PQ 6 Further Heat Calculations

Q and A

Q1

A 1.00×10^2-g mass of tungsten at 100.0°C is placed in 2.00×10^2 g of water at 20.0°C. The mixture reaches equilibrium at 21.6°C. Calculate the specific heat of tungsten.

$$\Delta Q_T + \Delta Q_W = 0$$

$$\text{or } m_T C_T \Delta T_T = -m_W C_W \Delta T_W$$

$$C_T = \frac{-m_W C_W \Delta T_W}{m_T \Delta T_T} = \frac{-(0.200\text{ kg})(4180\text{ J/kg·K})(21.6°\text{C} - 20.0°\text{C})}{(0.100\text{ kg})(21.6°\text{C} - 100.0°\text{C})}$$

$$= 171\text{ J/kg·K}$$

Q2

A 6.0×10^2-g sample of water at 90.0°C is mixed with 4.00×10^2 g of water at 22.0°C. Assume that there is no heat loss to the surroundings. What is the final temperature of the mixture?

$$T_f = \frac{m_A C_A \Delta T_{Ai} + m_B C_B \Delta T_{Bi}}{m_A C_A + m_B C_B}$$

but $C_A = C_B$ because both liquids are water, and the C's will divide out.

$$T_f = \frac{m_A T_{Ai} + m_B T_{Bi}}{m_A + m_B} = \frac{(6.0\times10^2\ \text{g})(90.0°\text{C}) + (4.00\times10^2\ \text{g})(22.0°\text{C})}{6.0\times10^2\ \text{g} + 4.00\times10^2\ \text{g}}$$

$$= 63°\text{C}$$

Q3

- A 10.0-kg piece of zinc at 71.0°C is placed in a container of water, The water has a mass of 20.0 kg and a temperature of 10.0°C before the zinc is added. What is the final temperature of the water and the zinc?

$$T_f = \frac{m_A C_A \Delta T_{Ai} + m_B C_B \Delta T_{Bi}}{m_A C_A + m_B C_B}$$

$$= \frac{(10.0\ \text{kg})(388\ \text{J/kg}\cdot\text{K})(71.0^\circ\text{C}) + (20.0\ \text{kg})(4180\ \text{J/kg}\cdot\text{K})(10.0^\circ\text{C})}{(10.0\ \text{kg})(388\ \text{J/kg}\cdot\text{K}) + (20.0\ \text{kg})(4180\ \text{J/kg}\cdot\text{K})}$$

$$= 12.7^\circ\text{C}$$

Q4

Car Engine A 2.50×10^2-kg cast-iron car engine contains water as a coolant. Suppose that the engine's temperature is 35.0°C when it is shut off, and the air temperature is 10.0°C. The heat given off by the engine and water in it as they cool to air temperature is 4.40×10^6 J. What mass of water is used to cool the engine?

$$Q = m_W C_W \Delta T + m_i C_i \Delta T$$

$$m_W = \frac{Q - m_i C_i \Delta T}{C_W \Delta T} = \frac{(4.4 \times 10^6\ \text{J}) - ((2.50 \times 10^2\ \text{kg})(450\ \text{J/kg}\cdot{}^\circ\text{C})(35.0^\circ\text{C} - 10.0^\circ\text{C}))}{(4180\ \text{J/kg}\cdot{}^\circ\text{C})(35.0^\circ\text{C} - 10.0^\circ\text{C})}$$

$$= 15\ \text{kg}$$

Q5

- Years ago, a block of ice with a mass of about 20.0 kg was used daily in a home icebox. The temperature of the ice was 0.0°C when it was delivered. As it melted, how much heat did the block of ice absorb?

$$Q = mH_f = (20.0\ \text{kg})(3.34\times10^5\ \text{J/kg}) = 6.68\times10^6\ \text{J}$$

Q6

- How much heat is added to 10.0 g of ice at 20.0°C to convert it to steam at 120.0°C?

Amount of heat needed to heat ice to 0.0°C:

$$Q = mC\Delta T$$

$$= (0.0100\ \text{kg})(2060\ \text{J/kg}\cdot{}^\circ\text{C})(0.0^\circ\text{C} - (-20.0^\circ\text{C}))$$

$$= 412\ \text{J}$$

Amount of heat to melt ice:

$$Q = mH_f$$

$$= (0.0100\ \text{kg})(3.34\times10^5\ \text{J/kg})$$

$$= 3.34\times10^3\ \text{J}$$

Q6 continued

Amount of heat to heat water to 100.0°C:

$$Q = mC\Delta T$$
$$= (0.0100\ \text{kg})(4180\ \text{J/kg}\cdot°\text{C})(100.0°\text{C} - 0.0°\text{C})$$
$$= 4.18\times10^{3}\ \text{J}$$

