PQ 4 Questions and Answers

Q1

Hypothermia can occur if the body temperature drops to 35.0°C, although people have been known to survive much lower temperatures. On January 19, 1985, 2-year-old Michael Trode was found in the snow near his Milwaukee home with a body temperature of 16.0°C. If Michael's mass was 10.0 kg, how much heat did his body lose, assuming his normal body temperature was 37.0°C? ($c_{\text{human body}} = 3470\ \text{J/kg°C}$)

Given: $m = 10.0\ \text{kg}$
$c = 3470\ \text{J/kg°C}$
$T_f = 16.0°\text{C}$
$T_o = 37.0°\text{C}$

Unknown: $\Delta Q = ?$
Original equation: $\Delta Q = mc\Delta T$

Solve: $\Delta Q = mc\Delta T = mc(T_f - T_o) = (10.0\ \text{kg})(3470\ \text{J/kg°C})(16.0°\text{C} - 37.0°\text{C})$
$= \mathbf{-729\ 000\ J}$

Q2

Gwyn's bowl is filled with 0.175 kg of 60.0°C soup (mostly water) that she stirs with a 20.0°C silver spoon of mass 0.0400 kg. The spoon slips out of her hand and slides into the soup. What equilibrium temperature will be reached if the spoon is allowed to remain in the soup and no heat is lost to the outside air? (c_{spoon} = 240. J/kg°C) Assume that the temperature of the bowl does not change.

Given: $m_{water} = 0.175$ kg
$c_{water} = 4187$ J/kg°C
$T_{water} = 60.0$°C
$m_{spoon} = 0.0400$ kg
$c_{spoon} = 240.$ J/kg°C
$T_{spoon} = 20.0$°C

Unknown: $T_f = ?$
Original equation: Heat lost = Heat gained

Solve: $mc\Delta T_{water} = mc\Delta T_{spoon}$

$$(0.175\text{ kg})(4187\text{ J/kg°C})(60.0\text{°C} - T_f) = (0.0400\text{ kg})(240.\text{ J/kg°C})(T_f - 20.0\text{°C})$$
$$43\,963\text{ J} - (732.7\,T_f)\text{J/°C} = (9.6\,T_f)\text{J/°C} - 192\text{ J}$$
$$44\,155\text{ J} = (742.3\,T_f)\text{J/°C}$$
$$T_f = \frac{44\,155\text{ J}}{742.3\text{ J/°C}} = \mathbf{59.5°C}$$

Therefore, the temperature of the spoon and soup both reach equilibrium at 59.5°C, so the spoon has become much hotter but the soup has only cooled by 0.5°C.

Q3

An igloo is made of 224 blocks of ice at 0°C, each with a mass of 12.0 kg. How much heat must be gained by the ice to melt the entire igloo?

Solution: The total mass of the ice is 224 (12.0 kg) = 2690 kg

Given: $m = 2690\ \text{kg}$
$h_f = 3.35 \times 10^5\ \text{J/kg}$

Unknown: $\Delta Q = ?$
Original equation: $\Delta Q = mh_f$

Solve: $\Delta Q = mh_f = (2690\ \text{kg})(3.35 \times 10^5\ \text{J/kg}) = \mathbf{9.01 \times 10^8\ J}$

Q4

Gus is cooking soup in his hot pot and finds that he has added too much water. If Gus needs to boil off 0.200 kg of water in order for his soup to have the correct consistency, how much additional heat must Gus add once the soup is boiling?

Given: $m = 0.200\ \text{kg}$
$h_v = 2.26 \times 10^6\ \text{J/kg}$

Unknown: $\Delta Q = ?$
Original equation: $\Delta Q = mh_v$

Solve: $\Delta Q = mh_v = (0.200\ \text{kg})(2.26 \times 10^6\ \text{J/kg}) = \mathbf{4.52 \times 10^6\ J}$

Q5

To cool her 0.200-kg cup of 75.0°C hot chocolate (mostly water), Heidi drops a 0.0300-kg ice cube at 0°C into her insulated foam cup. What is the temperature of the hot chocolate after all the ice is melted?

Solution: The relationship "Heat lost = Heat gained" can take on many forms depending upon what is happening in the exercise. In this exercise, heat is lost from the hot chocolate ($mc\Delta T_{water}$) and gained by the ice cube, first melting it (mh_f) and then raising its temperature ($mc\Delta T_{water}$).

Given:
$m_{ice} = 0.0300$ kg
$m_{water} = 0.200$ kg
$h_f = 3.35 \times 10^5$ J/kg
$c_{water} = 4187$ J/kg°C
$T_{water} = 75.0$°C
$T_{ice} = 0$°C

Unknown: $T_f = ?$

Original equation: Heat lost = Heat gained

Q5 continued

Solve: $mc\Delta T_{\text{water}} = mh_{\text{f(ice)}} + mc\Delta T_{\text{water}} = (0.200\ \text{kg})(4187\ \text{J/kg°C})(75.0°\text{C} - T_{\text{f}})$

$= (0.0300\ \text{kg})(3.35 \times 10^5\ \text{J/kg}) + (0.0300\ \text{kg})(4187\ \text{J/kg°C})(T_{\text{f}} - 0°\text{C})$

$= 62\,805\ \text{J} - (837.4\ T_{\text{f}})\text{J/°C} = 10\,050\ \text{J} + 125.6\ T_{\text{f}}(\text{J/°C})$

$= 52\,755\ \text{J} = (963.0\ T_{\text{f}})\text{J/°C} \qquad \text{so} \qquad T_{\text{f}} = \dfrac{52\,755\ \text{J}}{963.0\ \text{J/°C}} = \mathbf{54.8°C}$