

Questions ①

In questions 3, 4, and 5, assume that no heat energy is lost to the surroundings. Where appropriate, use the values for specific heat capacity given in the chart on page 144.

- Aluminium has a specific heat capacity of $900 \text{ J}/(\text{kg K})$. What does this mean? A 10 kg block of aluminium cools from 100°C to 50°C . How much thermal energy does it give out? What thermal energy would be given out by the same mass of water over the same temperature fall?
- Water has a very high specific heat capacity. In what ways is this useful?
- A 210 W heater is placed in 2 kg of water. What temperature rise is produced if the heater is switched on for 200 s ?
- An electric kettle has a power rating of 2.1 kW . The kettle is filled with 1.5 kg of water at a temperature of 20°C . How long after the kettle is switched on will the water start to boil?
- A lump of metal of mass 0.2 kg and temperature 100°C is placed in water of mass 0.4 kg and temperature 16°C . If the final temperature of the metal and water is 20°C , what is the specific heat capacity of the metal?

Questions ②

Where necessary, use the value of the specific latent heat of fusion of ice given in question 2.

- Why is thermal energy needed to turn a solid into a liquid?
- The specific latent heat of fusion of ice is $334\,000 \text{ J}/\text{kg}$. What does this mean?
- How much thermal energy must be removed from 5 kg of water at 0°C to turn it into ice?
- A substance is melted and then allowed to cool. A cooling curve is plotted as shown in figure 9. What is the melting point of the substance? What is happening to the substance between B and C? Over which of the sections AB, BC and CD, is the substance losing heat?
- What is the effect on the melting point of ice of a) exerting a high pressure on the ice b) adding salt to the ice?
- How much thermal energy must be removed from 2 kg of water at 100°C to turn it into ice at 0°C ? (The specific heat capacity of water is $4200 \text{ J}/(\text{kg K})$).
- A panful of crushed ice at 0°C is heated by a 167 W heater. What mass of ice will melt if the heater is switched on for 100 s ? State any assumptions you make in your calculation.

Questions ③

In all calculations, assume there are no heat losses to the container or to the outside. Where necessary, use the values of the specific heat capacity of, and specific latent heat of vaporization of, water given in questions 1 and 3.

- At 100°C , water has a specific latent heat of vaporization of $2\,260\,000 \text{ J}/\text{kg}$. What does this mean? How much thermal energy would be needed to change 2 kg of water at 100°C into steam at the same temperature? How much thermal energy would be needed to change 10 kg ?
- Explain in terms of the kinetic theory why a) thermal energy is needed to turn a liquid into a gas b) evaporation produces cooling.
- How much thermal energy is needed to turn 3.0 kg of water at 50°C into steam at 100°C ? (The specific heat capacity of water is $4200 \text{ J}/(\text{kg K})$.)
- Give two ways, other than by direct heating, in which a liquid may be made to evaporate more rapidly.
- Describe two practical applications of the cooling effect produced by evaporation.
- The heating element of a kettle has a power rating of 2.26 kW . If the kettle contains boiling water, what mass of steam will be produced in 10 minutes ?
- 0.9 kg of water at 0°C is heated by bubbling through it a jet of steam at 100°C . What is the temperature of the water when 0.1 kg of steam have condensed?

Solutions are on the second page!

Questions ①

① $c_{Al} = 900 \frac{J}{kg \cdot K}$

$m = 10 \text{ kg}$

$t_1 = 100^\circ C$

$t_2 = 50^\circ C$

$c_w = 4200 \frac{J}{kg \cdot K}$

$Q = m \cdot c_{Al} \cdot \Delta t$

$Q = 10 \cdot 900 \cdot 50$

$Q = 450 \text{ kJ}$

$Q = m \cdot c_w \cdot \Delta t$

$Q = 10 \cdot 4200 \cdot 50$

$Q = 2.1 \text{ MJ}$

③ $P = 210 \text{ W}$

$m = 2 \text{ kg}$

$t = 200 \text{ s}$

$\Delta t = ?^\circ C$

$c_w = 4200 \frac{J}{kg \cdot K}$

$P = \frac{W}{t} = \frac{Q}{t} \Rightarrow Q = P \cdot t$

$m \cdot c_w \cdot \Delta t = P \cdot t$

$\Delta t = \frac{P \cdot t}{m \cdot c_w}$

$\Delta t = \frac{210 \cdot 200}{2 \cdot 4200} = \underline{5^\circ C}$

④

$P = 2.1 \text{ kW} = 2100 \text{ W}$

$m = 1.5 \text{ kg}$

$t_1 = 20^\circ C$

$t_2 = 100^\circ C$

$t = ? \text{ s}$

$c_w = 4200 \frac{J}{kg \cdot ^\circ C}$

$P \cdot t = Q$

$t = \frac{Q}{P} = \frac{m \cdot c_w \cdot \Delta t}{P} = \frac{1.5 \cdot 4200 \cdot (100 - 20)}{2100} =$

$= \frac{1.5 \cdot 4200 \cdot 80}{2100} = 240 \text{ s} = \underline{4 \text{ min}}$

