PQ 9 Heat

Q and A

Q1

- A student immerses a 2.0kW electric heater in an insulated beaker of water. The heater is switched on and after 120 s the water reaches boiling point. The data collected during the experiment is given below.
- initial mass of beaker 25 g
- initial mass of beaker and water 750 g
- initial temperature of water 20 °C
- final temperature of water 100 °C

- Calculate the specific heat capacity of water if the thermal capacity of the beaker is negligi

$$mc\Delta\theta = Q = Pt$$

$0.725 \times c \times (100 - 20)$ **(1 mark)**

$= 2000 \times 120$ **(1 mark)**

$c = 4100$ **(1 mark)** $J\ kg^{-1}$ **(1 mark)**

Q2

- The student in part Q1 continues to heat the water so that it boils for 105 s. When the mass of the beaker and water is measured again, it is found that it has decreased by 94 g.
- (i) Calculate a value for the specific latent heat of vaporisation of water.

$Q = ml = Pt$

$94 \times 10^{-3} \times l = 2000 \times 105$ **(1 mark)**

$l = 2.2 \times 10^{6}$ J kg^{-1} **(1 mark)**

Q2 continued

- State two assumptions made in your calculation.

no evaporation (before water heated to boiling point) **(1 mark)**
no heat lost (to the surroundings) **(1 mark)**
heater 100% efficient **(1 mark)** - any two

Q3

- A tray containing 0.20 kg of water at 20 °C is placed in a freezer. The temperature of the water drops to 0 °C in 10 minutes. The specific heat capacity of water = 4200 J kg K
- Calculate:
- (i) the energy lost by the water as it cools to 0 °C,

$$\Delta Q = mc\Delta\theta$$

energy lost by water = 0.20 × 4200 × 20 **(1 mark)**

= 1.7×10^4 J **(1 mark)** [1.68×10^4 J]

- (ii) the average rate at which the water is losing energy, in J s

rate of loss of energy = (1.68×10^4)/(10 × 60) = 28W **(1 mark)**

Q3 continued

- (b) (i) Estimate the time taken for the water at 0 °C to turn completely into ice.

specific latent heat of fusion of water = 3.3×10^5 J kg^{-1}

$\Delta Q = ml = Pt$

$(28 \times t) = 0.20 \times 3.3 \times 10^5$ **(1 mark)**

$t = 2.4 \times 10^3$ s **(1 mark)** (2.36×10^3 s)

- (ii) State any assumptions you make

constant rate of heat loss **(1 mark)**

ice remains at 0oC **(1 mark)**

Q4

- (a) A 2.0kW heater is used to heat a room from 5 °C to 20 °C. The mass of air in the room is 30 kg. Under these conditions the specific
- heat capacity of air = 1000 J kg K

- Calculate
- (i) the gain in thermal energy of the air

$$\Delta Q = mc\Delta\theta$$

$$Q = 30 \times 1000 \times 15$$

$$= 4.5 \times 10^{5}\,J$$ **(1 mark)**

- (ii) the minimum time required to heat the room.

$$P \times t = 4.5 \times 10^{5}$$ **(1 mark)**

$$t = 45 \times 10^{5}/2000 = 225\ s$$ **(1 mark)**

Q4 continued

- (b) State and explain one reason why the actual time taken to heat the room is longer than the value calculated in part (a)(ii).

Heat is lost to surroundings or other objects in room or to heater itself **(1 mark)** therefore more (thermal) energy is required from heater **(1 mark)**

[or because convection currents cause uneven heating **or** rate of heat transfer decreases as temperature increases]

Q5

- A bicycle and its rider have a total mass of 95 kg. The bicycle is travelling along a horizontal road at a constant speed of 8.0ms
- (a) Calculate the kinetic energy of the bicycle and rider

$$Ek = \frac{1}{2} m v^2$$

$$Ek = \frac{1}{2} \times 95 \times 8.0^2$$ **(1 mark)**

$$= 3040\ J$$ **(1 mark)**

Q5 continued

- (b) The brakes are applied until the bicycle and rider come to rest. During braking, 60% of the kinetic energy of the bicycle and rider is converted to thermal energy in the brake blocks. The brake blocks have a total mass of 0.12 kg and the material from which they are made has a specific heat capacity of 1200 J kg K.
- (i) Calculate the maximum rise in temperature of the brake blocks

60% of the KE = 0.60 × 3040 = 1824 (J) **(1 mark)**

$\Delta Q = mc\Delta\theta$

1824 = 0.12 × 1200 × $\Delta\theta$ **(1 mark)** = 13 K **(1 mark)** (12.7 K)

- (ii) State an assumption you have made in part (b)(i).

No heat is lost to the surroundings **(1 mark)**

Q6

- A female runner of mass 60 kg generates thermal energy at a rate of 800W. Assuming that she loses no energy to the surroundings and that the average specific heat capacity of her body is 3900 J kg K calculate
- (i) the thermal energy generated in one minute,

Energy in one minute = $800 \times 60 = 48 \times 10^3$ J **(1 mark)**

- (ii) the temperature rise of her body in one minute.

$\Delta Q = mc\Delta\theta$

$48 \times 10^3 = 60 \times 3900 \times \Delta\theta$ **(1 mark)**

$\Delta\theta = 0.21$ K **(1 mark)** (0.205 K)

Q6 continued

- (b) In practice it is desirable for a runner to maintain a constant temperature. This may be achieved partly by the evaporation of sweat. The runner in part (a) loses energy at a rate of 500W by this process. Calculate the mass of sweat evaporated in one minute.
- specific latent heat of vaporisation of water = 2.3x106J kg

$\Delta Q = ml$

Energy in one minute: 500×60 **(1 mark)**

$= m \times 2.3 \times 10^6$ **(1 mark)**

So $m = 0.013$ kg **(1 mark)**

c) Explain why, when she stops running, her temperature is likely to fall.

She is not generating as much heat internally **(1 mark)** but is still losing heat (at the same rate) [or still sweating] **(1 mark)** hence her temperature will drop **(1 mark)**