Amount of heat to boil water:

$$Q = mH_{v}$$
$$= (0.0100\ \text{kg})(2.26\times10^{6}\ \text{J/kg})$$
$$= 2.26\times10^{4}\ \text{J}$$

Q6 continued

Amount of heat to heat steam to 120.0°C:

$$Q = mC\Delta T$$

$$= (0.0100 \text{ kg})(2060 \text{ J/kg·°C})(120.0\text{°C} - 100.0\text{°C})$$

$$= 404 \text{ J}$$

The total heat is

$$412 \text{ J} + 3.34\times10^{3} \text{ J} + 4.18\times10^{3} \text{ J} + 2.26\times10^{4} \text{ J} + 404 \text{ J} = 3.09\times10^{4} \text{ J}$$

Q7

- A cold pack bottle containing 400g of water is put in a icebox and the water frozen to a temperature of - 6 ° C. At 9.00am the cold pack is removed and placed in a box. Both the cold pack and box warm up at a rate of 10Js.
- When will the temperature of the water in the cold pack reach +5 ° C?

$$Q_{ice} \rightarrow Q_{water} = Q_{-6\rightarrow 0°c} + Q_{0°\rightarrow 0°c} + Q_{0°c \rightarrow +5°c}$$

$$= m_i c_i \Delta T_i + m L_f + m_w c_w \Delta T_w$$

$$= (0.4 \times 2.1 \times 10^3 \times 6) + (0.4 \times 3.34 \times 10^5) + (0.4 \times 4.2 \times 10^3 \times 5)$$

$$= 5040 + 133600 + 8400$$

$$= 147040 \text{ J}$$

$$\frac{Q}{t} = 10 \text{ Js} \quad = \quad t = \frac{147040}{10} = 14704 \text{ s}$$

$= 245$ minutes

$= 4.08$ hours

time = 11:45am.

Q7 continued

- What will the temperature of the water be at 10.00am?

$t = 2 \text{ hours} = 7200 s$

$Q_{2 \text{ hours}} = 10 J/s \times 7200 s$
$= 72000$

$Q_{-6 \to 0°C} = 5040 J$

$Q \text{ for melting} = 72000 - 5040$
$= 66960 J$

$mL_f = 133600 J$

$\therefore$ temperature $0°C$

Q8

- To make iced tea, you start by brewing the tea with hot water. Then you add ice. If you start with 1.0 L of 90°C tea, what is the minimum amount of ice needed to cool it to 0°C?

Heat lost by the tea

$$Q = mC\Delta T$$
$$= (1.0\ \text{kg})(4180\ \text{J/kg}\cdot\text{K})(90°\text{C})$$
$$= 376\ \text{kJ}$$

Amount of ice melted

$$m = \frac{Q}{H_f}$$
$$= \frac{376\ \text{kJ}}{334\ \text{kJ}} = 1.1\ \text{kg}$$

Q9

- Calculate the heat required to convert 5 kg of ice at –20°C into steam at 100°C.

a Warming of ice from −20°C to 0°C: specific heat

$\Delta T = 20°C$, $c = 2100\ J\ kg^{-1}\ K^{-1}$ for ice

$\Delta Q = cm\,\Delta T$

$\Delta Q = 2100 \times 5 \times 20$

$= 2.1 \times 10^5\ J = 0.21\ MJ$

b Melting the ice: latent heat of fusion

$\Delta Q = mL_f$, $L_f = 3.34 \times 10^5\ J\ kg^{-1}$ for ice

$\Delta Q = 3.34 \times 10^5 \times 5$

$= 1.67 \times 10^6\ J = 1.67\ MJ$

c Warming the water from 0°C to 100°C: specific heat

$\Delta T = 100°C$, $c = 4200\ J\ kg^{-1}\ K^{-1}$ for water

$\Delta Q = cm\,\Delta T$

$\Delta Q = 4200 \times 5 \times 100$

$= 2.1 \times 10^6\ J = 2.1\ MJ$

d Evaporating the water: latent heat of vaporisation

$\Delta Q = mL_v$, $L_v = 22.5 \times 10^5\ J\ kg^{-1}$ for water

$\Delta Q = 22.5 \times 105 \times 5$

$= 11.25 \times 10^6\ J = 11.25\ MJ$

Q10

- The hot water tap of a bath delivers water at 80°C. Ten litres of hot water is added to a bath containing 30 litres of water at 20°C. Ignoring energy losses to the surrounding environment, what will be the final temperature of the bath water?

Heat energy gained by the cold water = heat energy lost by the hot water.
In terms of the final temperature of the mixture:

$$cm(80 - T) = cm(T - 20)$$

Note that the specific heat of water will cancel out as it appears on both sides of the equation.

So, $10(80 - T) = 30(T - 20)$

Expanding: $800 - 10T = 30T - 600$

Rearranging: $800 + 600 = 30T + 10T$

and $1400 = 40T$

Hence $T = 35°\text{C}$