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Determining the Effectiveness of Container Lids on Heat Absorption: Measuring Heat of Reaction for NaOH(aq) and HCl(aq)

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ABSTRACT

In the General Chemistry I laboratory at Monroe Community College, students combine a strong base, 1.0M NaOH_(aq), with a strong acid, 1.0M HCl_(aq), to assess the temperature change of the solution as a result of the chemical reaction. The temperature change of the solution is used to calculate the heat of solution. The reaction is carried out in a Styrofoam cup with a wooden lid to retain heat as per experimental protocol. We assessed whether different lid composites would influence the heat of solution generated in the vessel during an experiment. There were four conditions to the experiment: (1) Control - no lid, (2) wood lid, (3) wood lined with Styrofoam lid and (4) Plexiglas lid. Thirty trials were run for each condition of the experiment. The mean heat of solution was significantly higher ($p < 0.05$) for Condition 1 (no lid) than Condition 2 (wood lid) or Condition 4 (Plexiglas lid). There was not a significant difference ($p > 0.05$) in the mean heat of reaction between Condition 1 and Condition 3 (wood with Styrofoam lined lid). Our results suggest that a lid is no better at retaining the heat of solution than no lid which supports the removal of the lid from the experiment.

Editor's note: Christine Burton won a 1st place scholarship award at the 2014 Scholars' Day for her presentation on this topic.

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Determining the Effectiveness of Container Lids on Heat Absorption: Measuring Heat of Reaction for NaOH(aq) and HCl(aq)

One experiment performed by Monroe Community College (MCC) students in General Chemistry I is experiment 8A “Chemical Change and Energy: What Fuel Makes the Best Energy Source? – Part I: reaction of aqueous sodium hydroxide and aqueous hydrochloric acid” (Monroe Community College Department of Chemistry and Geosciences, 2014). In the lab procedure, students combine hydrochloric acid and sodium hydroxide in a 250 mL Styrofoam coffee cup to form sodium chloride and water. The neutralization reaction releases heat, which causes a temperature change. The temperature change is calculated and used to determine heat of solution.

Balanced equation:



The laboratory protocol calls for a lid on the cup. It is thought that placing a lid on the reaction vessel would retain heat – an intuitive assumption. Our experimental question is whether covering the reaction vessel during the experiment actually retains a significant amount of heat, and therefore has an impact on the calculation of heat of solution.

PURPOSE

The purpose of our experiment was to assess the efficacy of a lid on a reaction vessel in retaining heat during a chemical reaction between $\text{HCl}_{(\text{aq})}$ and $\text{NaOH}_{(\text{aq})}$. Three different lid composites were tested and the results of those tests were compared to the results of tests on vessels without a lid. Data from this experiment will be used to recommend elimination or retention of a lid in the laboratory experiment.

METHODS

Solutions and equipment

Solutions used for this experiment included 25mL of 1 molar aqueous sodium hydroxide (NaOH) and 20 mL of 1 molar aqueous hydrochloric acid (HCl). The volumes used were based on the protocol from the original laboratory experiment performed by students. The $\text{HCl}_{(\text{aq})}$ acts as the limiting reactant. Equipment

included a 250 mL Styrofoam cup as our reaction vessel, magnetic stir bar, magnetic stirring platform, temperature probe, and three types of lids. This set-up is typically referred to as a “coffee cup calorimeter,” as shown in Figure 1.



Figure 1: Coffee cup calorimeter setup

Design

There were four conditions (variations) to this experiment. Condition 1: no lid (control), Condition 2: wood lid, Condition 3: wood lined with Styrofoam lid, and Condition 4: Plexiglas lid. These lids were chosen because they are commonly used at MCC in calorimeter experiments. Thirty trials of the experiment were performed for each condition.

Procedure

For each trial of the experiment, 25 mL of the $\text{NaOH}_{(\text{aq})}$ was measured using a graduated cylinder and added to the Styrofoam cup containing a magnetic stir bar. The magnetic stirrer was turned on low. A lid was selected, placed on the cup, and a temperature probe

inserted into the cup through a hole in the lid. Using Logger Pro software (Vernier Software & Technology, 2013), the temperature of the $\text{NaOH}_{(aq)}$ was recorded with the temperature probe until it stabilized. Then the 20mL of $\text{HCl}_{(aq)}$ was added and the temperature was recorded until it again stabilized. The lid and temperature probe had to be removed to add the $\text{HCl}_{(aq)}$. During the Condition 1 experiment, $\text{HCl}_{(aq)}$ was simply poured into the cup. After the reaction was complete, the software calculated initial and final temperatures of the reaction.

