Past-paper walk-through

Specific heat capacity and specific latent heat ▪ 14.3

eXercise

Questions in this set

- 9702/41 J25 Q3 ▪ 9 marks
- 9702/42 J25 Q3 ▪ 13 marks
- 9702/43 J25 Q3 ▪ 9 marks
- 9702/44 J25 Q2 ▪ 7 marks

Reading the mark scheme

- **B1** a mark that stands on its own – the point is either made or not.
- **M1** a *method* mark: the right approach, even if the number is wrong.
- **A1** an *answer* mark, and it usually needs its M mark first.
- **C1** a working mark on the way to the answer.
- // separates answers the examiner accepts equally.
- **ecf** = error carried forward: a later part is marked on your own earlier answer.
- **owtte** = "or words to that effect" – the wording need not match.

Question 3

9702/41 J25 ▪ Q3 ▪ 9 marks

(a) Define specific latent heat. **[2]**

(b) Explain why, for a substance, the specific latent heat of vaporisation is usually greater than the specific latent heat of fusion. **[3]**

(c) An ice cube of mass 37.0 g at temperature $0.0°$C is placed in a beaker containing water of mass 208 g at temperature $26.4°$C.

When all the ice has melted, and all the water in the beaker has reached thermal equilibrium, the final temperature of all the water is $10.3°$C.

The specific heat capacity of water is 4.18 J g^{-1} °C^{-1}.

The beaker has negligible specific heat capacity and is perfectly insulated from the surroundings.

Determine a value, to three significant figures, for the specific latent heat of fusion of water. **[4]**

Solution 3

(a)

Mark scheme

- (thermal) energy per unit mass (to cause state change) **B1**
- (thermal) energy to change state at constant temperature **B1**

Solution 3

(b)

Mark scheme

- (for vaporisation):
- involves greater change in volume (of substance) or involves greater increase in separation of molecules **B1**
- more work has to be done by molecules (to separate) or greater increase in potential energy of molecules **M1**
- kinetic energy of molecules unchanged, so more thermal energy needed **A1**

Solution 3

(c) Worked steps

Energy is conserved: what the warm water loses, the ice gains — and the ice gains it in **two** stages, which is where the marks are.

- Water cools by $\Delta\theta = 26.4 - 10.3 = 16.1$ °C, giving out $Q = mc\Delta\theta = 208 \times 4.18 \times 16.1 = 14\,000$ J.
- The ice first **melts** at 0 °C: $Q_1 = mL = 37.0L$.
- The melted water then **warms** from 0.0 to 10.3 °C: $Q_2 = 37.0 \times 4.18 \times 10.3 = 1590$ J.
- Setting gained equal to lost: $37.0L + 1590 = 14\,000$
- $L = 335$ J g^{-1}

Solution 3

The commonest error is forgetting the second stage — the melted ice does not stay at $0\ ^\circ$C, it ends at the final temperature with everything else.

Mark scheme

- $Q = mc\Delta\theta$ and $Q = mL$ **C1**
- $\Delta\theta$ for the water = 26.4 – 10.3 **C1**
- $(37.0 \times L) + (37.0 \times 4.18 \times 10.3) = (208 \times 4.18 \times 16.1)$ **C1**
- L = 335 J g–1 **A1**

Question 3

9702/42 J25 ▪ Q3 ▪ 13 marks

(a) Define specific heat capacity. **[2]**

(b)(i) Calculate the mass of the block. **[2]**

(b)(ii) Show that the volume of the block at a temperature of 500 °C is 3.722×10^{-3} m^3. **[1]**

(b)(iii) Use the information in **(b)(ii)** to determine the magnitude of the work done on the block when its temperature is raised from 0 °C to 500 °C. **[2]**

(b)(iv) Explain whether the work done on the block is positive or negative. **[2]**

(b)(v) Use the first law of thermodynamics to determine, to three significant figures, a value for the specific heat capacity of aluminium. Explain your reasoning. Give a unit with your answer. **[3]**

(c) Without further calculation, suggest with a reason how doubling the pressure in **(b)** is likely to affect the answer in **(b)(v)**. **[1]**

Solution 3

(a)

Mark scheme

- (thermal) energy per unit mass (to cause temperature change) **B1**
- (thermal) energy per unit change in temperature **B1**

Solution 3

(b)(i) Worked steps

Density links mass and volume, and both are given.

- $\rho = \frac{m}{V}$, so $m = \rho V$.
- $m = 2.700 \times 10^3 \times 3.612 \times 10^{-3}$
- $m = 9.752$ kg

Solution 3

Keep all four significant figures: this mass is used again in (b)(v), and rounding it to 9.8 here shifts the final specific heat capacity out of the accepted range.

Mark scheme

- density $=$ mass / volume **C1**
- mass $= 2.700 \times 103 \times 3.612 \times 10–3$
- $= 9.752$ kg **A1**

Solution 3

(b)(ii) Worked steps

The block's mass does not change when it is heated — only its volume does, and the density falls to match. So use the same mass twice.

