Physics 151 Class Exercise: Calorimetry-KEY

1. Each of the following situations involves the mixing of substances at different temperatures in an insulated calorimeter with negligible capacity. You should first estimate the correct answer before beginning any calculations and then write out the $Q_{lost} + Q_{gained} = 0$ equation for each and calculate the final temperature.

(a) 50g of water at 10 ºC is mixed with 50g of water at 50 ºC

$$m_{wa}c_w\left(T_f - T_{ai}\right) + m_{wb}c_w\left(T_f - T_{bi}\right) = 0$$

$$m_{wa}T_f - m_{wa}T_{ai} + m_{wb}T_f - m_{wb}T_{bi} = 0$$

$$T_f\left(m_{wa} + m_{wb}\right) = m_{wa}T_{ai} + m_{wb}T_{bi}$$

$$T_f = \frac{m_{wa}T_{ai} + m_{wb}T_{bi}}{\left(m_{wa} + m_{wb}\right)} = \frac{(50g)(10°C) + (50g)(50°C)}{(50g) + (50g)} = 30°C$$

(b) 10g of water at 10 ºC is mixed with 50g of water at 50 ºC

$$m_{wa}c_w\left(T_f - T_{ai}\right) + m_{wb}c_w\left(T_f - T_{bi}\right) = 0$$

$$m_{wa}T_f - m_{wa}T_{ai} + m_{wb}T_f - m_{wb}T_{bi} = 0$$

$$T_f\left(m_{wa} + m_{wb}\right) = m_{wa}T_{ai} + m_{wb}T_{bi}$$

$$T_f = \frac{m_{wa}T_{ai} + m_{wb}T_{bi}}{\left(m_{wa} + m_{wb}\right)} = \frac{(10g)(10°C) + (50g)(50°C)}{(10g) + (50g)} = 43°C$$

(c) 10.0g of Aluminum at 80.0 ºC is mixed with 10.0g of water at 10.0 ºC

$$m_{Al}c_{Al}\left(T_f - T_{iAl}\right) + m_w c_w\left(T_f - T_{iw}\right) = 0$$

$$m_{Al}c_{Al}T_f - m_{Al}c_{Al}T_{iAl} + m_w c_w T_f - m_w c_w T_{iw} = 0$$

$$T_f\left(m_{Al}c_{Al} + m_w c_w\right) = m_{Al}c_{Al}T_{iAl} + m_w c_w T_{iw}$$

$$T_f = \frac{m_{Al}c_{Al}T_{iAl} + m_w c_w T_{iw}}{\left(m_{Al}c_{Al} + m_w c_w\right)} = \frac{(10g)\left(0.215\frac{cal}{g-°C}\right)(80°C) + (10g)\left(1\frac{cal}{g-°C}\right)(10°C)}{(10g)\left(0.215\frac{cal}{g\bullet°C}\right) + (10g)\left(1\frac{cal}{g\bullet°C}\right)} = \frac{272cal}{12.15cal\bullet°C} = 22.4°C$$

(d) 50.0g of Lead at at 10.0 ºC is mixed with 10.0g of water at 80.0 ºC

$$m_{Pb}c_{Pb}\left(T_f - T_{iPb}\right) + m_w c_w\left(T_f - T_{iw}\right) = 0$$

$$m_{Pb}c_{Pb}T_f - m_{Pb}c_{Pb}T_{iPb} + m_w c_w T_f - m_w c_w T_{iw} = 0$$

$$T_f\left(m_{Pb}c_{Pb} + m_w c_w\right) = m_{Pb}c_{Pb}T_{iPb} + m_w c_w T_{iw}$$

$$T_f = \frac{m_{Pb}c_{Pb}T_{iPb} + m_w c_w T_{iw}}{\left(m_{Pb}c_{Pb} + m_w c_w\right)} = \frac{(50g)\left(0.031\frac{cal}{g-°C}\right)(10°C) + (10g)\left(1\frac{cal}{g-°C}\right)(80°C)}{(50g)\left(0.031\frac{cal}{g\bullet°C}\right) + (10g)\left(1\frac{cal}{g\bullet°C}\right)} = \frac{815.5cal}{10.31cal\bullet°C} = 79.1°C$$

2. Consider a double-paned window consisting of two panes of glass, each with a thickness of 0.500 cm and an area of $0.725\ \text{m}^2$, separated by a layer of air with a thickness of 1.75 cm. The temperature on one side of the window is 0.00 °C; the temperature on the other side is 20.0 °C. In addition, note that the thermal conductivity of glass is roughly 36 times greater than that of air. **(a)** Approximate the heat transfer through this window by ignoring the glass. That is, calculate the heat flow per second through 1.75 cm of air with a temperature difference of 20.0 C°. **(b)** Use the approximate heat flow found in part (a) to find an approximate temperature difference across each pane of glass.

(a) $$\frac{Q}{t} = kA\left(\frac{\Delta T}{L}\right) = \left(0.0234\ \frac{\text{W}}{\text{m}\cdot\text{K}}\right)(0.725\ \text{m}^2)\left(\frac{20.0\ \text{C}^\circ}{0.0175\ \text{m}}\right) = \boxed{19.4\ \text{J/s}}$$

(b) $$\Delta T = \left(\frac{Q}{t}\right)\left(\frac{L}{kA}\right) = \left(19.4\ \frac{\text{J}}{\text{s}}\right)\left[\frac{0.0050\ \text{m}}{\left(0.84\ \frac{\text{W}}{\text{m}\cdot\text{K}}\right)(0.725\ \text{m}^2)}\right] = \boxed{0.16\ \text{C}^\circ}$$