Dougherty Valley HS Chemistry - AP
Thermochemistry – Determining the Enthalpy of a Reaction

Worksheet #7

Name: **Period:** **Seat#:**

Required Sections: (Refer to R-15 for guidelines and requirements. Make note of any specific changes given by your teacher in class.)

Prelab: Purpose, Prelab Task, Materials, Reagent Table, Procedures, and set up Data Tables before you get to class.
During Lab: Data section – Fill out your data table that is already set up from the prelab.
Post-lab: Calculation section, Discussion Questions Section (both done in lab notebook), Post-Lab Two Pager (done on separate worksheet).

REMINDER - USE R-15 TO ENSURE YOU FOLLOW ALL GUIDELINES/EXPECATIONS/ REQUIREMENTS

Introduction

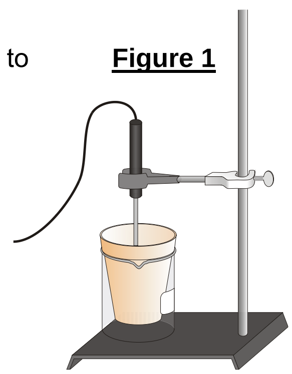
All chemical reactions involve an exchange of heat energy; therefore, it is tempting to plan to follow a reaction by measuring the enthalpy change (ΔH). However, it is often not possible to directly measure the heat energy change of the reactants and products (the system). We can measure the heat change that occurs in the surroundings by monitoring temperature changes. If we conduct a reaction between two substances in aqueous solution, then the enthalpy of the reaction can be indirectly calculated with the following equation.

$$q = m \times C_p \times \Delta T$$

The term q represents the heat energy that is gained or lost, m is the mass of water C_p is the specific heat of water, and ΔT is the temperature change of the reaction mixture. The specific heat and mass of water are used because water will either gain or lose heat energy in a reaction that occurs in aqueous solution. Furthermore, according to a principle known as Hess's law, the enthalpy changes of a series of reactions can be combined to calculate the enthalpy change of a reaction that is the sum of the components of the series.

In this experiment, you will measure the temperature change of two reactions, and use Hess's law to determine the enthalpy change, ΔH of a third reaction. You will use a Styrofoam cup nested in a beaker as a calorimeter, as shown in Figure 1. For purposes of this experiment, you may assume that the heat loss to the calorimeter and the surrounding air is negligible.

Figure 1



Objectives

- Use Hess's law to determine the enthalpy change of the reaction between aqueous ammonia and aqueous hydrochloric acid.
- Compare your calculated enthalpy change with the experimental results.

Prelab Task

You will conduct the following three reactions in this experiment. In 3 tables like the one shown below, finish writing the overall balanced equation and the balanced net ionic reactions, include any products not listed. Use the table of thermodynamic data from reference sheet R-19, to calculate the molar enthalpy of the reactions. *Hints* - Which reaction is actually happening – the overall, or the net ionic? Use THAT equation to do your Enthalpy calculation.
And remember...Products minus Reactants! Show your work.

Rxn 1: NaOH(aq) + HCl(aq) → H_2O(l) +
Rxn 2: NaOH(aq) + NH_4Cl(aq) → NH_3(aq) + H_2O +
Rxn 3: HCl(aq) + NH_3(aq) → NH_4Cl(aq) *(rxn 3 is already finished for you, write it in your chart and do the net ionic)*

Reaction #1	
Balanced Overall Equation	
Balanced Net Ionic Equation	
Molar Enthalpy of Reaction Calc. using R-19 data	

Materials – *don't forget to use an MSDS to do your reagent table!*

Chemicals
- 2.0 M hydrochloric acid, HCl
- 2.0 M sodium hydroxide, NaOH
- 2.0 M ammonium chloride, NH_4Cl
- 2.0 M ammonia, NH_3 (the NH_3 becomes NH_4OH in water, so the bottle may say NH_4OH, that's ok!)

Equipment
- Vernier computer interface
- Temperature Probe
- Styrofoam cup
- 250 mL beaker x 2
- 600 mL beaker
- 50 mL graduated cylinder
- Stir bar and stir bar retriever
- Stir plate
- Ring stand
- Utility clamp
- Distilled H_2O

SAFETY PRECAUTIONS
Handle the chemicals with care. They can cause painful burns if they come in contact with the skin. Alert your instructor if you get any of these chemicals on your skin during the lab.

Procedure – *Remember to make a flow chart, include diagrams/drawings of steps/equipment etc. Google "flow chart procedures" if you are not familiar with how to make a flow chart. You aren't just drawing boxes around all your sentences!*

NOTE - You will use the 250mL beaker to get your chemicals at the front of the classroom, and will bring the beakers back to your table. You will then use your graduated cylinder at your lab bench to measure precise volumes.

1) Obtain and wear goggles. It is best to conduct this experiment in a fume hood, or in a well-ventilated room.

2) Connect a Temperature Probe to Channel 1 of the Vernier computer interface. Connect the interface to the computer with the proper cable. Use a utility clamp to suspend the Temperature Probe from a ring stand, as shown in Figure 1.

3) Start the Logger *Pro* program on your computer. Open file "13 Enthalpy" from *Advanced Chemistry with Vernier* folder.

Reaction #1 - Conduct the Rxn Between NaOH and HCl

4) Nest a Styrofoam cup in a beaker (see Figure 1). Measure 50.0 mL of 2.0 M HCl solution into the cup. Lower the tip of the Temperature Probe into the HCl solution.

5) Measure out 50.0 mL of NaOH solution, but do not add it to the HCl solution yet.