- Mass is constant: $\rho_0 V_0 = \rho_{500} V_{500}$.
- Rearranged, $V_{500} = V_0 \times \dfrac{\rho_0}{\rho_{500}} = 3.612 \times 10^{-3} \times \dfrac{2.700}{2.620}$
- $V_{500} = 3.722 \times 10^{-3}$ m^3, as required.

Solution 3

The same answer comes from dividing the mass by the new density, $9.752/(2.620 \times 10^3)$ — either route earns the mark.
This is a *show that*, so the working must be visible and the final line must be written out in full. An answer with no substitution scores zero even though the number is printed in the question.

Mark scheme

- volume = 3.612 × 10–3 × (2.700 / 2.620) = 3.722 × 10–3 m3 or volume = 9.752 / (2.620 × 103) = 3.722 × 10–3 m3 **A1**

Solution 3

(b)(iii) Worked steps

The block expands against the surrounding air, which is at constant atmospheric pressure, so the work is pressure times the change in volume.

- $W = p\Delta V$
- $\Delta V = (3.722 - 3.612) \times 10^{-3} = 1.10 \times 10^{-4}\ \text{m}^3$
- $W = 1.01 \times 10^5 \times 1.10 \times 10^{-4}$
- $W = 11.1\ \text{J}$

Solution 3

Subtract the volumes **before** multiplying by 10^{-3} — the two volumes agree to three figures, so subtracting rounded values is where this calculation usually goes wrong. The question asks for the *magnitude*, so 11.1 J is the answer; the sign is part (b)(iv).

Mark scheme

- W = pΔV **C1**
- = 1.01 × 105 × (3.722 – 3.612) × 10–3
- = 11.1 J **A1**

Solution 3

(b)(iv)

Mark scheme

- volume (of block) increases **B1**
- work is done against the atmosphere so work done (on block) is negative **B1**

Solution 3

(b)(v) Worked steps

The first law says the thermal energy supplied is shared between the internal energy and the work done:

$$Q = \Delta U + W$$

- The energy supplied is the internal-energy rise plus the work done against the atmosphere: $Q = (4.38 \times 10^6) + 11.1$.
- That work is about **two millionths** of the total, so to three significant figures $Q = 4.38 \times 10^6$ J — saying so explicitly is the reasoning the question asks you to explain.
- Then $c = \dfrac{Q}{m\,\Delta\theta} = \dfrac{4.38 \times 10^6}{9.75 \times 500}$
- $c = 898\ \mathrm{J\,kg^{-1}\,{}^\circ C^{-1}}$

Solution 3

Three things are marked separately here, so give all three: the energy total, the substitution, and a **unit** with the answer. $\mathrm{J\,kg^{-1}\,K^{-1}}$ is equally acceptable — a temperature *interval* is the same size on both scales.

Mark scheme

- thermal energy $= (4.38 \times 106) + 11.1$ **B1**
- specific heat capacity $= (4.38 \times 106) / (9.75 \times 500)$ **C1**
- $=$ 898 J kg–1 °C–1 **A1**

Solution 3

(c)

Mark scheme

- work done is negligible compared with (change in) internal energy so (answer in (b)(v) would be) unchanged B1

Question 3

9702/43 J25 ▪ Q3 ▪ 9 marks

3 **(a)** Define specific latent heat.

Question 3

(b) Explain why, for a substance, the specific latent heat of vaporisation is usually greater than the specific latent heat of fusion.

Question 3

(c) An ice cube of mass 37.0 g at temperature 0.0 °C is placed in a beaker containing water of mass 208 g at temperature 26.4 °C.

When all the ice has melted, and all the water in the beaker has reached thermal equilibrium, the final temperature of all the water is 10.3 °C.

The specific heat capacity of water is 4.18 $J\,g^{-1}\,{}^{\circ}C^{-1}$.

The beaker has negligible specific heat capacity and is perfectly insulated from the surroundings.

Determine a value, to three significant figures, for the specific latent heat of fusion of water.

Question 3

Question 3

[Total: 9]

Solution 3

(a)

Mark scheme

- (thermal) energy per unit mass (to cause state change)
- (thermal) energy to change state at constant temperature

Solution 3

(b) Mark scheme

- (for vaporisation):
- involves greater change in volume (of substance)
- or
- involves greater increase in separation of molecules
- more work has to be done by molecules (to separate)
- or
- greater increase in potential energy of molecules
- kinetic energy of molecules unchanged, so more thermal energy needed

Solution 3

(c) Worked steps

This is an energy-conservation question, so write down what gains energy and what loses it, then set the totals equal. Two equations do all the work:

$$Q = mc\,\Delta\theta \qquad \text{and} \qquad Q = mL$$

Energy gained by the ice, which does two things in succession:

- it melts at 0 °C: $37.0 \times L$
- the melt-water then warms from 0 °C to the final 10.3 °C: $37.0 \times 4.18 \times 10.3$

Energy lost by the warm water, cooling from 26.4 °C to 10.3 °C, so $\Delta\theta = 26.4 - 10.3 = 16.1$ °C:

