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 unkown liquid and perform a known reaction that releases 400 kJ of heat. We measure an initial and final temperature of 25 ºC and 28.7 ºC, respectively. If the heat capacity of the calorimeter is 85 $J{\cdot}K^{-1}$, and the density of the liquid is 2.34 $g{\cdot}mL^{-1}$, what is the specific heat capacity of the unknown liquid?

ΔH = 400 kJ
$m = 3\ L * 1000\ mL{\cdot}L^{-1} * 2.34\ g{\cdot}mL^{-1} = 7020\ g$
$\Delta T = T_f - T_i = 28.7\ ºC - 25\ ºC = 3.7\ ºC = 3.7\ K$
$c_{cal} = 85\ J{\cdot}K^{-1} * .001\ kJ{\cdot}J^{-1} = 0.085\ kJ{\cdot}K^{-1}$
$\Delta H = m{\cdot}c{\cdot}\Delta T + c_{cal}{\cdot}\Delta T$
$c = (\Delta H - c_{cal}{\cdot}\Delta T)/(m{\cdot}\Delta T)$
$= (400\ kJ - 0.085\ kJ{\cdot}K^{-1} * 3.7\ K)/(7020\ g * 3.7\ K)$
$= 0.01539\ kJ{\cdot}g^{-1}{\cdot}K^{-1} = 15.39\ J{\cdot}g^{-1}{\cdot}K^{-1}$

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 ºC, but forgot to measure the inital temperature. Considering the density and specific heat capacity of water are 1 $g{\cdot}mL^{-1}$ and 4.184 $J{\cdot}g^{-1}{\cdot}K^{-1}$, 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 equation, so we can solve:
$\Delta H = m{\cdot}c{\cdot}\Delta T + c_{cal}{\cdot}\Delta T$ and $\Delta T = T_f - T_i$
$\Delta T = \Delta H/(m{\cdot}c + c_{cal}) = 400{,}000\ J/(3000\ g * 4.184\ J{\cdot}g^{-1}{\cdot}K^{-1} + 85\ J{\cdot}K^{-1})$
$= 32.34\ K = 32.34\ ºC$
Ti = Tf - ΔT = 57.56 ºC - 32.34 ºC = 25.22 ºC

3. Given the following data:

$P_4(s) + 6Cl_2(g) \leftrightarrow 4PCl_3(g)$	$\Delta H = -1{,}225.6\ kJ{\cdot}mol^{-1}$
$P_4(s) + 5O_2(g) \leftrightarrow P_4O_{10}(s)$	$\Delta H = -2{,}967.3\ kJ{\cdot}mol^{-1}$
$PCl_3(g) + Cl_2(g) \leftrightarrow PCl_5(g)$	$\Delta H = -84.2\ kJ{\cdot}mol^{-1}$
$PCl_3(g) + 1/2O_2(g) \leftrightarrow Cl_3PO(g)$	$\Delta H = -285.7\ kJ{\cdot}mol^{-1}$

calculate ΔH for the reaction
$P_4O_{10}(s) + 6PCl_5(g) \leftrightarrow 10Cl_3PO(g)$
$\Delta H_{rxn} = (1 * -1{,}225.6\ kJ{\cdot}mol^{-1}) + (-1 * -2{,}967.3\ kJ{\cdot}mol^{-1}) + (-6 * -84.2\ kJ{\cdot}mol^{-1}) + (10 * -285.7\ kJ{\cdot}mol^{-1})$
$= -610.1\ kJ{\cdot}mol^{-1}$

4. Given the following data:

$2O_3(g) \leftrightarrow 3O_2(g)$	$\Delta H = -427\ kJ{\cdot}mol^{-1}$
$O_2(g) \leftrightarrow 2O(g)$	$\Delta H = 495\ kJ{\cdot}mol^{-1}$
$NO(g) + O_3(g) \leftrightarrow NO_2(g) + O_2(g)$	$\Delta H = -199\ kJ{\cdot}mol^{-1}$

calculate ΔH for the reaction
$NO(g) + O(g) \leftrightarrow NO_2(g)$
$\Delta H_{rxn} = (-1/2*-427\ kJ{\cdot}mol^{-1}) + (-1/2*495\ kJ{\cdot}mol^{-1}) + (1*-199\ kJ{\cdot}mol^{-1})$
$= -233\ kJ{\cdot}mol^{-1}$

5. Hyrdoiodic 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.
$\Delta H_{rxn} = \Sigma H_{f,products} - \Sigma H_{f,reactants}$
$= (-287.78\ kJ{\cdot}mol^{-1} + -285.83\ kJ{\cdot}mol^{-1}) - (26.48\ kJ{\cdot}mol^{-1} + -425.61\ kJ{\cdot}mol^{-1})$
$= -174.48\ kJ{\cdot}mol^{-1}$