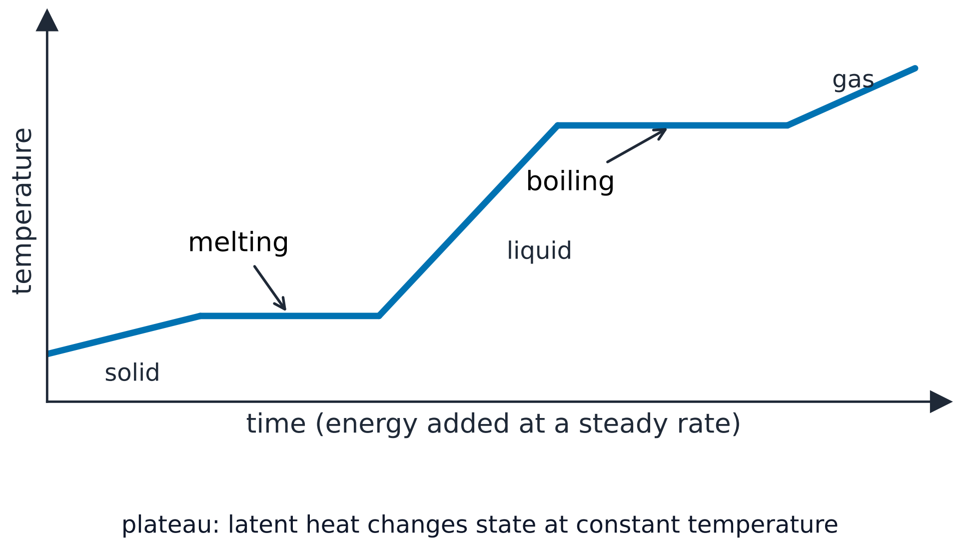
Build the skills to answer exam questions on **thermal properties** 热学性质 — the kelvin scale, **thermal expansion** 热膨胀, **specific heat capacity** 比热容, and melting/boiling/evaporation.

You must be able to:

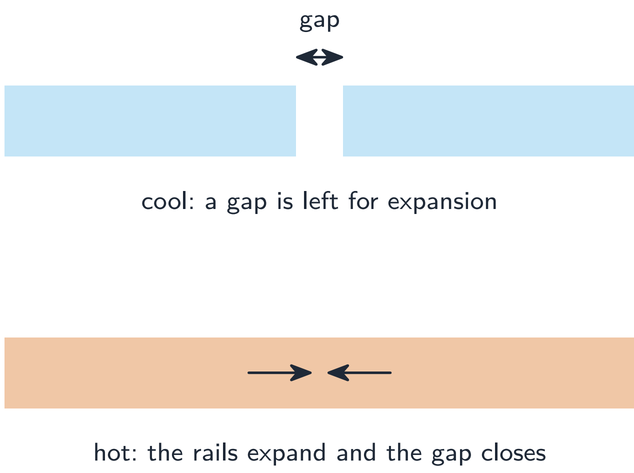
- convert between °C and kelvin ($T = \theta + 273$)
- use $\Delta E = mc\,\Delta\theta$
- describe state changes and explain cooling by evaporation

1 Worked examples

Specific heat capacity



During melting and boiling the temperature stays flat while energy is still added



Solids expand on heating — a gap is left so the track does not buckle

Heat 2.0 kg water by 50 °C ($c = 4200$): $\Delta E = mc\Delta\theta = 2.0 \times 4200 \times 50 = 420\,000$ J.

The state changes, and measuring c

Condensation 凝结 is a gas becoming a liquid: the particles slow down, come close together and the attractions hold them. **Solidification** 凝固 is a liquid becoming a solid: the particles lose more energy and settle into fixed positions in a lattice. During melting and boiling the temperature does not change, because the energy goes into breaking the forces between particles rather than into speeding them up.

Thermal expansion. Heated particles vibrate or move more and take up more space. Gases expand most, then liquids, then solids, because the forces between particles are weakest in a gas and strongest in a solid. Everyday consequences: gaps between railway rails, rollers under a bridge, a tight metal lid freed by hot water, and a liquid-in-glass thermometer working at all.