Solution 3

- $208 \times 4.18 \times 16.1$

Set them equal and solve:

- $(37.0 \times L) + (37.0 \times 4.18 \times 10.3) = 208 \times 4.18 \times 16.1$
- $37.0L + 1593 = 13998$
- $L = \dfrac{12405}{37.0} = 335\ \mathrm{J\,g^{-1}}$

Solution 3

Three traps, and all four marks pass through them. The melted ice **also has to be warmed** — leaving that term out gives 378 and is the commonest error. The two temperature changes are different (10.3 for the ice, 16.1 for the water), so work each out from the final temperature rather than reusing one. And the masses are in **grams**, so the answer is in $\mathrm{J\,g^{-1}}$; multiply by 1000 only if joules per kilogram are asked for.

Mark scheme

- $Q = mc\Delta\theta$ and $Q = mL$
- $\Delta\theta$ for the water $= 26.4 - 10.3$
- $(37.0 \times L) + (37.0 \times 4.18 \times 10.3) = (208 \times 4.18 \times 16.1)$
- L = 335 J g–1
- 9702/43
- May/June 2025

Question 2

9702/44 J25 ▪ Q2 ▪ 7 marks

2 **(a)** State what is meant by two objects being in thermal equilibrium.

Question 2

(b) A mass X of ice at $0\,°\mathrm{C}$ is placed in a beaker containing a mass M of water at Celsius temperature t. The beaker is perfectly insulated and has negligible heat capacity. After some time, the ice that was added reaches thermal equilibrium with the original water in the beaker.

The specific latent heat of fusion of water is L. The specific heat capacity of water is c.
The final Celsius temperature of the system is θ.

Give expressions, in terms of some or all of X, M, t, θ, L and c, for the thermal energy:

(i) E_1, gained by the ice as it melts to become water at $0\,°\mathrm{C}$

Question 2

(ii) E_2, lost by the water as its Celsius temperature decreases from t to θ

Question 2

(iii) E_3, gained by the melted ice as its Celsius temperature increases from $0\,°C$ to θ.

Question 2

(c) Use your answers in **(b)** to show that the final Celsius temperature θ of the system is given by

$$\theta = \frac{Mct - XL}{c(M + X)}.$$

[2]

[Total: 7]

Solution 2

(a)

Mark scheme

- same temperature (as each other)
- no net transfer of thermal energy (between them)

Solution 2

(b)(i)

Worked steps

Melting takes energy but no temperature change, so the specific **latent heat** applies and there is no $\Delta\theta$ in the expression.

- $E_1 = XL$

X is the mass of ice and L its specific latent heat of fusion. Every gram must melt before any of it can warm up, which is why this term stands on its own.

Mark scheme

- E1 = XL

Solution 2

(b)(ii)

Worked steps

The warm water **cools**, so its temperature change is from its starting value t down to the final value θ.

- $E_2 = Mc(t - \theta)$

Write the change as $(t - \theta)$, in that order: the water is losing energy, and this expression is the positive amount it loses. Reversing the bracket makes every later line change sign.

Mark scheme

- E2 = Mc(t – θ)

Solution 2

(b)(iii)

Worked steps

Once melted, the ice-water starts at 0 °C and has to be warmed to the same final temperature as everything else.

- $E_3 = Xc\theta$

The mass is X — the melt-water is the ice, now liquid — and the temperature change is $\theta - 0 = \theta$. This is the term most often left out of the energy balance in part (c), and writing it here separately is what the question is setting up.

Mark scheme

- $\mathrm{E3} = \mathrm{Xc}\theta$

Solution 2

(c) Worked steps

Nothing is substituted here — this is a derivation, so name the three energy transfers, write the conservation statement, and rearrange.

- E_1: energy to **melt** the ice, XL.
- E_2: energy **lost by the warm water** as it cools from t to the final temperature θ, that is $Mc(t-\theta)$.
- E_3: energy to **warm the melt-water** from 0 °C to θ, that is $Xc\theta$.

Energy is conserved, and the water supplies both of the other two:

- $E_2 = E_1 + E_3$, so $Mc(t-\theta) = XL + Xc\theta$.

Solution 2

Now collect the θ terms on one side:

- $Mct - Mc\theta = XL + Xc\theta$
- $Mct - XL = Xc\theta + Mc\theta = c\theta(M + X)$
- $\theta = \dfrac{Mct - XL}{c(M + X)}$

Both marks are for the route: one for the energy statement with all three terms present, one for finishing the algebra. The term most often dropped is $Xc\theta$ — the ice does not stop at melting, it then has to be warmed to the same final temperature as everything else.

Solution 2

A check on the final expression: $c(M + X)$ in the denominator is the heat capacity of **all** the water once the ice has melted, which is what the mixture ends up as.

Mark scheme

- E2 = E1 + E3
- Mc(t – θ) = XL + Xcθ
- and
- completion of algebra to reach θ = (Mct – XL) / c(M + X)
- 9702/44
- May/June 2025