INS Chemistry lab for weeks 3 and 4.
Measurement of Heats of Reaction.

Useful preparatory reading: review the definition for enthalpy from chapter 5 and the calorimetry described in section 5.5. Our experimental apparatus will be much like figure 5.18. You can also go through the calculations involved in the data analysis sections in advance. Note that the convention in heats of formation for aqueous solutions is for 1 M solutions.

The goal for today's lab is to measure (working in pairs) the enthalpy change for two different reactions. The first is the heat of neutralization of an acid and a base. The second will be the enthalpy change observed on the dissolving of a salt. (This is also known as the heat of solution.) At the start of the lab we will go through the software we use to produce a graph of time versus temperature.

Part I: Lab procedure for the heat of neutralization

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.
7. Repeat this process to obtain a second data set.

Data analysis:

1. Calculate the weights of HCl and NaOH solutions used in this experiment. How many moles of products and reactants were produced in this reaction?

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. Using the tabulated data from your text, estimate the theoretical enthalpy change for the neutralization reaction of sodium hydroxide and hydrochloric acid.
8. Compare the value you obtained above, to the theoretical value you estimated. Calculate the percentage error.

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

9. Give possible reasons for the above error.

Part II: Measurement of the heat of solution.

The materials used and setup are similar to part I. We have a set of pure salts and your group will be assigned one of them.

1. Set up your calorimeter with a known mass of water. (I would start with 50.00 ml; this may need to be adjusted.)
2. Set up the temperature monitoring system and obtain at least 2-4 minutes of time and temperature data from your water.
3. Weigh out about 5 g (analytical balance accuracy) of your salt.
4. Transfer your salt to your calorimeter and monitor time and temperature as in step 5 of the neutralization experiment.

Data Analysis for part II.

1. Find the number of moles of your salt that was added.
2. Without calculation, was your reaction endothermic or exothermic?
3. Find ΔT for this reaction.
4. Here the products of the reaction are the solvated cations and anions of your salt. To estimate heat capacity of dilute aqueous solutions, a useful approximation is that heat capacity is proportional to density. In this example, treat the heat capacity as that of water, but add the mass of the added salt to your water. (For

example, the heat capacity of 50 g of water and 5 g of salt is about the same as that of 55 g of water.)

5. You can estimate the theoretical heat of solution by tabulated data. Here, the starting material is your salt in solid form, and the products are the aqueous ions.