

NOTES #17                      AP CHEMISTRY                      2013/14                      A. COLLINS  
**HOW TO SET-UP AND SOLVE CALORIMETRY PROBLEMS**

I. Calculating the specific heat of a metal

$$q_{\text{metal}} = - [ q_{\text{H}_2\text{O}} + q_{\text{cal}} ]$$

$$m_{\text{metal}} \cdot c_{\text{metal}} \cdot \Delta T_{\text{metal}} = - [ (m_{\text{H}_2\text{O}} \cdot c_{\text{H}_2\text{O}} \cdot \Delta T_{\text{H}_2\text{O}}) + (C_{\text{cal}} \cdot \Delta T_{\text{cal}}) ]$$

$$s_{\text{metal}} = - \frac{ [ (m_{\text{H}_2\text{O}} \cdot c_{\text{H}_2\text{O}} \cdot \Delta T_{\text{H}_2\text{O}}) + (C_{\text{cal}} \cdot \Delta T_{\text{cal}}) ] }{ m_{\text{metal}} \cdot \Delta T_{\text{metal}} }$$

Ex ONE: 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. Using calorimetry data to calculate  $\Delta H$

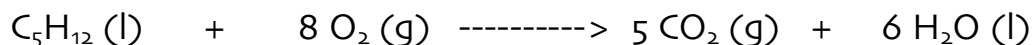
1. Use calorimetry data to calculate  $q_{\text{rxn}}$ .

$$q_{\text{rxn}} = - [ q_{\text{H}_2\text{O}} + q_{\text{cal}} ]$$

$$q_{\text{rxn}} = - [ (m_{\text{H}_2\text{O}} \cdot c_{\text{H}_2\text{O}} \cdot \Delta T_{\text{H}_2\text{O}}) + (C_{\text{cal}} \cdot \Delta T_{\text{cal}}) ]$$

2. Calculate  $q_{\text{rxn/g}}$  or  $q_{\text{rxn/mole}} =$                       or                       $\Delta H^\circ$  or                       $\Delta H_{\text{rxn}}$

Ex TWO: 1.105 grams of pentane ( $\text{C}_5\text{H}_{12}$ ) was combusted in a bomb calorimeter filled with 1000.0 g of water and an excess of  $\text{O}_2$  according to the following equation:



(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  $q_{\text{rxn}}$ ? (Answer = -53600 J)

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

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

### III. Using $\Delta H_{\text{rxn}}$ or $\Delta H^\circ$ to solve calorimetry problems.

1. Use  $\Delta H^\circ$  or  $\Delta H_{\text{rxn}}$  to calculate  $q_{\text{rxn}}$ .
2. Plug  $q_{\text{rxn}}$  into calorimeter expression and solve for whatever.... $T_i$ ,  $T_f$ ,  $\Delta T$ ,  $C_{\text{cal}}$

$$q_{\text{rxn}} = - [ q_{\text{H}_2\text{O}} + q_{\text{cal}} ]$$

$$q_{\text{rxn}} = - [ (m_{\text{H}_2\text{O}} \cdot c_{\text{H}_2\text{O}} \cdot \Delta T_{\text{H}_2\text{O}}) + (C_{\text{cal}} \cdot \Delta T_{\text{cal}}) ]$$

Ex THREE: 0.600 g of  $\text{B}_5\text{H}_9$  (s) was combusted in a calorimeter containing 1,000.0 g of  $\text{H}_2\text{O}$ . Predict  $\Delta T$  of water.  $C_{\text{cal}} = 1760. \text{ J}/^\circ\text{C}$ . (Answer  $q_{\text{rxn}} = -43100 \text{ J}$ , temp =  $7.25^\circ\text{C}$ )



## PRACTICE PROBLEMS

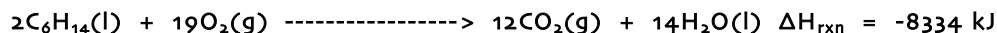
Ex FOUR: If we were to combine 123.51 mL of 0.110M  $\text{Pb}(\text{NO}_3)_2$  (aq) with 157.22 mL of 0.125 M  $\text{KI}$  (aq)  
(i). What is the balanced equation? (ii). What is the  $q$  of the process if  $\Delta H^\circ = -23.47 \text{ kJ/mol}$  of ppt? (Answer =  $-231 \text{ J}$ )

Ex FIVE: Benzoic acid ( $\text{C}_7\text{H}_6\text{O}_2$ ) 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  $\text{H}_2\text{O}$ , and the temperature of the water and the calorimeter rose  $9.98^\circ\text{C}$ ? (Answer  $q_{\text{rxn}} = -200,400 \text{ J}$ ,  $C_{\text{cal}} = 18,000 \text{ J}/^\circ\text{C}$ )

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

Ex SEVEN: A 342.50 g sample of lead (specific heat  $0.159 \text{ J/g}^\circ\text{C}$ ) was taken from a beaker of hot water at  $97.1^\circ\text{C}$ . The lead was placed into a calorimeter containing an unknown quantity of water at  $23.1^\circ\text{C}$ . The heat capacity of the calorimeter was determined in a different experiment to be  $93 \text{ J}/^\circ\text{C}$ . What is the mass of the water in the calorimeter if the final temperature of the calorimeter and its contents becomes  $29.7^\circ\text{C}$ ? (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  $654 \text{ J}/^\circ\text{C}$ . If the starting temperature of the calorimeter was  $22.1^\circ\text{C}$  and the temperature rose to  $37.4^\circ\text{C}$ , how many grams of hexane ( $\text{C}_6\text{H}_{14}$ ) was combusted completely? (Answer = 0.207 g hexane)



Ex NINE: A double displacement reaction took place in a coffee cup calorimeter that had a heat capacity of  $76.4 \text{ J}/^\circ\text{C}$ . One reagent was 1000.00 mL of 0.990M  $\text{Pb}(\text{NO}_3)_2$  (aq). The other reagent was 1117.38 mL of  $\text{KI}$  (aq) with an unknown molarity. Both solutions have a density of  $1.030 \text{ g/mL}$ . Both solutions started at  $21.3^\circ\text{C}$ . After the precipitation took place the temperature rose to  $23.4^\circ\text{C}$ . Assume the specific heat of each reagent is  $4.184 \text{ J/g}^\circ\text{C}$ . If  $\Delta H^\circ = -23.47 \text{ kJ/mol}$  of ppt. What is the molarity of the  $\text{KI}$  solution? (Answer = 1.47 M  $\text{KI}$ )