Lab Experiment - 2

Experiment Title:
UOTTAWA GEE GEE'S SPORT AND HEALTH DRINKS – A Tall Cold Drink of Water

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Suttinee Poolsup

Date Experiment Performed:
September 24th, 2019

Date Experiment Submitted:
October 1st, 2019

Attach here (if required, indicate the appropriate document(s)):

Medical or another Acceptable Document: _________
Change of Lab Day Form: _________
Change of Lab Section Form: _________
Late Pass: _________

Introduction:

In this lab experiment, thermochemistry and the verification of its laws are examined. Thermochemistry is widely used by engineers and chemists around the world to measure the enthalpy of a reaction. Enthalpy refers to the total amount of energy that is connected to the system plus the product of the pressure and volume of the system. Most often in a chemical reaction or process, reactants and products are present, where the reactants would either absorb or release heat. Reactions that absorb heat are called endothermic reactions while those who release heat are called exothermic reactions. To find whether a reaction is endothermic or exothermic, the enthalpy of the entire chemical process must be calculated. Enthalpy can be calculated by the equation $Q = mc\Delta T$

Hess's Law refers to the fact that regardless of what pathway a chemical reaction goes; the total enthalpy change for the reaction is the sum of all changes.

The salt that is used in the experiment is NH_4Cl. This salt is inexpensive and has fewer risks associated with it when compared to ammonium nitrate. Exposure to high concentrations of ammonium nitrate causes several health issues such as respiratory tract irritation. When NH_4Cl is placed in water it dissociates into its respective NH^{4+} and Cl^- ions. This reaction is endothermic. The heat from the surrounding water is absorbed by the solid NH_4Cl and used to break the crystal lattice structure of the salt crystal. Thus, the H_2O decreases in temperature rapidly.

This experiment is done in a Styrofoam insulating container with an aluminum calorimeter within, creating a closed system. Both Styrofoam container and aluminum calorimeter have the same amount of water within them. As this is a closed system, when the salt is added to the water within the Styrofoam container the temperature of the water within the calorimeter changes as well an equal amount.

Procedure:

1. Fill aluminum calorimeter with 100mL deionized H_2O.
2. Fill Styrofoam container with 100mL deionized H_2O.
3. Turn on the Thermometer by plugging it into the LabQuest2 and turning it on.
4. Record initial temperature of water in aluminum can.
5. Add 11.2 g of NH_4Cl to the 100mL of water in the Styrofoam calorimeter.
6. Place tin can in the calorimeter as fast as possible after adding NH_4Cl

7. Close the lid and insert the thermometer making sure the thermometer is not touching the base of the can. (to record temperature).
8. Wrap a paper towel around the calorimeter to prevent any heat loss during the experiment.
9. Shake gently for 5 min while recording temperature on the LabQuest 2.
10. After the 5 minutes save and record the data for your trial on to a USB stick.
11. Thoroughly clean and dry all equipment used in the experiment.
12. Repeat steps 1 to 11, adding two grams more of NH_4Cl for two more trials.

Discussion:

In this lab, the goal was to cool 100 mL of water by 5°C in five minutes using the dissolution reaction of an ionic salt. Using the laws of thermochemistry, it was possible to determine the theoretical mass of salt necessary to produce the desired result. In practice, however, calculations alone could not be relied upon as an answer to the problem and multiple trials were performed to narrow down the realistic mass. After accounting for the energy necessary to cool both volumes of water as well as the tin can, the amount of energy that needed to be absorbed by the endothermic dissolution was determined to be about 4212 joules. With this information, the mass of salt was then calculated to be 13.2g. As shown in Table 1 the mass of salt used for Trial 1 was 11.2g and yielded a temperature change of only 3.9°C. In Graph 1, ignoring the large temperature spike, the temperature change is relatively slow compared to the other graphs and appears to level out around the 3-minute mark, indicating the reaction has come to equilibrium. This result was expected because the mass of salt was lower than the theoretically required amount. In Trial 2 the amount of salt used was 13.2g and the expectation was that it potentially could produce the desired temperature change but likely wouldn't as the experiment was not a perfectly closed system, as calculations imply. This belief was proven true as the reaction only yielded a temperature change of 4.4°C. In Graph 2, the temperature change is at a visibly higher rate and the reaction proceeds longer than in Graph 1 suggesting that the greater mass of salt reacts faster and for a longer time. Finally, in Trial 3 the amount of salt was again increased by 2g to 15.2g and the expectation was that the desired temperature change would be achieved and even surpassed as the mass was much more than calculations suggested. The results of this trial showed a temperature change of 5.1°C, which was, unexpectedly, only slightly larger than the initial goal. In Graph 3 it is evident that the initial rate of temperature change is higher, and the reaction lasted longer than the other trials because the graph starts with a steep drop and gradually lowers for the full 5 minutes of the experiment.

