Matter and Motion

Fall 2015

Chemistry Lab 4: The Heat of Formation of MgO

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Overview and Background Information

This week we are going to study changes in enthalpy associated with chemical reactions. In today's lab we want to determine the enthalpy of formation of magnesium oxide.

$$Mg\ (s) + \tfrac{1}{2}\ O_2\ (g) \rightarrow MgO\ (s) \qquad \Delta H = ?$$

This is a very exothermic reaction. It is somewhat difficult to measure ΔH directly. So, we will take an indirect approach to measuring ΔH of this reaction, relying on Hess's Law. We can perform the following reactions in the lab.

A $$Mg\ (s) + 2H^+\ (aq) \rightarrow Mg^{2+}\ (aq) + H_2\ (g) \qquad \Delta H_1 = ?$$

B $$MgO\ (s) + 2H^+\ (aq) \rightarrow Mg^{2+}\ (aq) + H_2O \qquad \Delta H_2 = ?$$

Using Hess's Law we know we can add or subtract reactions A and B and that ΔH for the new reaction will be the sum or difference of ΔH's for the individual reactions. We subtract the two reactions above and obtain:

$$Mg(s) + H_2O\ (l) \rightarrow MgO\ (s) + H_2\ (g) \qquad \Delta H = \Delta H_1 - \Delta H_2$$

While this is mathematically correct, the reaction we obtain is not the same as that for the enthalpy of formation of MgO that was written above in the very first reaction. We seem to be missing something. If you look in your table of standard enthalpies of formation you can find ΔH^o for liquid water.

C $$H_2\ (g) + \tfrac{1}{2}\ O_2\ (g) \rightarrow H_2O\ (l) \qquad \Delta H_3 = ?$$

Now we can use reactions A, B, and C to create the correct reaction for the enthalpy of formation of magnesium oxide.

So this is what we are going to do. Dissolve a known mass of magnesium metal in HCl and measure the heat released. Repeat this with MgO. Calculate the heat released if we had used 1 mole of Mg and MgO instead of the amount we actually used. Use these heats together with the literature value for enthalpy of formation of water to calculate the enthalpy of formation of MgO. Compare experimental results with the literature value for ΔH^o of MgO.

How do we measure heat? We can measure temperature, but we cannot measure heat directly. First we will use a chemical reaction for which the enthalpy is known in order to calibrate the heat capacity of our system. The units of heat capacity (C_P) are Joules/K. The subscript P means heat capacity at constant pressure. Then, knowing the number of Joules of heat that are required to raise the temperature of our reaction system 1 K, we can use the change in temperature from subsequent reactions to calculate the number of Joules of heat released from the reaction.

PRELAB QUESTIONS

Read the entire lab carefully (including the Post-lab) then complete the Pre-lab before coming to lab. It should be completed in your chemistry lab notebook and presented for a check as you walk in the door.

1. Some of the words in this lab may be new to you. Make a list of any new vocabulary and their definitions.
2. Describe all of the data/measurements you will take during this lab. Be as specific as possible, i.e, include the units used and the number of times each measurement made.
3. Create an equation for calculating ΔH^o for MgO from the ΔH's for the reactions A, B, and C.

EXPERIMENTAL PROCEDURE

You will need a partner for this lab. We encourage you to work with someone you have not worked with before.

******SAFETY****** **<u>You must wear your goggles at all times in the lab</u>. This week we are using acids and bases of considerable strength. Remind yourself of the eyewash locations before starting the lab. Rinse your skin immediately and thoroughly with water if you contact any acid or base. Wash your hands thoroughly at the end of lab.**

Other concerns: The temperature probes can be damaged if left sitting in an acid solution too long. Please only immerse your temperature probe while it is necessary to record temperature. The waste produced in this lab can be poured down the drain.

1. Obtain and assemble pieces for an adiabatic calorimeter (adiabatic - An isolated system where heat does not exchange with the surroundings). These consist of 2 nested styrofoam cups, a beaker, a lid, a stirring bar, and a temperature probe. Sketch a diagram of your calorimeter in your notebook.

2. Calibration Phase - Determine the heat capacity of your styrofoam cup calorimeter. 1.0 M HCl and 1.2 M NaOH should be available and should be at the same (room) temperature. HCl is the limiting reagent, NaOH will be present in excess if equal volumes are mixed. Obtain about 80 mL of each solution. Measure their temperatures. Use a graduated cylinder to measure 50.0 mL HCl and add it to the calorimeter cup. Begin measuring temperature at regular intervals (every 15 sec). After sufficient data has been collected to establish a baseline, add 50.0 mL NaOH to the styrofoam cup and continue measuring temperature until a linear baseline had been obtained (about 5 min). Stir the mixture to assure mixing. Don't splash onto side of cup where reagents may not mix and react. Empty calorimeter, rinse and dry.

3. Now you want to measure the heat released from the reaction of a known mass of Mg and MgO with HCl. Obtain about 0.15 g Mg ribbon. (Mg ribbon weighs about 9 mg/cm. How many cm will you need?) Remove oxidation by buffing with some steel wool. Accurately measure the mass of magnesium and fold the ribbon into a small ball. Measure 100.0 mL HCl and transfer to the calorimeter. (Is there sufficient HCl to react with all of the Mg?) Begin measuring temperature as before. When a baseline has been established add the Mg to the calorimeter and complete the temperature run.

4. Repeat step 3 using about 0.5 g MgO (accurately measured) in place of Mg. (you don't have to polish the MgO.)

CLEAN UP

- Waste can be disposed of down the drain
- Rinse your glassware and any laboratory tools used
- Clean and dry any spills in your area and/or around the sinks
- Ask Sina for a community job.

Continue with Post-Lab if time allows.

POSTLAB: Calculations and Analysis

Please show your work/calculations clearly. The Postlab is due with your lab notebook at 9 am Tuesday, Nov. 9th.

1. From data obtained in step 2, determine the temperature change that occurred in the reaction. Using the standard enthalpies of formation for H+ (aq), OH- (aq), and H2O (l), calculate the heat (J) released by your reaction of 1 M HCl with excess NaOH. The heat capacity of your calorimeter is the ratio of these two values (J/K).

2. From the data in step 3, calculate the temperature change that occurred. Using the heat capacity of the calorimeter (J/K) and the temperature change, calculate the heat released from the reaction. From the mass of Mg calculate the enthalpy of reaction in kJ/mole.

3. From the data in step 4, calculate the temperature change that occurred. Using the heat capacity of the calorimeter (J/K) and the temperature change, calculate the heat released from the reaction. From the mass of MgO calculate the enthalpy of reaction in kJ/mole.

4. Using the standard enthalpy of formation for water and the enthalpies of reaction for Mg and MgO, above, calculate the standard enthalpy of formation for MgO. Compare to a literature value and properly cite your reference.

5. If a student rinsed the calorimeter cup with water but did not dry it before determining the temperature change in the reaction between HCl and Mg, how would this error affect the final result for the heat of formation of magnesium oxide? Be specific in your discussion, will the end result be higher or lower than it should be?

6. Discuss the effectiveness of your calorimeter. What evidence, if any, did you see that indicates heat was lost from the calorimeter to the surroundings during the experiment?

7. Discus the important sources of error in this experiment and explain what effect each would have on the results. Distinguish between errors in the experiment design and additional errors that you may have made.