Enthalpy of Various Reactions

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Intro

The enthalpy of a reaction is the heat energy released or added to a system when a reaction occurs, thereby the change of heat energy. To calculate enthalpy, the equation, $q=mc\Delta T$ can be used, where q is the enthalpy in joules, m is the mass of the substance in grams, c is the specific heat capacity in g/J°C and ΔT is the change in temperature in degrees celsius. When q results in a positive number, this indicates that the reaction is endothermic meaning heat was added to the reaction. Nevertheless when q is negative, it is an exothermic reaction because this means that heat was released from the reaction.

In a dissolution reaction, there are two main forms of energy that occur, lattice energy and hydration energy. Firstly, lattice energy is the energy required to break the chemical bonds of the salt, since bonds have energy stored within them, to form gaseous ions. Since heat is being used to break apart the bond, lattice energy is endothermic. Secondly, the hydration energy is the energy released when the gaseous ions are solvated by the water to form two aqueous ions and this exothermic since energy is being released. The total enthalpy change of a solution is equal to the sum of these two enthalpies and can be expressed as $\Delta sH°$ = (- heat loss of H2O) + (- heat loss of salt)[1]. This is Hess's Law which states that the total enthalpy change for a reaction is equal to the sum of the energy changes in the individual reactions compromising it[2].

Intro (continued)

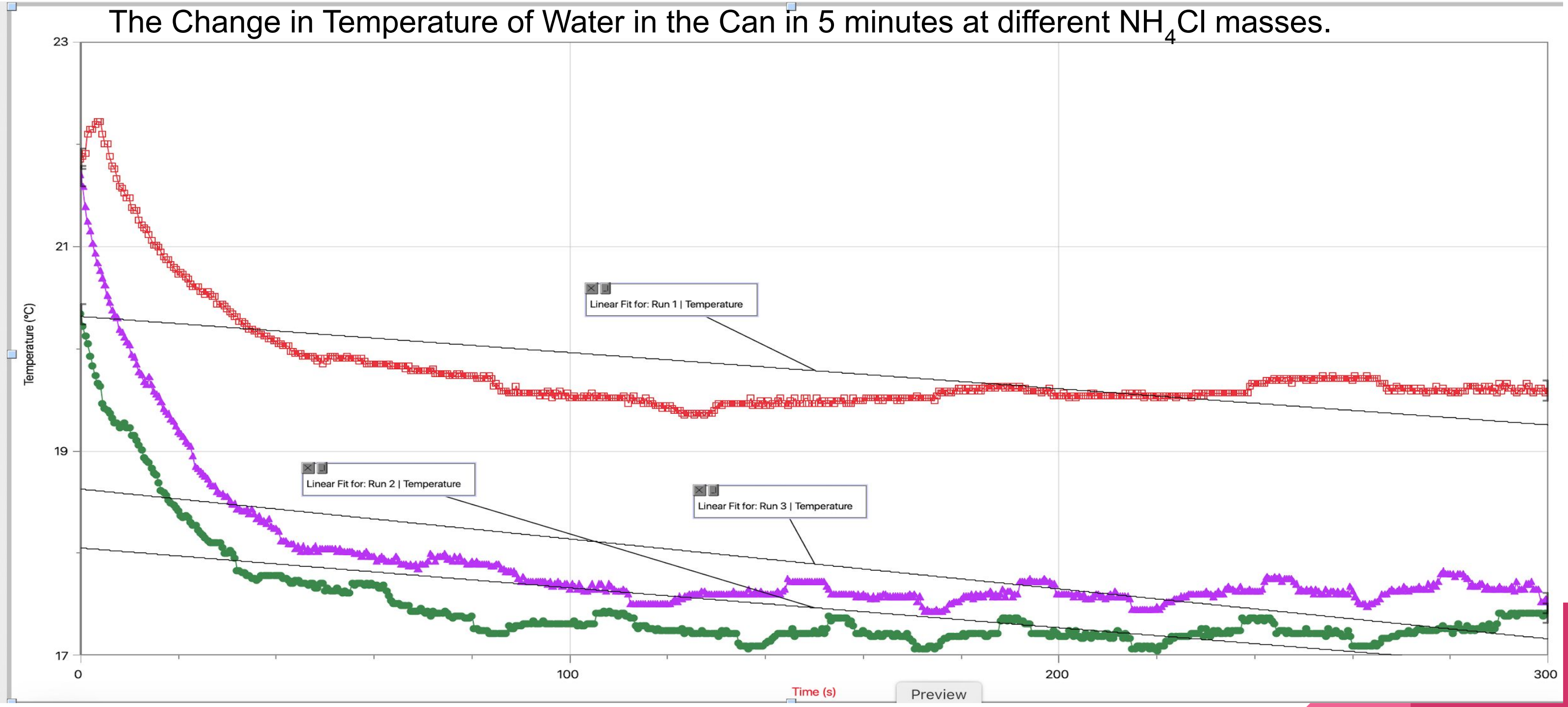
The expectation of this experiment was to dissolve a salt in water and in doing so, decrease the temperature of 100 cm^3 of water by 5 °C in 5 minutes. We were given the choice to use either ammonium chloride (NH_4Cl) or ammonium nitrate (NH_4NO_3) as the salt being used to cool the drink down. Ultimately, we decided to use NH_4Cl in order to perform this task. It was a clear decision after researching both substances and looking at on the chemical properties of each that ammonium nitrate would be unfit. Recognizably, ammonium nitrate is a highly toxic substance that is used in fertilizers, often contaminating water and harmful aquatic life, therefore would be toxic to ingest (Ortiz-santaliestra, Manuel, and Adolfo Marc). Ammonium chloride is a substance used in some medications, therefore was evidently the better option (J. Li et al) and it is used in some foods, such as black licorice, therefore evidently being the better option.