Measuring specific heat capacity. Use a metal block with two holes, one for an electric heater and one for a thermometer. Measure the mass m; switch the heater on for a measured time t, recording I and V, so the energy supplied is $E = IVt$; record the temperature rise $\Delta\theta$ and use $c = \dfrac{E}{m\,\Delta\theta}$. For a liquid, heat a known mass in a container and stir it. Insulate the block or container, because energy escaping to the air makes the value of c come out too large.

Worked example. A 2.0 kg block is heated by a 50 W heater for 5.0 minutes and rises from 7.0 °C to 22.0 °C. Energy supplied $= Pt = 50 \times 300 = 15\,000$ J; $\Delta\theta = 15.0$ °C; $c = \dfrac{15\,000}{2.0 \times 15.0} = 500$ J/(kg °C).

2 Practice

2.1 Convert 25 °C to kelvin. [1]

2.2 State why a liquid cools as it evaporates. [1]

2.3 Describe condensation and solidification in terms of particles. [2]

2.4 Explain why a gas expands more than a solid for the same temperature rise. [2]

2.5 State two everyday consequences of thermal expansion. [2]

3 Exam-style questions

3.1 While a pure solid is melting, its temperature: [1]

- **A** rises steadily
- **B** stays constant
- **C** falls
- **D** rises then falls

3.2 A 0.50 kg metal block is given 9000 J of energy and its temperature rises by 40 °C.

(a) Find the specific heat capacity of the metal. [3]

(b) State one reason the actual value might be higher than calculated. [1]

3.3 Explain, using the particle model, why evaporation cools the remaining liquid. [2]

3.3 A student measures the specific heat capacity of sand. She puts 0.80 kg of dry sand in an insulated pot with an electric heater and a thermometer.

(a) Describe the measurements she must take. [3]

(b) The 50 W heater runs for 4.0 minutes and the temperature rises from 7.0 °C to 22.0 °C. Calculate the energy supplied. [2]

(c) Calculate the specific heat capacity of the sand. [3]

(d) Her value is larger than the true value. Explain why, and state one improvement. [2]

(e) The heater is left on and the temperature of the sand stops rising. Explain why. [1]

Solutions

2.1 $25 + 273 = 298$ K.

2.2 the fastest particles escape, lowering the average energy of those left.

3.1 **B**. The temperature stays constant during a change of state.

3.2 (a) $c = \dfrac{\Delta E}{m\,\Delta\theta} = \dfrac{9000}{0.50 \times 40}$; $= 450$ J/(kg °C).
(b) some energy is lost to the surroundings, so more than 9000 J was really needed.

3.3 the most energetic particles leave the surface; so the average kinetic energy — and the temperature — of the remaining particles falls.

2.3 Condensation: the gas particles slow down and come close enough for the attractions between them to hold them as a liquid. Solidification: the liquid particles lose more energy and settle into fixed positions in a regular pattern.

2.4 The forces between gas particles are very weak, so they are free to spread much further apart; in a solid strong forces hold the particles in a lattice, so they only vibrate a little more.

2.5 Any two of: gaps left between railway rails; a bridge resting on rollers; a tight metal lid loosened in hot water; the liquid rising in a thermometer.

3.3 (a) The mass of the sand; the temperature before and after heating, giving the rise; the time the heater is on together with its power, or the current and voltage, giving the energy.
(b) $E = Pt = 50 \times (4.0 \times 60) = 12\,000$ J.
(c) $\Delta\theta = 22.0 - 7.0 = 15.0$ °C; $c = \dfrac{E}{m\,\Delta\theta} = \dfrac{12\,000}{0.80 \times 15.0} = 1000$ J/(kg °C).
(d) Some supplied energy escapes to the surroundings instead of heating the sand, so the calculated c is too large; add more insulation, or a lid.
(e) The sand is losing energy to the surroundings as fast as the heater supplies it, so there is no net gain.