NOTES #17 AP CHEMISTRY 2013/14 A. COLLINS

HOW TO SET-UP AND SOLVE CALORIMETRY PROBLEMS

I. <u>Calculating the specific heat of a metal</u> $q_{metal} = -[\, q_{H2O} + q_{cal}\,]$

$$m_{metal} \cdot c_{metal} \cdot \Delta T_{metal} = -[\,(m_{H2O} \cdot c_{H2O} \cdot \Delta T_{H2O}) + (C_{cal} \cdot \Delta T_{cal})\,]$$

$$s_{metal} = -\frac{[\,(m_{H2O} \cdot c_{H2O} \cdot \Delta T_{H2O}) + (C_{cal} \cdot \Delta T_{cal})\,]}{m_{metal} \cdot \Delta T_{metal}}$$

<u>Ex ONE</u>: A 188.0 g sample of an unknown metal at 73.00°C was placed in a constant-pressure calorimeter containing 400.00 g of water at 22.00°C. The final temperature of the system was found to be 24.00°C. Calculate the specific heat of the metal. The heat capacity of the calorimeter is 100. J/°C.
(Answer = 0.385 J/g°C)

II. <u>Using calorimetry data to calculate</u> ΔH

1. Use calorimetry data to calculate q_{rxn}. $q_{rxn} = -[\, q_{H2O} + q_{cal}\,]$

$$q_{rxn} = -[\,(m_{H2O} \cdot c_{H2O} \cdot \Delta T_{H2O}) + (C_{cal} \cdot \Delta T_{cal})\,]$$

2. Calculate $q_{rxn/g}$ or $q_{rxn/mole}$ = or ΔH° or ΔH_{rxn}

<u>Ex TWO</u>: 1.105 grams of pentane (C_5H_{12}) was combusted in a bomb calorimeter filled with 1000.0 g of water and an excess of O_2 according to the following equation:

$$C_5H_{12}\,(l) \quad + \quad 8\,O_2\,(g) \;\text{---------->}\; 5\,CO_2\,(g) \quad + \quad 6\,H_2O\,(l)$$

(a) If the heat capacity of the calorimeter is 1,800.0 J/°C and the temperature of the calorimeter and water rose from 21.22°C to 30.18°C, what is the q_{rxn}? (Answer = -53600 J)

(b) Calculate the heat released per gram of pentane. (Answer = -48500 J/g)

(c) Calculate $\Delta H°_{comb}$. (-3,500,000 J/mol)

III. Using ΔH_{rxn} or $\Delta H°$ to solve calorimetry problems.

1. Use $\Delta H°$ or ΔH_{rxn} to calculate q_{rxn}.
2. Plug q_{rxn} into calorimeter expression and solve for whatever....T_i, T_f, ΔT, C_{cal}

$$q_{rxn} = - [q_{H2O} + q_{cal}]$$

$$q_{rxn} = - [(m_{H2O} \cdot c_{H2O} \cdot \Delta T_{H2O}) + (C_{cal} \cdot \Delta T_{cal})]$$

Ex THREE: 0.600 g of B_5H_9 (s) was combusted in a calorimeter containing 1,000.0 g of H_2O. Predict ΔT of water. Ccal = 1760. J/°C. (Answer q_{rxn} = -43100 J, temp = 7.25 °C)

$$2\ B_5H_9\ (s) + 12\ O_2\ (g) \text{ ----> } 5\ B_2O_3\ (g) + 9\ H_2O\ (l) \qquad \Delta H_{rxn} = -9080\ kJ$$

PRACTICE PROBLEMS

Ex FOUR: If we were to combine 123.51 mL of 0.110M $Pb(NO_3)_{2\,(aq)}$ with 157.22 mL of 0.125 M $KI_{(aq)}$
(i). What is the balanced equation? (ii). What is the q of the process if $\Delta H°$ = -23.47 kJ/mol $_{of\ ppt}$? (Answer = -231 J)

Ex FIVE: Benzoic acid ($C_7H_6O_2$) is known to release 26.42 kJ/g when completely combusted. What is the heat capacity of a calorimeter when 7.5840 g of benzoic acid is combusted in calorimeter containing 500.00 g H_2O, and the temperature of the water and the calorimeter rose 9.98°C? (Answer q_{rxn} = -200,400 J, C_{cal} = 18,000 J/°C)

Ex SIX: 100.00 g of 38.42°C water was added to a calorimeter containing 72.45 g of 22.15°C water. The contents of the calorimeter ended up being 27.44°C. What is the heat capacity of the calorimeter? (Answer = 565 J/°C)

Ex SEVEN: A 342.50 g sample of lead (specific heat 0.159 J/g°C) was taken from a beaker of hot water at 97.1°C. The lead was placed into a calorimeter containing an unknown quantity of water at 23.1°C. The heat capacity of the calorimeter was determined in a different experiment to be 93 J/°C. What is the mass of the water in the calorimeter if the final temperature of the calorimeter and its contents becomes 29.7°C? (Answer = 110 grams)

Ex EIGHT: A bomb calorimeter was calibrated using the combustion of benzoic acid. Through this process the heat capacity of the calorimeter was determined to be 654 J/°C. If the starting temperature of the calorimeter was 22.1°C and the temperature rose to 37.4°C, how many grams of hexane (C_6H_{14}) was combusted completely? (Answer = 0.207 g hexane)

$$2C_6H_{14}(l) + 19O_2(g) \text{ -----------------> } 12CO_2(g) + 14H_2O(l) \quad \Delta H_{rxn} = -8334\ kJ$$

Ex NINE: A double displacement reaction took place in a coffee cup calorimeter that had a heat capacity of 76.4 J/°C. One reagent was 1000.00 mL of 0.990M $Pb(NO_3)_{2\,(aq)}$. The other reagent was 1117.38 mL of $KI_{(aq)}$ with an unknown molarity. Both solutions have a density of 1.030 g/mL. Both solutions started at 21.3°C. After the precipitation took place the temperature rose to 23.4°C. Assume the specific heat of each reagent is 4.184 J/g°C. If $\Delta H°$ = -23.47 kJ/mol $_{of\ ppt}$. What is the molarity of the KI solution? (Answer = 1.47 M KI)