

Hess' Law Lab

By Maya Parks

Partners: Ben Seufert, Kelsea Floyd

5/8/15

Abstract:

In this lab, we performed 3 reactions to verify Hess' Law. These were the dissolution of solid NaOH in water, solid NaOH and aqueous HCl, and aqueous NaOH and aqueous HCl. We measured the initial and final temperature and calculated the change in enthalpy that occurred as a result of these reactions. We then used these values to test Hess' Law. The percent error for this lab was 1.52%. We didn't always measure the exact amount of solution, and sometimes, the NaOH was not completely dissolved, but the percent error was under 5% and the lab was rather successful. This lab is helpful for illustrating class concepts like Hess' Law as well as stressing the importance of understanding thermodynamics.

Objectives:




This lab will be performed to verify Hess' Law. We will determine the change of enthalpy of a reaction between NaOH and HCl, both aqueous, using the reaction of solid NaOH and HCl (aq) and the dissolution of solid NaOH. This lab will demonstrate Hess' Law, which we learned in class and will help us further understand the concepts of thermochemistry.

Materials:

Power Macintosh or Windows PC	100 mL of water
Vernier computer interface	4.00 g of solid NaOH
Logger <i>Pro</i>	ring stand
Temperature Probe	utility clamp
50 mL of 1.0 M NaOH	stirring rod
50 mL of 1.0 M HCl	Styrofoam cup
100 mL of 0.50 M HCl	250-mL beaker

Procedure:

Obtain and wear goggles.

2. Prepare the computer for data collection by opening the Experiment 18 folder from *Chemistry with Computers*. Then open the experiment file that matches the probe you are using. The vertical axis has temperature scaled from 15°C to 40°C. The horizontal axis has time scaled from 0 to 200 seconds.
3. Place a Styrofoam cup into a 250-mL beaker as shown in Figure 1. Measure out 100.0 mL of water into the Styrofoam cup. Lower the Temperature Probe into the solution.
4. Use a utility clamp to suspend a Temperature Probe from a ring stand as shown in Figure 1.
5. Weigh out about 2 grams of solid sodium hydroxide, NaOH, and record the mass to the nearest 0.01 g. Since sodium hydroxide readily picks up moisture from the air, it is necessary to weigh it and proceed to the next step without delay. **CAUTION:** *Handle the NaOH and resulting solution with care.*
6. Click on  to begin data collection and obtain the initial temperature, t_1 . It may take several seconds for the Temperature Probe to equilibrate at the temperature of the solution. After three or four readings at the same temperature have been obtained, add the solid NaOH to the Styrofoam cup. Using the stirring rod, stir continuously for the remainder of the 200 seconds or until the temperature maximizes. As soon as the temperature has begun to drop after reaching a maximum, you may terminate the trial by clicking .
7. Examine the initial readings in the Table window to determine the initial temperature, t_1 . To determine the final temperature, t_2 , click the Statistics button, . The maximum temperature is listed in the statistics box on the graph. Record t_1 and t_2 in your data table.
8. Rinse and dry the Temperature Probe, Styrofoam cup, and stirring rod. Dispose of the solution as directed by your instructor.

Reaction 2

9. Repeat Steps 3-8 using 100.0 mL of 0.50 M hydrochloric acid, HCl, instead of water. **CAUTION:** *Handle the HCl solution and NaOH solid with care.*

Reaction 3

10. Repeat Steps 3-8, initially measuring out 50.0 mL of 1.0 M HCl (instead of water) into the Styrofoam calorimeter. In Step 5, instead of solid NaOH, measure 50.0 mL of 1.0 M NaOH solution into a graduated cylinder. After t_1 has been determined for the 1.0 M HCl, add the 1.0 M NaOH solution to the Styrofoam cup. **CAUTION:** *Handle the HCl and NaOH solutions with care.*

Data:

Trial	1	2	3
Mass of NaOH	2.06g	2.03g	50.0mL of 1M NaOH
Final Temperature	26.1°C	32.6°C	29.1°C
Initial Temperature	22.3°C	22.5°C	22.8°C

Calculations:

1. Determine the mass of solution for each reaction (assume the density of each solution is 1.00 g/mL).

- Turn mL of solution into grams by multiplying mL by 1.00g/mL and add grams of solid NaOH
- Trial 1: $100.0\text{mL} \times \frac{1.00\text{g}}{\text{mL}} = 100.0\text{g} + 2.06\text{g} = 102.06\text{g}$
- Trial 2: 102.03g
- Trial 3: 100.0mL

2. Determine the temperature change, Δt , for each reaction.

- Subtract initial temperature from final temperature
- Trial 1: $\Delta T = 26.1 - 22.3 = 3.8^\circ\text{C}$
- Trial 2: $\Delta T = 10.1^\circ\text{C}$
- Trial 3: $\Delta T = 6.3^\circ\text{C}$

3. Calculate the heat released by each reaction, q , by using the formula:

$$q = m \cdot c_p \cdot \Delta t \quad (c_p = 4.184 \text{ J/g}^\circ\text{C})$$

Convert joules to kJ in your final answer.

