Lab Session 9, Experiment 8: Calorimetry, Heat of Reaction

Specific heat is an intensive property of a single phase (solid, liquid or gas) sample that describes how the temperature of the sample changes as it either absorbs or loses heat energy. Specific heat is generally a function of temperature, but, to a good approximation, it can be treated as being constant for a single phase over a moderate temperature range. The table below lists the specific heats at 25^{o}C of liquid water and selected metal solids.

The Zeroth Law of Thermodynamics states: "If two samples of matter, initially at different

We can possibly identify an unknown metal by determining its specific heat using the preceding heat exchange formula with the specific heat of water taken to be 4.184 J/g ^{o}C. From the table above, it is obvious that we cannot distinguish between copper and zinc, or between chromium and nickel, on the basis of specific heat alone. Additional information is needed, such as color. (Copper has the characteristic "copper" color, whereas zinc is gray.) Rearranging the heat exchange formula and inserting the specific heat of water gives

$$\text{sp ht}_{\text{metal}} = \frac{(m_{\text{water}})(T_F - T_C)(4.184\ \text{J/g°C})}{(m_{\text{metal}})(T_H - T_F)}.$$

A major source of error in the preceding example is

4.184 J/g °C, without introducing much error. We can also assume that the density of the dilute salt solution is that of water, 1.00 g/mL. The heat exchange equation in this case is:

heat given off by the reaction = heat gained by the water

+ heat gained by the calorimeter and surroundings.

If the calorimeter, the HCl solution, and the NaOH solution all start at the same initial temperature T_I and warm to a final temperature T_F, then

heat given off by the reaction = $(m_{water})(T_F - T_I)(4.184 \text{ J/g °C}) + (\boldsymbol{C})(T_F - T_I)$

$= [(V_{water} \text{ in mL})(1.00 \text{ g/mL})(4.184 \text{ J/g °C}) + (\boldsymbol{C})](T_F - T_I)$.

(Note: V_{water} = 100 mL)

At constant pressure, the heat given off by the reaction is equal to the change in enthalpy (ΔH) for the reaction. Since the reaction involves $(2.00 \frac{\text{mol}}{\text{L}}) \frac{10^{-3}\text{ L}}{1\text{ mL}}$ (50.0 mL) = 0.100 mol of HCl = 0.100 mol of NaOH, we can calculate the change in enthalpy for the acid/base reaction as follows (the minus sign is inserted to indicate that the reaction is exothermic):

$$\Delta H = \frac{-\text{(heat) J}}{0.100\text{ mol}} \quad \frac{1\text{ kJ}}{10^3\text{ J}} = \frac{-\text{(heat)}}{100} \text{ in kJ/mol.}$$

8A Experiment: Determination of Calorimeter Constant

1. Obtain or assemble a calorimeter as shown in Figure 9. The experiment will require two thermometers, one for the calorimeter and one for the heated water.

2. Using a graduated cylinder, measure 50.0 mL of water and pour it into the calorimeter. Measure an additional 50.0 mL of water and pout it into a clean, previously dried beaker.

3. One lab partner should stir the calorimeter contents for at least 5 minutes and then record the temperature inside the calorimeter as T_C.

4. Meanwhile, the other lab partner should heat (bunsen burner) and stir the water in the beaker until it reaches a temperature of 55-60 ^{o}C. After removing the burner, stir and record the exact temperature of the water in the beaker as T_H.

5. At that point, pour the hot water into the calorimeter, replace the top and stir the contents well while recording the temperature at 15 second intervals. The highest temperature should occur within 2 minutes. Record this maximum temperature as T_F.

6. Calculate the heat capacity ***C*** of the calorimeter in J/^{o}C using the formula given in the preceding section with $m_H = m_C$ = (50.0 mL)(1.00 g/mL) = 50.0 g.

7. Repeat steps 1 through 6 in order to make a second determination of ***C***. Reverse the thermometers for the second determination of ***C***.

First Determination of ***C***		Second Determination of ***C***	
T_C =	°C	T_C =	°C
T_H =	°C	T_H =	°C
Temperature inside calorimeter at 15 s intervals:		Temperature inside calorimeter at 15 s intervals:	
°C	°C	°C	°C
°C	°C	°C	°C
°C	°C	°C	°C
°C	°C	°C	°C
°C	°C	°C	°C
°C	°C	°C	°C
T_F =	°C	T_F =	°C
C =	J/°C	***C*** =	J/°C
		Average ***C*** =	J/°C

8B Experiment: Determination of Reaction Enthalpy

1. Dry the calorimeter and reassemble it.

2. Using a clean, dry graduated cylinder, measure 50.0 mL of a 2.0 M aqueous NaOH solution and pour it into the calorimeter. (*Caution*: NaOH is corrosive and, if spilled on the skin, should be washed away immediately with copious amounts of water.)

3. Using a clean, dry graduated cylinder, measure 50.0 mL of a 2.0 M aqueous HCl solution and pour it into a clean, dry beaker. (*Caution*: HCl is corrosive and, if spilled on the skin, should be washed away immediately with copious amounts of water.)

4. Stir the two solutions (the NaOH (aq) in the calorimeter, and the HCl(aq) in the beaker) until they exhibit the same temperature. Record this temperature as T_I.

5. Pour the HCl solution into the calorimeter, replace the top, and stir while recording the temperature at 15 second intervals.

6. Record the highest temperature reached as T_F.

8C Exercises

1. Suppose that one were to mix 30.0 g of aluminum pellets, originally at 97.0 ^oC, with 100 grams of water, originally at 23.0 ^oC, in a perfect calorimeter. What will be the equilibrium temperature T_F in the calorimeter? T_F = ____________ ^oC.

2. Repeat the calculation of Exercise 1, but in the calorimeter you used in lab rather than in a perfect calorimeter. T_F = ____________ ^oC.

3. When 100 g of an unknown metal at 98.0 ^oC were mixed in a perfect calorimeter with 50.0 g of water at 22.0 ^oC, the final temperature T_F was observed to be 26.4 ^oC. Presuming that the metal is one of those listed in the table of specific heats given above, which one is it?
   Unknown metal = _______________.

Report Form 8: Calorimetry, Heat of Reaction

Name____________________________________
Partner_____________________Section #_____

8A Experiment: Determination of Calorimeter Constant

First Determination of ***C***		Second Determination of ***C***	
T_C =	°C	T_C =	°C
T_H =	°C	T_H =	°C
Temperature inside calorimeter at 15 s intervals:		Temperature inside calorimeter at 15 s intervals:	
°C	°C	°C	°C
°C	°C	°C	°C
°C	°C	°C	°C
°C	°C	°C	°C
°C	°C	°C	°C
°C	°C	°C	°C
T_F =	°C	T_F =	°C
C =	J/°C	***C*** =	J/°C
		Average ***C*** =	J/°C

8B Experiment: Determination of Reaction Enthalpy

First Determination of ΔH		Second Determination of ΔH	
T_I =	°C	T_I =	°C
Temperature inside calorimeter at 15 s intervals:		Temperature inside calorimeter at 15 s intervals:	
°C	°C	°C	°C
°C	°C	°C	°C
°C	°C	°C	°C
°C	°C	°C	°C
°C	°C	°C	°C
°C	°C	°C	°C
T_F =	°C	T_F =	°C
heat =	J	heat =	J
ΔH =	kJ/mol	ΔH =	kJ/mol
		Average ΔH =	kJ/mol
% error = [(|ΔH| - |55.8|)/55.8] x 100 =			%

8C Exercises

1. T_F = ________________°C.
2. T_F = ________________°C.
3. Unknown metal = ________________ .