Introduction to Natural Science (2006/07)

Spring 2007 Quarter

Chemistry Lab I: Thermochemistry

Prepared by: Dr. Dharshi Bopegedera

Experiment I: Determination of the enthalpy of neutralization of and acid-base reaction

We will use constant pressure calorimetry to determine the enthalpy change for the reaction between hydrochloric acid and sodium hydroxide. The calorimeter we will use is a homemade device made of Styrofoam coffee cups. We will compare the experimental value for the enthalpy of neutralization obtained in the lab to theoretical values calculated using standard tables.

Pre-Lab Assignment:

1. In an acid-base neutralization reaction 50.00 ml of 2.00M HCl was mixed with 50.00 ml of 2.00M NaOH. Calculate the number of moles of HCl (aq) and NaOH (aq) in the above samples. Also calculate the number of moles of each of the products formed by the above reaction.

2. Is there a limiting reagent for the above reaction? If so, which one? Which one is the excess reagent? Show all work.

3. Using $\Delta H_f°$ values, calculate the enthalpy of neutralization for the reaction between 1 mole of HCl and 1 mol of NaOH. Refer to standard tables in your chemistry text to obtain $\Delta H_f°$ values. **Show all work.**

4. Is this reaction endothermic or exothermic? Why?

5. Draw a diagram of a "coffee cup calorimeter". Refer to your chemistry text if you need help.

Lab Assignment: **Do this lab in pairs.**
Obtain following supplies.

- Three Styrofoam coffee cups
- Magnetic stir bar
- Magnetic stirrer
- Thermometer set up connected to Vernier software

1. To a clean beaker, obtain 50.00 ml of 2.00M HCl. Weigh the beaker (analytical balance) after the HCl is placed in it and record the weight. Label the beaker.

2. To a second clean beaker obtain 50.00 ml of 2.00M NaOH. Weigh the beaker (analytical balance) after the NaOH is placed in it and record the weight. Label the beaker.

3. Nest one Styrofoam cup in another and pour the HCl into a Styrofoam coffee cup. **Do not clean or discard the beaker that contained HCl.** Use the third Styrofoam cup to make a cover for the cups containing the acid (this will be shown in lab). You also need to make a hole in the cover to insert the thermometer (as shown in lab). Now you have a "coffee cup calorimeter". Put the bar magnet into this calorimeter. Start recording the temperature of the contents in the coffee cup calorimeter using the data recording system as shown in lab. **Record the temperature every 15 seconds.**

4. After about 2 minutes, while continuing stirring and recording the temperature, pour all of the NaOH into the coffee cup calorimeter quickly and close the cover. **Do not discard or clean the beaker containing NaOH.**

5. Continue to record the temperature every 15 seconds. You will notice that upon the addition of NaOH the temperature rises quickly and then begins to slowly taper off. When the temperature tends to go down again (a slow process), record for another 2 minutes and stop.

6. Weigh the empty HCl and NaOH beakers using the analytical balance. Record this data.

<u>Post lab Assignment:</u>

1. Calculate the weights of HCl and NaOH used in this experiment.

2. Without doing calculations, determine if this is an exothermic reaction or an endothermic reaction. State the reasons for your decision.

3. Using the temperature curve, determine ΔT for this reaction (instructions will be given in class). Report in units of Kelvin.

4. The products of the reaction are NaCl and water. Since there is very little NaCl, we can assume that the entire product is "water". Calculate the heat absorbed by "water" when the reaction was completed. In order to do this, you need to know the mass of "water" [take this as the mass of HCl (aq) + the mass of NaOH (aq)] and the specific heat of water (look up in standard tables or your chemistry text book).

5. Use the above information to calculate the enthalpy change for the reaction between HCl and NaOH.

6. Because the base neutralizes the acid, the enthalpy change for this reaction is called the "enthalpy of neutralization". It is commonly given the symbol $\Delta H_{neutralization}$. Now calculate the enthalpy of neutralization for one mole of HCl reacting with one mole of NaOH.

7. Compare the value you obtained above, to the theoretical value you calculated in the pre-lab assignment. Calculate the percentage error. Show all work.

$$\text{Percentage error} = \left[\frac{\text{experimental value} - \text{theoretical value}}{\text{theoretical value}} \right] 100\%$$

8. Give reasons for the above error.

Experiment II: Determination of the calorie content in nuts using bomb calorimetry

Bomb calorimetry (constant volume calorimetry) is often used to determine the calorie content in food products. In this experiment, we will use this technique to determine the calorie content of nuts.

