CH1020 Exercises (Worksheet 17)
(Calorimetry)

1. When a 6.50 g sample of solid sodium hydroxide dissolves in 100.0 g of water in a coffee-cup calorimeter, the temperature rises from 21.6 ºC to 37.8 ºC. Calculate ΔH (in kJ/mol NaOH) for the solution process
   $$NaOH(s) \rightarrow Na^{+}(aq) + OH^{-}(aq)$$
   Assume that the specific heat of the solution is the same as that of pure water.

$$q_{soln} = 106.5g \cdot 4.18\frac{J}{g \cdot °C} \cdot 16.2°C$$
$$q_{soln} = 7212J$$
$$\#moles = 6.5g \cdot \frac{1mol}{40.0g} = 0.1625mol$$
$$\Delta H = -7212J$$
$$\Delta H_{rxn} = \frac{-7212J}{0.1625mol} = 44381\frac{J}{mol} \cdot \frac{1kJ}{1000J} = 44.4kJmol^{-1}$$

2. Instant cold packs, often used to ice athletic injuries on the field, contain ammonium nitrate and water separated by a thin plastic divider. When the divider is broken, the ammonium nitrate dissolves according to the following endothermic reaction;
   $$NH_4NO_3(s) \rightarrow NH_4^{+}(aq) + NO_3^{-}(aq)$$

   In order to measure the enthalpy change for this reaction, 1.25 g of NH_4NO_3 is dissolved in enough water to make 25.0 mL of solution. The initial temperature is 25.8 ºC and the final temperature (after the solid dissolves) is 21.9 ºC. Calculate the change in enthalpy for the reaction in kJ. (Use 1.00 g/mL as the density of the solution and 4.18 J/goC as the specific heat capacity)

   +26.1 kJ / mol

3. When 10.4 g H_2SO_4(l) is added to 270. mL water in a coffee-cup calorimeter, the temperature rises from 22.5 ºC to 31.1 ºC. Calculate enthalpy change, ΔH (in kJ/mol H_2SO_4) for the process $H_2SO_4(l) \rightarrow H_2SO_4(aq.)$ Assume that the specific heat of the solution is the same as that of pure water.

   -95.3 kJ / mol H_2SO_4

4. When a student mixes 50 mL of 1.0 M HCl and 50 mL of 1.0 M NaOH in a coffee-cup calorimeter, the temperature of the resultant solution increases from

21.0 °C to 27.5 °C. Calculate the enthalpy change for the reaction, assuming that the calorimeter loses only a negligible quantity of heat, that the total volume of the solution is 100 mL, that its density is 1.0 g/mL, and that its specific heat is 4.18 J/g-K

$$mass_{solution} = 100mL \cdot 1\tfrac{g}{mL} = 100g$$
$$q_{\text{soln}} = 100g \cdot 4.18Jg^{-1o}C^{-1} \cdot (27.5\,^{\circ}\text{C} - 21\,^{\circ}\text{C})$$
$$q_{\text{soln}} = 2717\ J$$
$$q_{rxn} = -2717J$$

$$\#\text{moles(HCl)} = 1\ mol/L \cdot 0.05\,L = 0.05\,mol$$

(you could have also used moles NaOH in this case; you are calculating the enthalpy for the reaction)

$$\Delta\text{H}_{rxn} = \frac{-2717J}{0.05\,mol} = -54.3kJ/mol$$

5. Calculate the ΔH_{rxn} for the following reaction. When 50.0 mL of 0.100 M $AgNO_3$ is combined with 50.0 mL of 0.100 M HCl in a coffee-cup calorimeter, the temperature changes from 23.40 °C to 24.21°C. Assume that the density of the solution is 1.0 g/mL, and that its specific heat is 4.18 J/g-K.

   $AgNO_3(aq) + HCl(aq) \rightarrow AgCl(s) + HNO_3(aq)$

   -68 kJ/mol

6. When 25.0 mL of 0.500 M H_2SO_4 is added to 25.0 mL of 2.00 M KOH in a coffee-cup calorimeter at 23.50 °C, the temperature rises to 30.17°C. Calculate ΔH of this reaction per mole of H_2SO_4 reacted. (Assume the total volume is the sum of the individual volumes and that the density is 1.00 g/mL and specific heat capacity of solution is 4.184 J/g°C).

   – 112 kJ/mol H_2SO_4

7. When 1.550 g of liquid hexane (C_6H_{14}) undergoes combustion in a bomb calorimeter, the temperature rises from 25.87°C to 38.13°C. Find ΔE_{rxn} for the reaction in kJ/mol hexane. The heat capacity of the bomb calorimeter, determined in a separate experiment, is 5.73 kJ/°C.

   -3.91 x 10^3 ***kJ/mol*** C_6H_{14}

8. A 0.1964 g sample of quinone ($C_6H_4O_2$) is burned in a bomb calorimeter that has a heat capacity of 1.56 kJ/°C. The temperature of the calorimeter increases by 3.2 °C. Calculate the energy of the combustion of quinone per gram and per mole.

-25 kJ /g   -2700 kJ / mol

9. A 1.80 g sample of octane, C_8H_{18}, was burned in a bomb calorimeter whose total heat capacity is 11.66 kJ/°C. The temperature of the calorimeter plus contents increased from 21.36 °C to 28.78 °C. What is the heat of combustion per gram of octane? Per mole of octane?

$$q_{cal} = 11.66\,kJ\,°C^{-1} \cdot \left(28.78°C - 21.36°C\right) = 86.51\,kJ$$

$$heat\ of\ combustion\ per\ gram = \frac{86.51\,kJ}{1.80\,g} = 48.06\,kJ\,g^{-1}$$

$$\#\,of\ moles = \frac{1.8\,g}{114.2\,g \cdot mol^{-1}} = 0.01576\,mol$$

$$\Delta H_{rxn} = \frac{86.51\,kJ}{0.01576\,mol} = 5489\,kJ\,mol^{-1}$$

10. Mothballs are composed primarily of the hydrocarbon, naphthalene ($C_{10}H_8$). When 1.25 g of naphthalene burns in a bomb calorimeter, the temperature rises from 24.25°C to 32.33 °C. Find ΔE_{rxn} for the combustion of one mole of naphthalene. The heat capacity of the calorimeter, determined in a separate experiment, is 5.11 kJ/°C.

-4.23 x 10³ kJ / mol