To do this lab, we began by calculating the theoretical mass of salt that would allow us to decrease the volume of 100mL of water by 5 °C in 5 minutes, which was 13.67g. However when doing so, we took into account the mass of the can as well since it would also be within the system meaning that it would also be absorbing heat, even if it is only a little since aluminium does not absorb well. Nevertheless, we knew that the theoretical mass doesn't always end up working out exactly as calculated so, we decided to choose two other masses that would be close to the calculated one by adding and removing 5g and thus got 8.67g and 18.67g. Furthermore, to measure the heat transfer of the reaction, we used a styrofoam cup calorimeter. This is because calorimeters create a closed system meaning that no heat will escape from the inside and no heat will from the surrounding creating no interference to the enthalpy of the reaction. Additionally, a styrofoam cup calorimeter was specifically chosen because of its ability to insulate the heat of a reaction. Lastly, the salt was added to water surrounding the can inside the calorimeter for two reasons. The more conventional reasoning is because it would be more safe to drink if the salt wasn't inside the can. Regardless of that, to decrease the temperature of the water inside the can, we had to put the salt in the surrounding water so that it uses energy from the water to break its bonds causing the water in the styrofoam cup to get colder. This would then cause the temperature of the water inside the can to also decrease because it would give some of its heat to the water outside to equalize the temperature of the system as a whole. This type of transfer of energy is referred to as conduction since energy is being transferred from the more energetic particles in the water in the can to adjacent less energetic particles in the system.