Overall, the design of the experiment was very successful because a reasonable mass of salt was found, the water was effectively cooled, and it was cooled in the 5-minute time expectation. The fact that only one variable (mass of salt) was altered while the other variables (volume of water and duration of experiment) were kept constant, yielded very positive results. Had the results of the experiment been that the required amount of salt was double the expected amount, or that the water needed more or less than 5 minutes to cool by 5°C, the experiment would have been flawed and a change of approach would be necessary. The difference between theoretical and experimental masses in this lab was slight enough that they could be explained by slight errors and inefficiencies compounding together. The result of the experiment was that the time and temperature goals were achieved, with only slightly more salt than expected.

Although the results of this lab were positive, calculations indicate there are certain aspects of the experiment that should be improved to boost efficiency. Some of the potential issues were observable during the experiment. One of such observations was the fact that water appeared to be leaking from the calorimeter, indicating that there was enough space for heat and the reactant solution to transfer between the system and the environment. This issue likely had an impact on the results of the experiment because if the solution (water and NH4Cl) was escaping the calorimeter then it was impossible for the full potential of the reaction to apply to the water in the can and cool it completely. Another impactful issue with the experiment was the quality of the calorimeter used. The calorimeter in the experiment was made of relatively thin Styrofoam which is not the most effective of insulators. Heat was likely able to enter the calorimeter during the experiment which would cause the final recorded temperature to be higher. A third potential problem with the experiment was that the method for encouraging the dissolution of the salt was shaking the calorimeter and it was impossible to tell how the liquids on the inside were being impacted. The solution might have been mixing with what was supposed to be the clean water and changing the volumes of the liquids. The main improvement that would fix all three of these experimental problems is the use of a higher quality calorimeter. Having a better calorimeter with a well-sealed lid, improved insulation, and assurance of liquid containment inside would fix the three main issues that likely impacted the results of the experiment.

Conclusion:

Overall after completing the 3 trials it was determined that the proper mass of ammonium chloride necessary to cool 100 mL of water in an aluminum can by 5°C is 15.2 grams dissolved in 100 mL of water surrounding the aluminum can.

References:

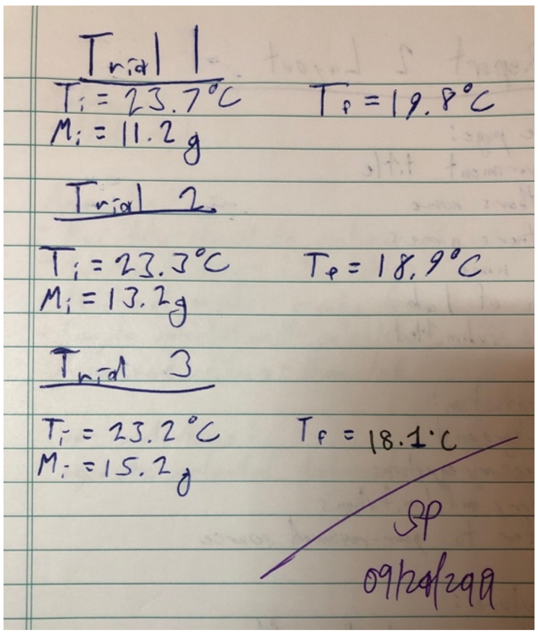
“Chemical Engineering.” *American Chemical Society*, ACS, www.acs.org/content/acs/en/careers/college-to-career/chemistry-careers/chemical-engineering.html.

Libretexts. “Hess's Law.” *Chemistry LibreTexts*, Libretexts, 5 June 2019, chem.libretexts.org/Bookshelves/Physical_and_Theoretical_Chemistry_Textbook_Maps/S

upplemental_Modules_(Physical_and_Theoretical_Chemistry)/Thermodynamics/Thermodynamic_Cycles/Hess's_Law.