Figure 2 shows a Logger Pro display used to record the temperature and calculate the initial and final temperatures of the reaction. The first part of the line (A) indicates the temperature of $\text{NaOH}_{(aq)}$ before adding the $\text{HCl}_{(aq)}$. Point B is where the $\text{HCl}_{(aq)}$ was added. The temperature rises sharply upwards, indicating the reaction is taking place. The flat line at the top (C) indicates the reaction is complete and the temperature is again stabilized. Equations of the top and bottom lines were calculated by the software and used to determine the initial and final temperatures of the solution. This information is displayed in box D. Additionally, temperature information can be read from the data chart on the left (E).

Calculations

During this experiment, the change in temperature of the reaction was used to calculate the heat of solution using the following equation: $q_{\text{solution}} = mc\Delta T$. Because the acid and base are aqueous solutions,

meaning the ions of the acid and base are surrounded by water, the properties of the solutions are similar to water. Considering the significant figures and concentrations of solutions used in this study, the difference in densities between water and the $\text{HCl}_{(aq)}$ and $\text{NaOH}_{(aq)}$ solutions are not significant. Since there are 45 milliliters of solution, the density of water (1.0 g/mL) was used to determine that the mass (m) of the solution is 45 grams. Additionally, the specific heat of the solution (a measure of how much energy is needed to raise the temperature of a substance) is the same as pure water. The specific heat of water and the solution is 4.184 Joules per gram degree Celsius. The change in temperature (ΔT) was determined from the Logger Pro software as described above. When mass, specific heat, and change in temperature are multiplied together, the result is the heat of solution in Joules.

Subsequent calculations and analysis for this experiment are based on the heats of solution as determined by this formula. During the lab experiment, students use the heat of solution to determine the heat of reaction. Since the energy absorbed by the solution (the surroundings) is equal to the heat given off by the reaction (the system), the heat of solution is equal to negative heat of reaction ($q_{\text{solution}} = -q_{\text{reaction}}$). Students then use the heat of reaction to estimate the enthalpy of reaction: heat of reaction divided by moles of product (water) as demonstrated in the following equation: $\Delta H \approx q_{\text{reaction}}/\text{moles of product}$.

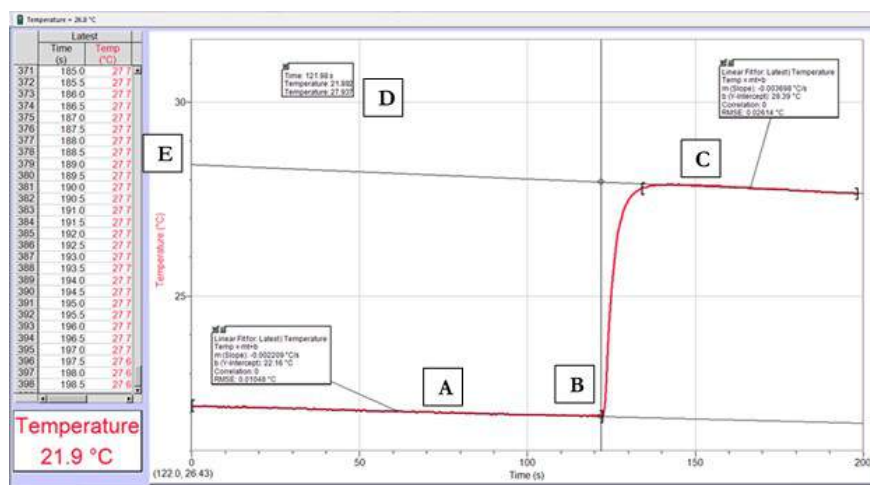


Figure 2: Logger Pro display

A hypothesis test was created and the Student's t-distribution was used to determine if the mean heats of solution for the three different lids were significantly different from the heat of solution when using no lid. A two-sample t-test was performed using Minitab 16 (Minitab Inc., 2013) with an alpha (level of significance) of 0.05.

