Heat of Neutralization Lab AP Chemistry

Objective: To measure, using a calorimeter, the energy change accompanying neutralization reactions.

Introduction: Every chemical change is accompanied by a change in energy, usually in the form of heat. The energy change of a reaction that occurs at constant pressure is termed the *heat of reaction* or *the enthalpy change*. The symbol ΔH is used to denote the enthalpy change. In this experiment, you will measure the heat of neutralization when an acid and base react to form 1 mole of water.

This quantity of heat is measured experimentally by allowing the reaction to take place in a thermally insulated Styrofoam cup calorimeter. The heat liberated in the neutralization reaction will cause an increase in the temperature of the solution and of the calorimeter. The heat lost by the neutralization reaction will equal the heat gained by the water and calorimeter. Because we are concerned with the heat of the reaction and because some heat is absorbed by the calorimeter itself, in the first part of this lab, we will determine the heat capacity of the calorimeter. This will be done by measuring the temperature change that occurs when a known amount of hot water is added to a known amount of cold water in the calorimeter. The heat lost by the water is equal to the heat gained by the cold water and the calorimeter.

Once the heat capacity of the calorimeter is determined, we will then determine the heat released in the neutralization reaction as instructed in the procedure.

Pre-lab Question: Have these questions done BEFORE you come to lab.

1. Given the following data, calculate the heat capacity of the calorimeter. This calculation mirrors what you will need to do in part A of the lab.

Temperature of 50 mL of warmer water:	37.9° C
Temperature of 50 mL of cooler water:	20.9° C
Temperature after mixing:	29.1° C
Specific heat of water:	4.184 J/g°C
Density of water:	1.00 g/mL

   Q(lost by warm water) = -[q(gained by cold water) + q(gained by calorimeter)]
2. The specific heat of a solution is 4.184 J/g°C and its density is 1.02g/mL. The solution is formed by combining 20.0 mL of solution A with 30.0 mL of solution B, both initially at 21.4° C. The final temperature is 25.3° C. calculate the heat of reaction (qrxn) assuming that no heat is lost to the calorimeter. Watch your sig figs!
3. In problem #2, the calorimeter has a heat capacity of 8.20 J/°C. If you include a correction for the heat absorbed by the calorimeter, qcal, what would the new heat of reaction, qrxn, be?
4. What is the difference between specific heat and heat capacity?

Procedure:

PART A: *Determine Heat Capacity of Calorimeter*

Construct a calorimeter by nesting two fast food cups in a 400-mL beaker to provide stability. The calorimeter lid should have a slit to hold a thermometer. Place close to 50.0mL of tap water in the calorimeter cup and replace the cover and thermometer, be sure that the thermometer is not resting on the bottom of the calorimeter. Leave the thermometer in the calorimeter.

Measure close to 50.0mL of warm water from the sink at the front of the room. This water should be 15 to 20 degrees Celsius above room temperature. Allow the hot water to stand for a minute or two, using another thermometer, quickly record its temperature and pour its contents completely into the calorimeter. Replace the lid (incorporated with the thermometer) and carefully swirl the calorimeter. Observe the temperature for the next three minutes. You should see the temperature go up sharply and then, after a short time, it will start to cool back down (losing heat to surroundings). Record in your data table the absolute HIGHEST temperature that you note. Calculate the heat capacity of the calorimeter.

PART B: *Determine the Heat of Neutralization (*$\Delta H°$) of HCl + NaOH

Dry the calorimeter and thermometer with paper towel. Measure out 50.0mL of 1.0M NaOH and add it to the calorimeter. Place the lid on the calorimeter but leave the thermometer out. Measure out exactly 50.0mL of HCl into a dry graduated cylinder. Allow it to stand near the calorimeter for about 3 minutes. Measure the temperature of the acid. Rinse the thermometer with tap water and wipe dry. Insert the thermometer into the calorimeter and measure the temperature of the NaOH solution.

The temperature of the NaOH and the HCl should not differ by more than 0.5° C. If the difference is greater than that, adjust the temperature of the HCl by either warming it by holding the graduated cylinder in your hand or cooling the outside with tap water until the temperature is within 0.5° C of the NaOH.

Record the temperature of the NaOH solution. Lift the lid carefully and add the 1M HCl all at once. Be careful not to splash any on the upper side of the cup. Swirl the solution (gently) and observe the temperature for the next 3 minutes. Record the absolute HIGHEST temperature that you note. Calculate the heat of neutralization per mole of water formed. You may assume that the NaCl solution has the same density and specific heat as water. [Note: this is not exactly true, it may be useful when explaining your errors.**]
Contents of calorimeter can safely be poured into the sink. Be sure to clean out your calorimeter.

Data:

PART A:		PART B:	
Volume of water in calorimeter	mL	Molarity of NaOH soln.	_____M
Initial Temp. of calorimeter/water before mixing	° C	Molarity of HCl soln.	_____M
Volume warm water added	mL	Volume of NaOH used in calorimeter	mL
Initial temp. warm water	° C	Volume of HCl soln. Added	mL
Final temp. combined water/calorimeter	° C	Temp. of calorimeter and NaOH before mixing	° C
Density of water	1.00g/mL	Temp. of HCl	° C
Specific Heat of water	4.184 J/g°C	Density of reaction mixture soln.	1.00 g/mL**
		Specific heat of reaction mixture	4.184 J/g°C
		Temp. after mixing	° C

Calculations: SHOW YOUR WORK AND LABEL EVERYTHING!

1. Using the equation: q(lost by warm water) = -[q(gained by cold water) + q(gained by calorimeter)], solve for the heat gained by the calorimeter. After this, determine the heat capacity of the calorimeter (the heat needed to raise the temperature of the calorimeter 1 degree Celsius). C = -q/ΔT. Be sure that ΔT only refers to the change in temperature of the calorimeter!
2. Now using the equation qrxn = -[qsoln + qcal], calculate the heat released in the neutralization reaction, q rxn.

$$HCl\ (aq) + NaOH\ (aq) \rightarrow H_2O\ (l) + NaCl\ (aq)$$

3. But, we are interested in the heat released per the coefficient of the balanced equation mole, ΔH_{rxn}.
$\Delta H_{rxn} = q_{rxn}$/mol of water. Since you are given amounts of both reactions and products, you need to think a little about limiting reactants before you get too far!!

Conclusion: The theoretical (accepted) ΔH_{rxn} for this neutralization reaction is -56.2 kJ. (What is your value?).

Error Analysis: Be sure to calculate a percent error for your calculation… Be specific about your errors!

Discussion of Theory: 1) Discuss the heart of the lab… major theory or take home messages. 2) Describe the theoretical basis for the calculations you did.