Appendix:

Raw Data


Trial 1
Ti = 23.7°C   Tf = 19.8°C
Mi = 11.2 g

Trial 2
Ti = 23.3°C   Tf = 18.9°C
Mi = 13.2 g

Trial 3
Ti = 23.2°C   Tf = 18.1°C
Mi = 15.2 g

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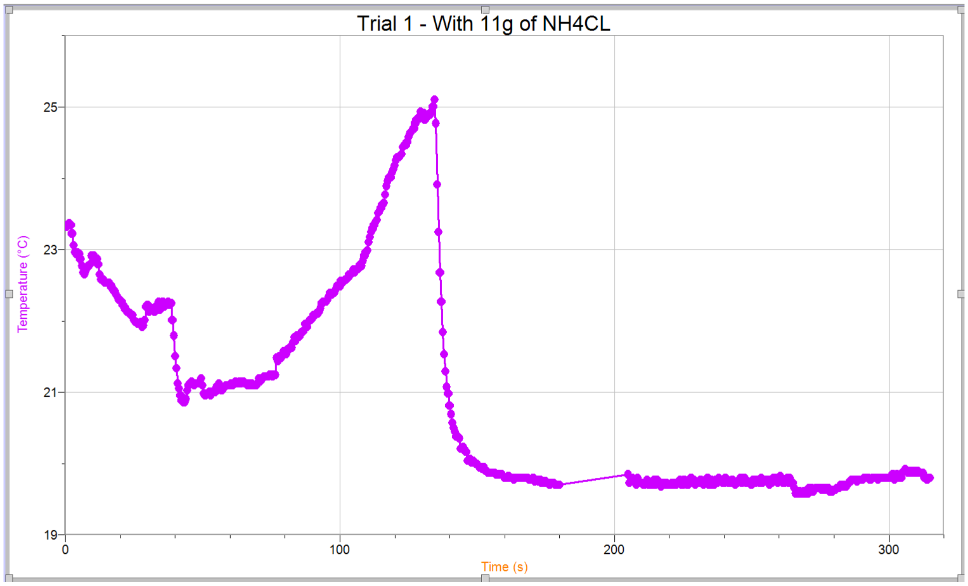
Additional Data

Table 1: Trials with their related mass and temperatures

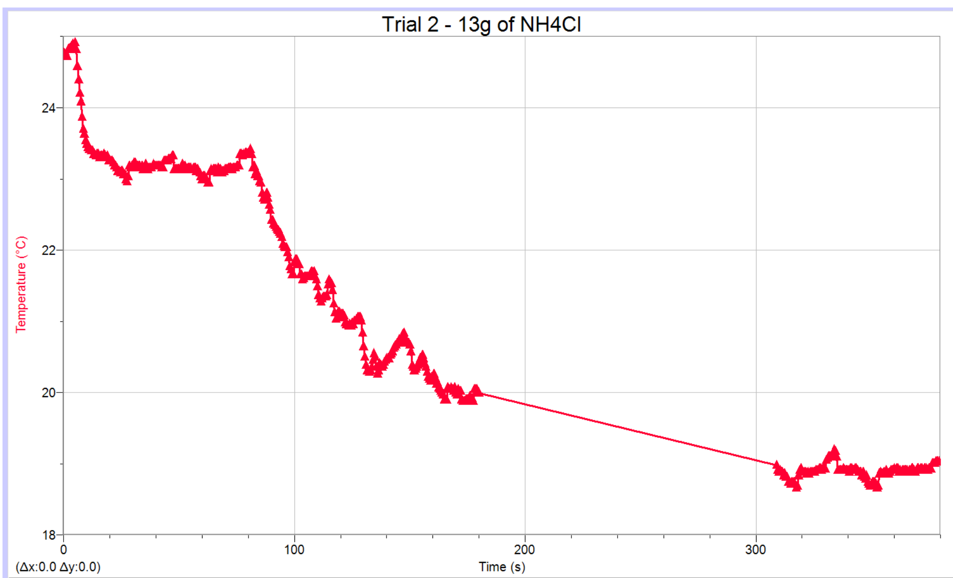
Trail	Mass of NH_4Cl (grams)	Initial Temperature (°C)	Final Temperature (°C)	Change in Temperature (°C)
Trial 1	11.2	23.7	19.8	3.9
Trial 2	13.2	23.3	18.9	4.4
Trial 3	15.2	23.2	18.1	5.1

Additional Graphs:

