CH301 Fall 2008 Worksheet 12 Answer Key

1. Assume we want to use a bomb calorimeter to determine the specific heat capacity of an unknown liquid. We use 3 L of the unknown liquid and perform a known reaction that releases 400 kJ of heat. We measure an initial and final temperature of 25 °C and 28.7 °C, respectively. If the heat capacity of the calorimeter is 85 J·K^{-1}, and the density of the liquid is 2.34 g·mL^{-1}, what is the specific heat capacity of the unknown liquid?

ΔH = 400 kJ

m = 3 L * 1000 mL·L^{-1} * 2.34 g·mL^{-1} = 7020 g

$\Delta T = T_f - T_i$ = 28.7 °C - 25 °C = 3.7 °C = 3.7 K

C_{cal} = 85 J·K^{-1} * .001 kJ·J^{-1} = 0.085 kJ·K^{-1}

$\Delta H = m \cdot c \cdot \Delta T + C_{cal} \cdot \Delta T$

$c = (\Delta H - C_{cal} \cdot \Delta T)/(m \cdot \Delta T)$

= (400 kJ - 0.085 kJ·K^{-1} * 3.7 K)/(7020 g * 3.7 K)

= 0.01539 kJ·g^{-1}·K^{-1} = 15.39 J·g^{-1}·K^{-1}

2. Lets say we filled the calorimeter above with 3 L of water and performed the same known reaction above. We measured a final temperature of 57.56 °C, but forgot to measure the initial temperature. Considering the density and specific heat capacity of water are 1 g·mL^{-1} and 4.184 J·g^{-1}·K^{-1}, could we calculate what the initial temperature must have been? If so, what was the initial temperature?

Yes, we can determine T_i. We don't know the value of either ΔT or T_i, so we have two unknowns, but we also have two equations, so we can solve:

$\Delta H = m \cdot c \cdot \Delta T + C_{cal} \cdot \Delta T$ and $\Delta T = T_f - T_i$

$\Delta T = \Delta H/(m \cdot c + C_{cal})$ = 400,000 J/(3000 g * 4.184 J·g^{-1}·K^{-1} + 85 J·K^{-1})

= 32.34 K = 32.34 °C

$T_i = T_f - \Delta T$ = 57.56 °C - 32.34 °C = 25.22 °C

3. Given the following data:

$P_4(s) + 6Cl_2(g) \rightarrow 4PCl_3(l)$ ΔH = -1,225.6 kJ·mol^{-1}

$P_4(s) + 5O_2(g) \rightarrow P_4O_{10}(s)$ ΔH = -2,967.3 kJ·mol^{-1}

$PCl_3(l) + Cl_2(g) \rightarrow PCl_5(s)$ ΔH = -84.2 kJ·mol^{-1}

$PCl_3(l) + 1/2O_2(g) \rightarrow Cl_3PO(l)$ ΔH = -285.7 kJ·mol^{-1}

calculate ΔH for the reaction

$P_4O_{10}(s) + 6PCl_5(s) \rightarrow 10Cl_3PO(l)$

ΔH_{rxn} = (1 * -1,225.6 kJ·mol^{-1}) + (-1 * -2,967.3 kJ·mol^{-1}) + (-6 * -84.2 kJ·mol^{-1}) + (10 * -285.7 kJ·mol^{-1})

= -610.1 kJ·mol^{-1}

4. Given the following data:

$2O_3(g) \rightarrow 3O_2(g)$ ΔH = -427 kJ·mol^{-1}

$O_2(g) \rightarrow 2O(g)$ ΔH = 495 kJ·mol^{-1}

$NO(g) + O_3(g) \rightarrow NO_2(g) + O_2(g)$ ΔH = -199 kJ·mol^{-1}

calculate ΔH for the reaction

$NO(g) + O(g) \rightarrow NO_2(g)$

ΔH_{rxn} = (-1/2*-427 kJ·mol^{-1}) + (-1/2*495 kJ·mol^{-1}) + (1*-199 kJ·mol^{-1})

= -233 kJ·mol^{-1}

5. Hydroiodic acid (HI) and sodium hydroxide (NaOH) are a strong acid and strong base respectively. Calculate the change in enthalpy for their neutralization reaction:

$HI(g) + NaOH(s) \rightarrow NaI(s)$ and $H_2O(l)$

Consult Appendix 2 in your ebook for standard enthalpy of formation values.

$\Delta H_{rxn} = \Sigma H_{products} - \Sigma H_{reactants}$

= (-287.78 kJ·mol^{-1} + -285.83 kJ·mol^{-1}) - (26.48 kJ·mol^{-1} + -425.61 kJ·mol^{-1})

= -174.48 kJ·mol^{-1}