Unit 11 · Quantity of Heat

ANSWER KEY · FOR TEACHERS

Full marks 32

Give the marks for the points in the marking scheme; an answer in other words that says the same is right.

1 Key words

1. heat capacity → **e.** the heat needed to raise a whole body's temperature by 1 K
2. specific heat capacity → **a.** the heat needed to raise 1 kg of a substance by 1 K
3. calorimetry → **g.** the measurement of quantities of heat
4. latent heat → **c.** heat that changes the phase without changing the temperature
5. evaporation → **i.** the change from liquid to vapour at the surface, at any temperature
6. regelation → **b.** melting under pressure and freezing again when the pressure is removed
7. triple point → **f.** the one temperature and pressure at which ice, water and vapour exist together
8. melting point → **d.** the steady temperature at which a solid turns into a liquid

K · 4

Each carries 0.5 mark.

2 Label the diagram

1. stirrer
2. cotton or wool
3. copper calorimeter
4. wooden box

K · 2

Each carries 0.5 mark.

3 Multiple choice

i. **b.** J/(kg K) — K · 1

$s = Q/(m\Delta\theta)$, so J/(kg K). J/K is the unit of heat capacity, J/kg of latent heat.

ii. **c.** 940 J/K — A · 1

Heat capacity = $ms = 2.0 \times 470 = 940$ J/K.

iii. **b.** increases the potential energy of its molecules, not their kinetic energy — U · 1

Latent heat pulls the molecules apart against their attraction: their potential energy rises, while the temperature (their average kinetic energy) stays at 0 °C.

iv. **b.** the higher pressure raises the boiling point of water — U · 1

At higher pressure water boils above 100 °C (about 120 °C in a cooker), so the food is cooked in hotter water.

v. **c.** it happens at any temperature, from the surface only — U · 1

Evaporation takes place at any temperature, from the surface; boiling throughout the liquid at the boiling point. Both need latent heat.

4 Short answers

a. MARKING SCHEME — U · 2

- ✓ Water's specific heat capacity is high.
- ✓ So it takes or gives much heat for a small change of temperature (carries heat away; cools slowly).

b. MARKING SCHEME — U · 2

- ✓ Water seeps through the clay and evaporates from its surface.
- ✓ Evaporation takes latent heat from the pot and the water, cooling them.

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c. MARKING SCHEME A · 3

- ✓ Heat for the water, 672 000 J.
- ✓ Heat for the kettle, 36 400 J.
- ✓ Total 7.08×10^5 J.

5 Long answer

ANSWER U · 4

A copper calorimeter with its stirrer is weighed (m_1), then weighed again with some water in it (water m_w); its temperature θ_1 is read. The metal (mass m_s) is heated in steam (Regnault's apparatus) to a steady temperature θ_2, then dropped quickly into the calorimeter. The mixture is stirred and the highest steady temperature θ is read.

By the principle of calorimetry, heat lost by the metal = heat gained by the water and the calorimeter:

$m_s\, s(\theta_2 - \theta) = (m_w\, s_w + m_1\, s_c)(\theta - \theta_1)$, so $s = \dfrac{(m_w\, s_w + m_1\, s_c)(\theta - \theta_1)}{m_s(\theta_2 - \theta)}$.

The calorimeter is kept in a box packed with cotton or wool so that little heat is lost.

MARKING SCHEME

- ✓ The masses of the calorimeter, the water and the metal, and θ_1, measured.
- ✓ The metal heated to θ_2 and dropped in quickly; the final temperature θ read.
- ✓ Heat lost by the metal = heat gained by the water and the calorimeter.
- ✓ The equation for s.

6 Numerical problems

a. ANSWER A · 4

Heat to melt all the ice: $0.050 \times 3.36 \times 10^5 = 16\,800$ J. Heat the water could give in cooling to 0 °C: $0.250 \times 4200 \times 30 = 31\,500$ J. That is more, so all the ice melts.

Heat lost by the warm water = heat to melt the ice + heat to warm the melted ice:

$0.250 \times 4200 \times (30 - \theta) = 16\,800 + 0.050 \times 4200 \times \theta$, so $31\,500 - 1050\theta = 16\,800 + 210\theta$, and $\theta = 14\,700 \div 1260 =$ **11.7 °C**.

MARKING SCHEME

- ✓ 16 800 J to melt the ice, less than the 31 500 J available: all melts.
- ✓ Heat lost = latent heat + heat to warm the melted ice.
- ✓ The equation set up.
- ✓ $\theta = 11.7$ °C.

b. ANSWER A · 3

Heat gained by the water: $1.0 \times 4200 \times 60 = 252\,000$ J.

Heat given by m kg of steam condensing and cooling to 80 °C: $m(2.26 \times 10^6 + 4200 \times 20) = m \times 2.344 \times 10^6$.

$m = 252\,000 \div 2.344 \times 10^6 =$ **0.108 kg** (108 g).

MARKING SCHEME

- ✓ Heat gained by the water, 252 000 J.
- ✓ Heat from the steam: latent heat plus cooling from 100 to 80 °C.
- ✓ m = 0.108 kg.

7 Think

ANSWER HA · 3

Hardly. The air pressure is low up there, so water boils at a lower temperature. Once it is boiling, extra heat from the stove doesn't raise its temperature: it goes into latent heat, turning more water into steam faster. The rice still cooks in water at that low boiling point, so it takes just as long. A pressure cooker helps, by raising the boiling point.

MARKING SCHEME

- ✓ Low pressure, so a low boiling point.
- ✓ At the boiling point extra heat only boils the water away faster (latent heat); the temperature doesn't rise.
- ✓ So no help; a pressure cooker would raise the boiling point.

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8 Activity: A cooling curve

(not marked)

WHAT STUDENTS SHOULD FIND

The water cools fastest at the start, when it is hottest, and more and more slowly as it nears room temperature. By Newton's law of cooling the rate of losing heat is proportional to the excess temperature over the surroundings, so the excess falls by roughly the same fraction in each equal stretch of time (more nearly so once the water is not very hot).

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	7	11	11	3	**32**

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