Pre-Lab Assignment:
Draw a block diagram of a bomb calorimeter. Refer to your chemistry text for help. Label the important components clearly.

Lab Assignment: **Do this lab in pairs.**

You will be given instructions on how to operate the bomb calorimeter.

1. Select a nut (use forceps only to handle it) and weigh it using the analytical balance.

2. Measure out about 10 cm of the wire provided for the bomb calorimeter. Record the exact length of the wire.

3. Place the nut in the bomb calorimeter as directed in lab.

4. Place 1.00 ml of distilled water into the bomb as directed in lab.

5. Place 2000.0g of distilled water into the outer chamber of the bomb calorimeter as directed in lab.

6. Record the initial temperature of water as directed in lab. Continue recording the temperature for about 2 minutes.

7. Ignite the nut inside the calorimeter while continuing to record the temperature.

8. You will note that the temperature will increase and then begin to taper off. Continue recording the temperature for another 2 minutes. Save and print the temperature data (raw data as well as the temperature vs. time graph).

9. Disassemble the bomb calorimeter. Remove any left over wire and measure the unburned length of the wire carefully. Record this in your lab notebook.

10. Read the nutrition label on the nut package carefully. Write down the calorie content of nuts as reported on the label. Write down the brand name on the package.

11. Collect data from students who did this experiment with other nuts. Be sure to read the nutrition label on the nut packages carefully. Write down the calorie content of nuts as reported on the label. Write down the brand name on the packages.

<u>Post-Lab Assignment:</u>

For your data only:

1. Note that the bomb and the water in the calorimeter absorb heat. Calculate the heat absorbed by the water in the calorimeter (in Joules).

2. Calculate the heat absorbed by the bomb. In order to do so, you need the calorimeter constant and the temperature change. The value of the calorimeter constant will be given to you in lab.

   Note:
   calorimeter constant = (specific heat of the bomb) (mass of the bomb)
   heat absorbed by the bomb = (calorimeter constant) (ΔT in Kelvin)

3. The heat absorbed by the bomb and water came from the combustion of the nut and the combustion of the wire. Assuming that there is no heat loss to the environment, calculate the heat given off by the nut during its combustion (in calories).

4. Calculate the calories per gram of nut.

5. Calculate the kilocalories per gram of nut. Then express your answer in food calories. Note that a chemist's calorie is given the symbol cal, a kilocalorie is given the symbol kcal and a food calorie is given the symbol Cal. Also 1000 cal = 1kcal = 1 Cal

6. Compare the value you obtained above, with the calorie content reported on the nut package. You may have to do additional calculations in order to make a reasonable comparison. Calculate the percentage error.

$$\text{Percentage error} = \left[\frac{\text{experimental value - recorded value on the package}}{\text{recorded value on the package}}\right]100\%$$

7. Suggest reasons for the above error.

8. Now repeat the above steps for the other nuts collected by other students.

9. Compare the calorie content in all the nuts analyzed by your class.

Experiment III: Determination of the specific heat capacities of metals

Adopted from: Mary Laing & Michael Laing, Journal of Chemical Education, *83*, 1499, October 2006.

The specific heat capacity of a metal (*c*), is defined as the amount of energy required to raise the temperature of 1 gram of metal by 1°C. It is a characteristic physical property of a metal similar to its density and melting point. In this lab, we will set up an experiment to determine the specific heat capacity of metals. We will then compare them with the specific heat capacities calculated using Dulong-Petit Law.

Pre-lab Assignment:

1. You are provided with the following data pertaining to metallic elements. Draw a graph of specific heat capacity (y axis) as a function of the atomic weight (x axis) using Microsoft Excel. If this is not a linear graph try other relationships until you get a linear graph (for example you can try specific heat capacity versus 1/atomic weight and other such combinations). Once you get a line graph, draw a line of best fit and use Excel to print the equation of the line and the R^2 value on your graph. Print all the graphs you generated and bring to lab.