- Multiply the mass by the change in temperature and the c given
- Trial 1: $q = (102.06\text{g}) \left(\frac{4.184\text{J}}{\text{g}^\circ\text{C}} \right) (3.8^\circ\text{C}) = 1622.6723\text{J} = 1.6\text{kJ}$
- Trial 2: 4.3kJ
- Trial 3: 2.6kJ

4. Find ΔH ($\Delta H = -q$).

- Take the negative of q
- Trial 1: -1.6kJ
- Trial 2: -4.3 kJ
- Trial 3: -2.6kJ

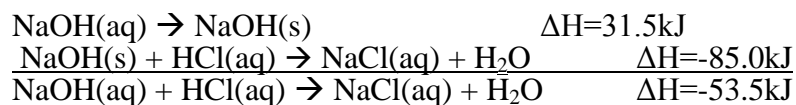
5. Calculate moles of NaOH used in each reaction. In Reactions 1 and 2, this can be found from the mass of the NaOH. In Reaction 3, it can be found using the molarity, M , of the NaOH and its volume, in L.

- Trial 1: $2.06\text{g} \times \frac{1\text{mol}}{39.997109\text{g}} = .0515037\text{mol}$
- Trial 2: .0507536
- Trial 3: $50\text{mL} \times \frac{1\text{L}}{1000\text{mL}} \times \frac{1\text{mol}}{1\text{L}} = .0500\text{mol}$

6. Use the results of the Step 4 and Step 5 calculations to determine $\Delta H/\text{mol NaOH}$ in each of the three reactions.

- Trial 1: $-1.62\text{kJ} \div .0515037 = -31.505936\text{kJ/mol}$
- Trial 2: -84.952092kJ/mol
- Trial 3: -52.7184kJ/mol

7. Mathematically verify Hess's Law and explain how you came to this conclusion



Actual $\Delta H=52.7\text{kJ}$

I found the experimental value of -53.5 by mathematically combining the experiments above which we found the ΔH for in the previous calculations. Then by combining the H values, you can find the ΔH for the desired reaction.

Error Analysis:

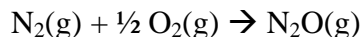
1. $\%e = \frac{53.5-52.7}{52.7} \times 100 = 1.52\%$
2. During the lab, we didn't record the volumes of the solutions of HCl or NaOH and so the calculations might be slightly off. I used the values the lab procedure gave, but most likely it was not exact. If we had made sure it was exact, or if we had taken the volumes, it would have allowed for more accurate results. If we used too much NaOH or too much HCl, the ΔH would be greater, and the opposite if we didn't have enough.

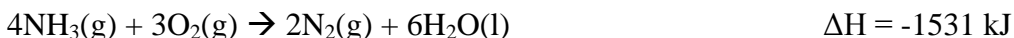
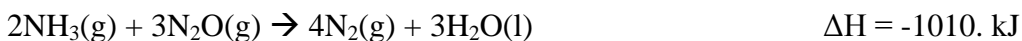
When using the solid NaOH, it is possible that not all of it was dissolved, as when it got smaller, it was harder to see and actually mix up, so some of it might not have dissolved completely. If this happened, ΔH would be less than it should have been, which if it happened in the first trial, would cause the final ΔH to be less (greater negative number) and if it happened in the second trial, would cause final ΔH to be greater (closer to 0)

3. I think it would be better to simply take the highest number collected as the final temperature and the lowest number collected for the initial temperature, as this is much simpler and easier to understand than going to statistics and whatever else, and gives very accurate results. Additionally, it would help to make sure the water coming from the faucet is room temperature, as often when it first comes out, it is cold, so waiting five minutes would be helpful.

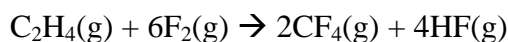
Conclusions:

1. Use Hess's Law and the following equations and ΔH values to determine the heat of reaction for the reaction:

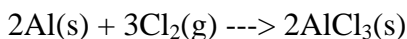




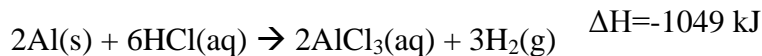
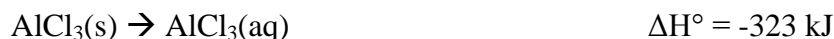
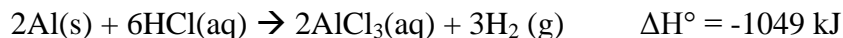
2. Use Hess's Law and the following equations and ΔH values to determine the heat of reaction for the reaction:

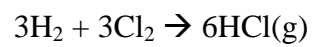


3. Calculate the reaction enthalpy for the formation of anhydrous aluminum chloride:

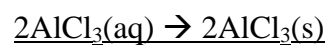


from the following data:

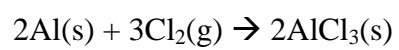




$$\Delta\text{H} = -555 \text{ kJ}$$



$$\underline{\Delta\text{H} = 646 \text{ kJ}}$$



$$\Delta\text{H} = -1407 \text{ kJ}$$