InkPhysics

ANSWER BOOK

Thermal energy transfer and specific heat capacity

Thermal physics · Year 13

AQA 3.6.2.1 · CIE 14.1.1, 14.1.2, 14.3.1, 14.3.2, 16.1.1, 16.1.2, 16.2.2
OCR A 5.1.1(a), 5.1.2(a), 5.1.2(b), 5.1.2(d), 5.1.2(f), 5.1.2(g), 5.1.3(a), 5.1.3(b)(i), 5.1.3(c), 5.1.3(d)(i)

20 questions · 64 marks

NAVY EDITION

SECTION A · Warm-up

A1 The internal energy is the sum of the kinetic and potential energies of all the particles in the substance (1). These energies are randomly distributed (1). [2]

A2 $Q = mc\Delta\theta = 0.50 \times 4200 \times 20$ (1) [2]
$Q = 42000$ J (1)

A3 The supplied energy goes into breaking the bonds between particles, increasing their potential energy, not into increasing their kinetic energy (1). Since temperature depends on average kinetic energy, it stays constant until the change of state is complete (1). [2]

A4 They are at the same temperature, so there is no net transfer of energy between them (1). [1]

A5 $\Delta U = q + w$ (1) [2]
$\Delta U = 250 + 90 = 340$ J (1)

A6 $\Delta\theta = 43 - 18 = 25$ K (1). A temperature difference has the same numerical value in °C and K, because the two scales have intervals of equal size and differ only in the position of their zero (1). [2]

SECTION B · Standard

B1 $\Delta\theta = 70 - 20 = 50$ K (1) [3]
$Q = mc\Delta\theta = 2.0 \times 900 \times 50$ (1)
$Q = 90000$ J (1)

B2 $Q = ml = 0.30 \times 3.34 \times 10^5$ (1) [4]
$Q = 1.002 \times 10^5$ J (1)
The energy goes into breaking bonds between molecules, raising their potential energy (1)
It does not raise their kinetic energy, so the temperature stays constant (1)

B3 $c = Q/(m\Delta\theta)$ (1) [3]
$c = 5000/(0.20 \times 25)$ (1)
$c = 1000$ J kg^{-1} K^{-1} (1)

B4 $Q = mc\Delta\theta = 1.5 \times 4200 \times 30 = 189000$ J (1) [3]
$t = Q/P = 189000/2000$ (1)
$t = 94.5$ s (1)

B5 Each second 8.0 g = 0.0080 kg of water flows through (1) [3]
Energy gained by the water each second = $mc\Delta\theta = 0.0080 \times 4200 \times 40.0 = 1344$ W (1)
Rate of loss = 1500 - 1344 = 156 W (1)

B6 $Q = mc\Delta\theta = 0.90 \times 4200 \times 85 = 321300$ J (1) [3]
$t = Q/P = 321300/750$ (1)
$t = 428$ s = 7.1 min, which is about 7 minutes (1)

B7 $Q = mc\Delta\theta$ (1) [4]
$Q = 140 \times 4200 \times 43 = 2.53 \times 10^7$ J (1)
$E = 2.53 \times 10^7/(3.6 \times 10^6) = 7.02$ kWh (1)
Cost = 7.02 × 28p = 197p ≈ £1.97 (1)

SECTION C · Stretch

C1 Melting: $Q = ml = 0.20 \times 3.34 \times 10^5$ (1) [4]
$Q = 66800$ J (1)
Warming: $Q = mc\Delta\theta = 0.20 \times 4200 \times 20 = 16800$ J (1)
Total = 83600 J (1)

C2 Energy lost by the hot water = energy gained by the cold water (1) [4]
$0.10 \times c \times (80 - T) = 0.20 \times c \times (T - 20)$ (1)
The c cancels (1)
$T = 40$°C (1)

C3 Heating transfers energy because of a temperature difference, from a hotter body to a cooler one (1). Doing work transfers energy mechanically, for example by compressing the gas with a piston (1). Both raise the internal energy, but by different means (1). [3]

C4 Mass needed $m = Q/(c\Delta\theta)$: W needs 30.7 kg, X needs 60.0 kg, Y needs 29.0 kg (1) [5]
Volume = m/ρ: W 0.0133 m³, X 0.0083 m³, Y 0.0057 m³ (1)
W is larger than the 0.0090 m³ casing, so it is rejected (1)
Cost: X = 60.0 × 60p = £36, Y = 29.0 × 90p = £26 (1)
Both X and Y fit, and Y is cheaper, so the manufacturer should choose Y (1)

C5 $Q = ml = 0.50 \times 2.26 \times 10^6 = 1.13 \times 10^6$ J (1) [3]
$t = Q/P = 1.13 \times 10^6/2400$ (1)
$t = 471$ s = 7.8 min, which is about 8 minutes (1)

C6 The graph shows a rising section for the ice, a plateau at 0°C, a rising section for the water and a second plateau at 100°C (1). During the rising sections the energy supplied increases the average kinetic energy of the molecules, and temperature measures this kinetic energy (1). During the plateaus the energy supplied increases the potential energy of the molecules as intermolecular bonds are broken, so the kinetic energy and the temperature are unchanged (1). The two rising sections have different gradients because ice and water have different specific heat capacities; the smaller c of ice gives the steeper line for the same power (1). The plateau at 100°C is much longer than the plateau at 0°C because the specific latent heat of vaporisation is much larger than the specific latent heat of fusion (1). Because the power is constant, the time spent on each section of the graph is proportional to the energy that stage needs (1). [6]

C7 Each run gives $P = mc\Delta\theta + h$, with m the mass passing per second and h the rate of energy loss: $1290 = 0.0120c\Delta\theta + h$ and $870 = 0.0080c\Delta\theta + h$ (1) [5]
The inlet and outlet temperatures are the same in both runs, so h is the same and subtracting eliminates it: $P_1 - P_2 = (m_1 - m_2)c\Delta\theta$ (1)
$c = (1290 - 870)/((0.0120 - 0.0080) \times 25.0)$ (1)
$c = 4200$ J kg^{-1} K^{-1} (1)
$h = 1290 - 0.0120 \times 4200 \times 25.0 = 30$ W; a single run has both c and h unknown, so one run cannot give either (1)