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: Prelab Questions, 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, Post-Lab Two Pager done on separate Worksheet.

Introduction

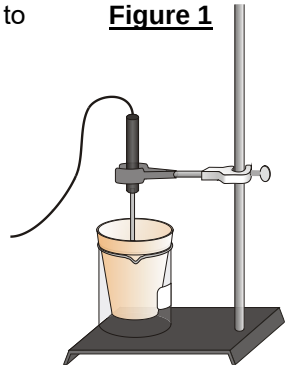
All chemical reactions involve an exchange of heat energy; therefore, it is tempting to plan to follow a reaction by measuring the enthalpy change (ΔH). However, it is often not possible to directly measure the heat energy change of the reactants and products (the system). We can measure the heat change 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.

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

The term q represents the heat energy that is gained or lost. C_p is the specific heat of water, m is the mass 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

In this experiment, you will

- 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.

Materials

Chemicals

- 2.0 M hydrochloric acid, HCl
- 2.0 M sodium hydroxide, NaOH
- 2.0 M ammonium chloride, NH_4Cl
- 2.0 M ammonium hydroxide, NH_4OH

Equipment

- Vernier computer interface
- Temperature Probe
- Styrofoam cup x 2
- 250 mL beaker x 2
- 600 mL beaker
- 50 mL graduated cylinder
- Stir bar
- 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.

Prelab Questions (Part of your Prelab Assignment)

You will conduct the following three reactions in this experiment. In a table like the one shown below, write the overall equation and the balanced net ionic reaction equations from the descriptions, include any products not listed. Use the table of thermodynamic data from an approved source to calculate the molar enthalpy of the reactions. Show your work.

Rxn 1: An aqueous solution of sodium hydroxide reacts with an aqueous solution of hydrochloric acid, yielding water.
Rxn 2: An aq. solution of sodium hydroxide reacts with an aq. solution of ammonium chloride yielding aq. NH_3, and water.
Rxn 3: An aqueous solution of hydrochloric acid reacts with aqueous NH_3, yielding aqueous ammonium chloride.

Reaction #1
Balanced Overall Equation:
Balanced Net Ionic Equation:
Molar Enthalpy of Reaction:

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Procedure

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 the file "13 Enthalpy" from the *Advanced Chemistry with Vernier* folder.

Part I Conduct the Reaction Between Solutions of 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. *Handle the HCl with care. It can cause painful burns.*

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

6) Conduct the reaction.

a) Click ▶ Collect to begin the data collection and obtain the initial temperature of the HCl solution.

b) After three or four readings have been recorded at the same temperature, add the 50.0 mL of NaOH 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.

Part II Conduct the Reaction Between Solutions of 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.

a) Click ▶ Collect to begin the data collection.

b) After three or four readings have been recorded at the same temperature, add the 50.0 mL of NH_4Cl 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.

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

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

15) Perform two more trials.

Part III Conduct the Reaction Between Solutions of HCl and NH_4OH

16) 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.

17) Measure out 50.0 mL of 2.0 M NH_4OH solution, but do not add it to the HCl solution yet.

18) Conduct this reaction in a fume hood or in a well-ventilated area. Repeat Step 10 to conduct the reaction and collect temperature data.

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Part IV Data Analysis – done after all trials are completed

19) Save your data file from the experiment.

20) 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.

21) At home – open the data file.

22) 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.

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

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

25) Perform two more trials.

*****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 may 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/4kw2nbfs
Must be logged in with SRVUSD email to open file

Disposal and Cleanup

Your teacher will provide disposal and cleanup instructions.

Data Table

	Reaction 1			Reaction 2			Reaction 3		
	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)									
Heat energy produced, q (J)									
Enthalpy change, ΔH (kJ/mol)									

Calculations

Record all values into your Data Table

1. Calculate the amount of heat energy, q, produced in each reaction. 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

Answer as part of your post lab. Do not recopy the questions, just paraphrase them into your answer so the reader can infer what the question was.

1. Use your answers from 2 above, and Hess's Law to determine the experimental molar enthalpy for Reaction 3
2. Use Hess's law, and the accepted values of ΔH in the Pre-Lab Questions to calculate the ΔH for Reaction 3. How does the accepted value compare to your experimental value?
3. Does this experimental process support Hess's Law? Suggest ways of improving your results.