6) Conduct the reaction.

a) Click [▶ Collect] to begin the data collection and obtain the initial temperature of the solution in the Styrofoam cup.

b) After three or four readings have been recorded at the same temperature, add the 50.0 mL of your other solution to the Styrofoam cup all at once. Stir the mixture throughout the reaction.

c) Data collection will end after three minutes. If the temperature readings are no longer changing, you may terminate the trial early by clicking [■ Stop].

7) Rinse and dry the Temperature Probe, Styrofoam cup, and the stirring rod. Dispose of the solution as directed.

8) Between each trial Click "Experiment" → "Store Latest Run" → Make a note of which color data line is which trial.

9) Perform two more trials. *(If time allows)*

Reaction #2 - Conduct the Rxn Between NaOH and NH_4Cl

10) Measure out 50.0 mL of 2.0 M NaOH solution into a nested Styrofoam cup (see Figure 1). Lower the tip of the Temperature Probe into the cup of NaOH solution.

11) Measure out 50.0 mL of 2.0 M NH_4Cl solution, but do not add it to the NaOH solution yet.

12) Conduct the reaction ***– see step 6a, 6b, 6c***

13) Repeat steps 7, 8, 9

Reaction #3 - Conduct the Rxn Between HCl and NH_3 *(the NH_3 becomes NH_4OH in water, so the bottle may say NH_4OH)*

14) Measure out 50.0 mL of 2.0 M HCl solution into a nested Styrofoam cup (see Figure 1). Lower the tip of the Temperature Probe into the cup of HCl solution.

15) Measure out 50.0 mL of 2.0 M NH_3 solution (bottle may say NH_4OH), but do not add it to the HCl solution yet.

16) Conduct the reaction ***– see steps 6a, 6b, 6c***

17) Repeat steps 7, 8, 9

Part IV Data Analysis – done after all trials are completed

18) Save your data file from the experiment.

19) Either email the file to all group members, or make a shared Google Folder/Drive for your lab group and put the file there so all lab group members can access the file to complete their work.

20) At home – open the data file.

21) For each trial performed - Click the Statistics button, . The minimum and maximum temperatures are listed in the statistics box on the graph. If the lowest temperature is not a suitable initial temperature, examine the graph and determine the initial temperature.

22) Record the initial and maximum temperatures in your data table.

23) Between each trial Click "Experiment" → "Store Latest Run" → Make a note of which color data line is which trial.

24) Add your group's data to the Shared Data Spreadsheet linked below. One person per group can do this. Ensure that someone from your group did it!

*****NOTE***** You may not be doing all three reactions - the teacher may split it up so you perform multiple trials of one reaction and then share data with the groups. You will also be adding your data to a shared spreadsheet so that you can perform your calculations with AVERAGED data which is more accurate. Your teacher will inform you of these potential changes in class if they apply (depends on the year). ***Shared Data Spreadsheet:*** **https://tinyurl.com/2p894e48**
You will do the prelab for ALL sections. *Must be logged in with SRVUSD email to open file*

Disposal and Cleanup
Your teacher will provide disposal and cleanup instructions.

Data Table
1. Make your own data table! Remember, you need to make sure your data table has all required elements! A sample is provided below. You will need to add a descriptive title, units on all rows/columns, and a spot for qualitative data, the one below is not adequate! Remember to use enough space, make it look professional, etc!
2. Make sure you make a table for all three reactions, even though you will not be doing all three in the lab. You need a place to record data from your class mates!
3. Glue in a copy of your Logger Pro graph(s) below your data table.

	Reaction 1			**Reaction 2**			**Reaction 3**		
Reactants:									
	Trial 1	**Trial 2**	**Trial 3**	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 1**	**Trial 2**	**Trial 3**
Maximum temperature (°C)									
Initial temperature (°C)									
Temperature change (ΔT)									

Calculations - *Show all calculations, use proper dimensional analysis, units everywhere, proper sig figs, etc.*
After performing all calculations, create a "Results Table" to record the final <u>results</u> of the following calculations. Same expectations as a Data Table with regards to descriptive titles, tables, units, etc. You can either average your data and then perform the calculations once, or you can do the calculations for each trial and then average your final results. Either way, be mindful of rounding issues.

1. Calculate the amount of heat energy, q, produced in each reaction in terms of J. Use 1.03 g/mL for the density of all solutions. Use the specific heat of water, 4.18 J/g°C, for all solutions.
2. Calculate the enthalpy change, ΔH, for each reaction in terms of kJ/mol of each reactant.

Post Lab Discussion Questions - *Do not recopy the questions, just paraphrase them into your answer.*
Between the Prelab, Calculation Section, and the Post Lab Questions you will end up with FOUR different values for the molar enthalpy for Reaction 3, ΔH_{rxn3}. One accepted value from R-19 data, one experimentally determined calorimetry based value, one accepted Hess's Law value, and one experimental Hess's Law value.

1. What was your *"accepted value based on R-19 data for ΔH_{rxn3}"* that you calculated in the Prelab?
2. What was your *"experimentally determined calorimetry based value for ΔH_{rxn3}"* based on actually performing Rxn 3 in the lab? You found this is Calculation Section Q#2.
3. Use Hess's law, and the accepted values of ΔH_{rxn1} and ΔH_{rxn2} in the Pre-lab Questions to calculate ΔH_{rxn3}. This is your *"accepted Hess's Law value for Reaction 3."*
4. Use your experimentally determined values for ΔH_{rxn1} and ΔH_{rxn2} from Calculation Q#2, and Hess's Law to determine ΔH_{rxn3}. This is your *"experimental Hess's Law value for Reaction 3."*
5. Make a little chart with all four values of ΔH_{rxn3}. How do the four values for ΔH_{rxn3} compare? You have two different accepted values, and two different experimental values.
6. Describe how this experimental process supports Hess's Law. *Hint* - it should...yes we have some % error, but it should be decently close.