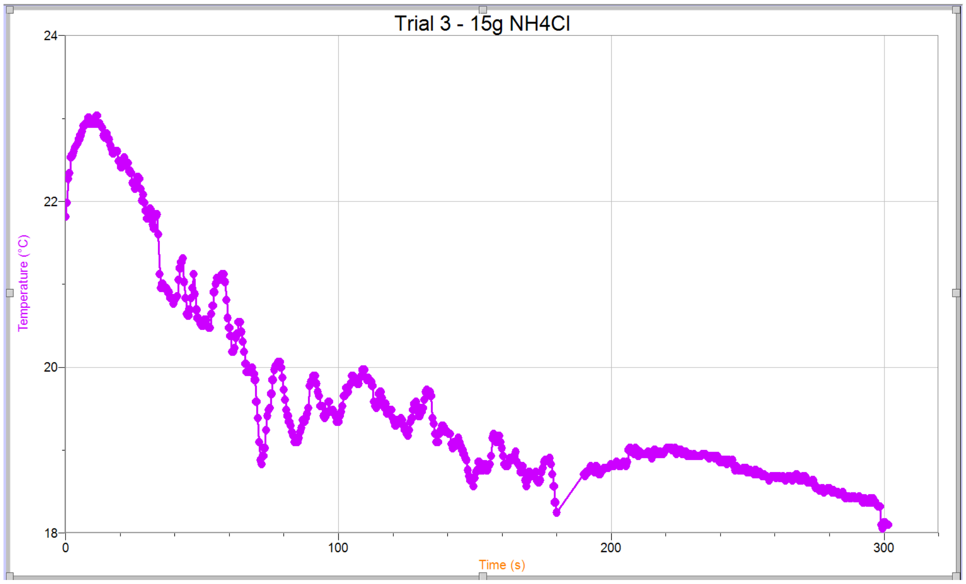
Graph 1: Trial 1, observing the rate of reaction between 11.2 grams of NH_4Cl and H_2O over five minutes



Graph 2: Trial 2, observing the rate of reaction between 13.2 grams NH_4Cl and H_2O over five minutes



Graph 3: Trial 3, observing the rate of reaction between 15.2 grams NH_4Cl and H_2O over five minutes



Sample Calculations

1.
   a. $q_{total} = \left[q_{H_2O,can} + q_{H_2O,calorimeter} + q_{al}\right]$
   b. $q_{total} = [(m_{H_2O,can} + m_{H_2O,calorimeter})c_{H_2O}\Delta T + m_{Al}c_{Al}\Delta T]$
   c. $q_{total} = [(200g)\left(4.18\frac{J}{g\cdot K}\right)(-5K) + (7.2g)\left(0.902\frac{J}{g\cdot K}\right)(-5K)]$
   d. $q_{total} = -4212J$
2.
   a. $n_{NH_4Cl} = \frac{q_{rxn}}{\Delta H_{sol}}$
   b. $n_{NH_4Cl} = \frac{4.212kJ}{17\frac{kJ}{mol}}$
   c. $n_{NH_4Cl} = 0.248mol$
3.
   a. $m_{NH_4Cl} = n_{NH_4Cl} \cdot M_{NH_4Cl}$
   b. $m_{NH_4Cl} = (0.248mol)\left(53.5\frac{g}{mol}\right)$
   c. $m_{NH_4Cl} = 13.2g$

Assessment Criteria Sheet

Assessment Criteria for Planning A Tall Cold Drink of Water
(print and paste in your lab notebook before coming to lab)

A13

TA Name: Sutthinee		Names of Students in Group:	a. Humza Muhammad
			b. Sung Jun (Ryan) Cho
			c. Maya Williams
			d. Cameron Jackson
		Date: Sept 24, 2019	
Criteria:	**Marks Possible**	**Assessment Self**	**Assessment TA**
1. Identify the problem and state it clearly in a way that can be tested.	1		1
2. Use proper apparatus, techniques and safety precautions.	0.5		0
3. Plan to vary only one independent variable at a time.	1		0
4. Controls on other variables are clearly stated.	0.5		0.5
5. Measurement errors are minimized by appropriate procedures or apparatus.	0.5		0.5
6. No invalid assumptions are made.	0.5		0.5
7. Reagents that need accurate measurement are identified.	0.5		0
8. Lab trials and repeats are clearly stated.	0.5		0.5
TOTAL:	5		3/5

Note: This grade will count towards your prelab grade.

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