DATA AND RESULTS

Figure 3 shows the mean heat of solution by lid type, as well as the standard deviations. Using no lid resulted in the highest heat of solution, followed by the Styrofoam wood lid, then the wood lid, and finally the Plexiglas lid. Figure 3 also illustrates that the variability in the results were similar for no lid and the wood lid, slightly higher for the Styrofoam wood lid, and even higher for the Plexiglas lid.

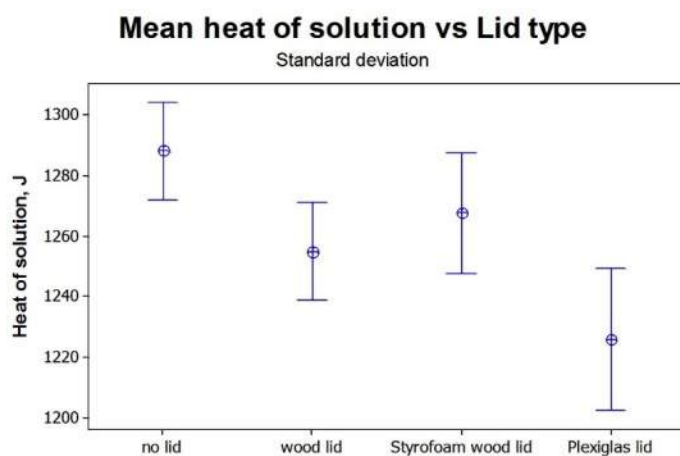


Figure 3: Heats of solution and standard deviations

The data and results are summarized in Table 1. In addition to the mean heats of solution and standard deviations as shown in Figure 3, the percent deviation shows that using no lid produced the least variability in heats of solution. The variability may be due to the difficulty in removing the lids to add the $\text{HCl}_{(aq)}$. The lid is not on the calorimeter for the same amount of time for each trial of the experiment, which introduces another variable.

There was no significant difference in the mean heat of solution generate by Condition 1 (no lid) and Condition 3 (wood Styrofoam lid; $p > 0.05$). The mean

heat of solution generated by Condition 1 (no lid) was significantly higher than for Condition 2 (wood lid) and Condition 4 (Plexiglas lid; $p < 0.05$).

CONCLUSION

The highest mean temperatures of solution, and most consistent results, were attained when performing the experiment without a lid. Experiments performed with the wood lid (Condition 2) and Plexiglas lid (Condition 4) showed higher variability in results and statistically significant lower mean heat of solution values than the results of experiments without a lid. Although there was no significant difference in the mean heat of solution between a wood lid lined with Styrofoam (Condition 3) and no lid, the results using a wood lid lined with Styrofoam showed a higher degree of variability. These results support a proposal to eliminate the lid from the experiment.

The results of our experiment were not expected. We assumed, through personal experiences, that placing a lid on a vessel containing a heat-generating chemical reaction would retain the heat of reaction and may elevate temperature. We do not know why this happened. It is possible that the wood and Plexiglas lids absorbed heat from the reaction, causing the heats of solutions to be falsely low. It could be the lids somehow suppressed the reaction. Future experiments could investigate these possibilities and additional sources of heat loss such as conduction, convection, radiation, or evaporative cooling, and their effects on the heat of solution.

The wide deviations of results within conditions of tests using lids could have been due to the variability in the fit of the lids on the vessels from one experimental trial to the next. We found that the wood lid was most difficult to fit tight on the vessel, followed by the wood lid lined by Styrofoam, and then the Plexiglas lid.

Based on the results of our study, there is no benefit for heat generation to using a lid in the experiment. The results are most efficient and reliable when running the experiment without a lid. We suggest that the General Chemistry I laboratory procedure can be modified to eliminate the lid.

	q _{solution} , J			correlation to control	
	mean	standard deviation	percent deviation	Hypothesis test, $\alpha = .05$ 2.05 rejection	
no lid	1288.1	43.4	3.37		
wood lid	1255.0	43.3	3.45	2.96	different
Styrofoam wood lid	1267.6	53.1	4.19	1.64	same
Plexiglas	1225.8	62.9	5.13	4.46	different

Table 1: Mean heats and deviations of conditions

REFERENCES

Minitab, Inc. (2013). Minitab 16 [Computer software]. State College, PA: Minitab, Inc.

Monroe Community College Department of Chemistry and Geosciences (2014). *General Chemistry 151 Laboratory Manual*.

Vernier Software & Technology (2013). *Logger Pro* (version 3.8.6.1) [Computer software]. Beaverton, OR: Vernier Software & Technology.

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