⑤ $m_m = 0.2 \text{ kg}$

$t_m = 100^\circ C$

$m_w = 0.4 \text{ kg}$

$t_w = 16^\circ C$

$t = 20^\circ C$

$c_m = ? \frac{J}{kg \cdot K}$

$c_w = 4200 \frac{J}{kg \cdot K}$

$m_m \cdot c_m \cdot (t_m - t) = m_w \cdot c_w \cdot (t - t_w)$

$c_m = \frac{m_w \cdot c_w \cdot (t - t_w)}{m_m \cdot (t_m - t)}$

$c_m = \frac{0.4 \cdot 4200 \cdot (20 - 16)}{0.2 \cdot (100 - 20)} = \underline{420 \frac{J}{kg \cdot ^\circ C}}$

Questions (2):

3. $Q = ? \text{ J}$
 $m = 5 \text{ kg}$
 $l_{ice} = 334\,000 \frac{\text{J}}{\text{kg}}$

$$Q = L = m \cdot l = 5 \cdot 334\,000 = \underline{\underline{1\,670\,000 \text{ J}}}$$

6. $Q = ? \text{ J}$
 $m_{wr} = 2 \text{ kg}$
 $t_1 = 100^\circ\text{C}$
 $t_2 = 0^\circ\text{C}$
 $c_{wr} = 4200 \frac{\text{J}}{\text{kg}\cdot\text{K}}$
 $l_i = 334\,000 \frac{\text{J}}{\text{kg}}$

$$\begin{aligned} Q &= Q_1 + L \\ Q &= m_{wr} \cdot c_{wr} (t_1 - t_2) + m_{wr} \cdot l_i = \\ &= 2 \cdot 4200 \cdot (100 - 0) + 2 \cdot 334\,000 = \\ &= \underline{\underline{1\,508\,000 \text{ J}}} \end{aligned}$$

7. $P = 167 \text{ W}$
 $t = 100 \text{ s}$
 $l_i = 334\,000 \frac{\text{J}}{\text{kg}}$
 $m_i = ? \text{ kg}$

$$\begin{aligned} Q &= P \cdot t \\ m_i \cdot l_i &= P \cdot t \\ m_i &= \frac{P \cdot t}{l_i} = \frac{167 \cdot 100}{334\,000} = 0.05 \text{ kg} = \underline{\underline{50 \text{ g}}} \end{aligned}$$

Questions (3):

① $t = 100^\circ\text{C}$
 $l_{\text{nr}} = 2\,260\,000 \frac{\text{J}}{\text{kg}}$
 $m_1 = 2 \text{ kg}$
 $m_2 = 10 \text{ kg}$
 $Q_1 = ? \text{ J}$
 $Q_2 = ? \text{ J}$

$$Q_1 = m_1 \cdot l_{\text{nr}} = 2 \times 2\,260\,000 = \underline{4.52 \text{ MJ}}$$

$$Q_2 = m_2 \cdot l_{\text{nr}} = 10 \times 2\,260\,000 = \underline{22.6 \text{ MJ}}$$

③ $m_{\text{nr}} = 3 \text{ kg}$
 $c_{\text{nr}} = 4200 \frac{\text{J}}{\text{kg K}}$
 $t_{\text{nr}} = 50^\circ\text{C}$
 $t_s = 100^\circ\text{C}$
 $l_{\text{nr}} = 2\,260\,000 \frac{\text{J}}{\text{kg}}$
 $Q = ? \text{ J}$

$$Q = m_{\text{nr}} c_{\text{nr}} (t_s - t_{\text{nr}}) + m_{\text{nr}} \cdot l_{\text{nr}} =$$

$$= 3 \times 4200 (100 - 50) + 3 \cdot 2\,260\,000 =$$

$$= \underline{7.41 \text{ MJ}}$$

⑥ $P = 2.26 \text{ kW} = 2260 \text{ W}$ $P = \frac{W}{t} = \frac{Q}{t} \Rightarrow Q = P \cdot t = 2260 \times 600 =$
 $t = 100^\circ\text{C}$ t t $= \underline{1356 \text{ kJ}}$
 $m_{\text{A}} = ?$

$t = 10 \text{ min} = 600 \text{ s}$
 $l_{\text{nr}} = 2\,260\,000 \frac{\text{J}}{\text{kg}}$

$$Q = L$$

$$Q = m_{\text{A}} \cdot l_{\text{nr}}$$

$$m_{\text{A}} = \frac{Q}{l_{\text{nr}}} = \frac{1356\,000}{2\,260\,000} = \underline{0.6 \text{ kg}}$$

⑦ $m_{\text{nr}} = 0.9 \text{ kg}$
 $t_{\text{nr}_1} = 0^\circ\text{C}$
 $t_s = 100^\circ\text{C}$
 $t_{\text{nr}_2} = 2^\circ\text{C}$
 $l_{\text{nr}} = 2\,260\,000 \frac{\text{J}}{\text{kg}}$
 $m_{\text{A}} = 0.1 \text{ kg}$

$$L = l_{\text{nr}} \cdot m_{\text{A}} = 2\,260\,000 \times 0.1 = 226\,000 \text{ J}$$

$$Q = L$$

$$m_{\text{nr}} \cdot c_{\text{nr}} \cdot (t_{\text{nr}_2} - t_{\text{nr}_1}) = L$$

$$\Delta t = \frac{L}{m_{\text{nr}} \cdot c_{\text{nr}}} = \frac{226\,000}{0.9 \times 4200} = \underline{60^\circ\text{C}}$$