Metal	**Atomic Weight (g/mol)**	**Specific heat capacity ($J\ g^{-1}K^{-1}$)**
Li	6.9	3.582
K	39.1	0.757
Mg	24.3	1.023
Ca	40.1	0.647
Al	27	0.897
Sc	45	0.568
Y	88.9	0.298
La	138.9	0.195
Ce**	140.1	0.192
Sm	150.3	0.197
Eu	152	0.182
Yb	173	0.155
Lu	175	0.154
Ti	47.9	0.523
Zr	91.2	0.278
Hf	178.5	0.144
V	50.9	0.489
Cr	52	0.449
Mo	95.9	0.251
Mn	54.9	0.479
Fe	55.8	0.449
Ru	101.1	0.238
Co	58.9	0.421
Rh	102.9	0.243

Ni	58.7	0.444
Pd	106.4	0.246
Pt	195.1	0.133
Cu	63.5	0.385
Ag	107.9	0.235
Au	197	0.129
Zn	65.4	0.388
Cd	112.4	0.232
Hg	200.6	0.14
Ga	69.7	0.371
In**	114.8	0.233
Sn	118.7	0.228
Pb	207.2	0.129
Sb	121.7	0.207
Bi	209	0.122
Th	232	0.113
U**	238	0.116

** The atomic weights of these three elements were corrected by Mendeleev in 1870 by the method of Dulong and Petit

2. Use the linear graph you obtained above to calculate the specific heat capacities of mercury and bismuth. Using the CRC Handbook, obtain values for the specific heat capacity of mercury and bismuth and determine percentage error. State your reference correctly.
3. Use the data given in the spreadsheet to calculate the molar heat capacity (in J mol^{-1} K^{-1}). Determine if there is a relationship between the atomic weight and the molar heat capacity of metals. This relationship is known as the Dulong and Petit's Law named after French chemists Pierre Louis Dulong and Alexis Thérèse Petit. Print out your spreadsheet and attach to pre-lab assignment.
4. What is Dulong and Petit's Law? Use a reference (a book is preferred over a web site) to find your answer and cite the reference correctly.

<u>Lab Assignment **(do this lab in pairs)**</u>

5. Weigh a test tube to the nearest mg.
6. Place pellets of the metal into the test tube to a depth of about 30 mm, and reweigh the test tube to the nearest mg.
7. Heat the tube containing the metal pellets in a bath of boiling water, as shown in the following figure for at least 15 mins.
8. Record the temperature of the boiling water accurately.
9. Using some ice chips, cool about 50 ml of water to about 10° below room temperature.
10. Accurately weigh approx 50 ml of this cold water into the nested polystyrene cup calorimeter. Record the temperature of the water accurately.
11. Pour the hot metal pellets into the cold water, while stirring gently with the thermometer. Note the highest temperature attained as accurately as possible.
12. Note the physical properties of your metal sample.

13. Repeat with one more metal if you have time.
14. Obtain data for at least two other metals from classmates before you leave the lab.

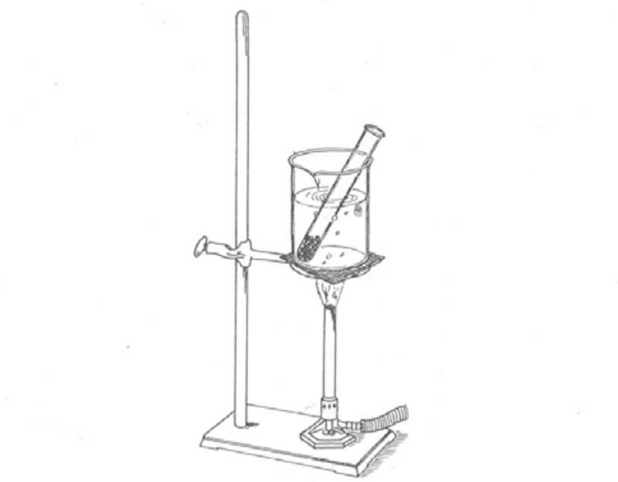

Fig A Arrangement for heating the sample of metal

Fig B Coffee-cup calorimeter

<u>Post-lab Assignment</u>

1. For all the data (yours and others you borrowed) determine the specific heat capacity of the metals.
2. Using Dulong and Petit's Law determine the atomic weight of each of the metals.
3. Use the atomic weight as well as the physical properties of your metals to identify the metals in the sample.
4. Sodium is a metal that reacts violently with water. Describe how you would use the spreadsheet data from your pre-lab only to determine its specific heat capacity.
5. Describe how you would use your experience from this lab only to determine the specific heat capacity of sodium.