Procedure

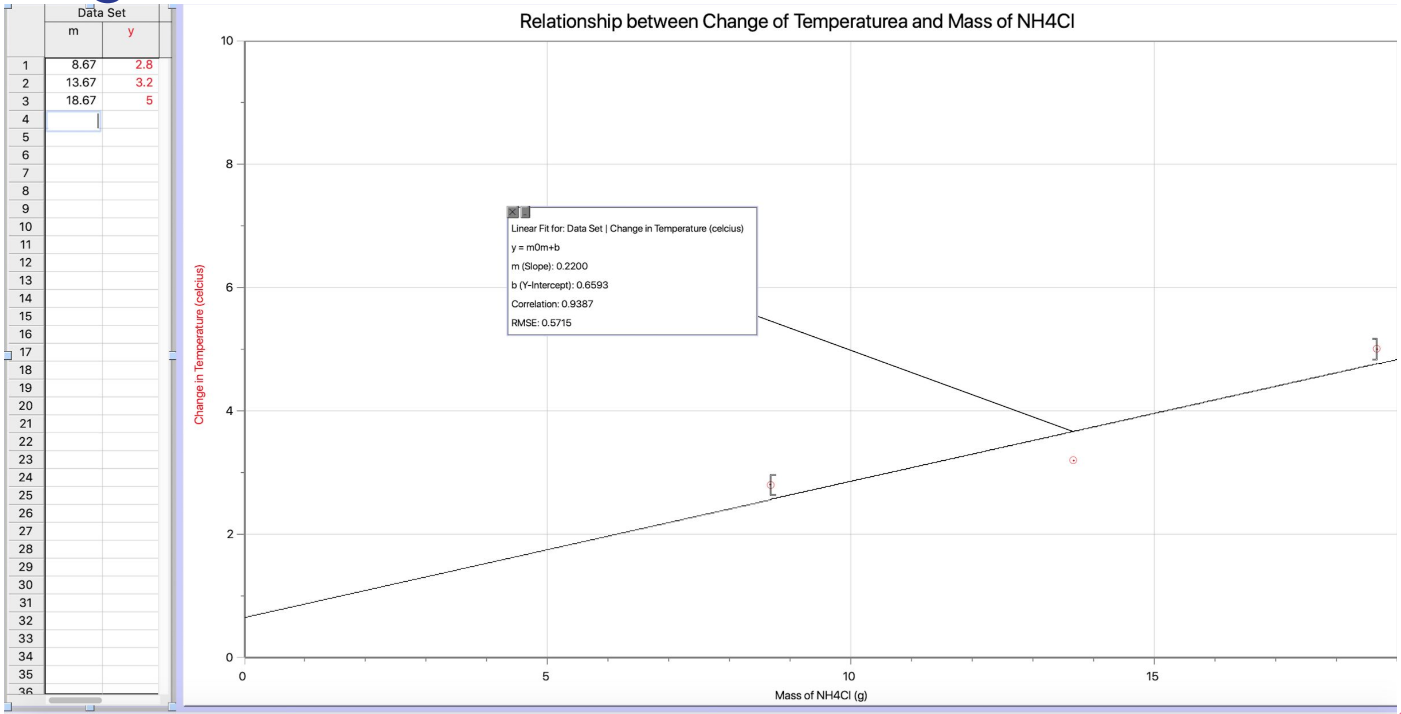
1. Connect your calorimeter to your LabQuest2.
2. Add 100 mL of water in your styrofoam cup and 100 mL of water into the pepsi can.
3. Record the initial temperature as of the water inside the pepsi can.
4. Add 8.67g of NH_4Cl into your styrofoam cup.
5. After 5 minutes, record the final temperature of the water inside the pepsi can.
6. Repeat steps 2-5 but with 13.67g of NH_4Cl (add 5g to original amount).
7. Repeat steps 2-5 once more but with 18.67g of NH_4Cl (add another 5g to the original amount).

Figure 1.1



This graph represents the decline in temperature of the water in the can, measured in degree celsius, over the course of 5 minuters, measured in seconds. Red is m=8.67g, green is m=13.67 and purple is m=18/67.

Figure 1.2



This graph visually represents the relationship between the mass and change in temperature. As the mass (shown on the x-axis) increases, you can see that the slope increases which means that the temperature (shown on the y-axis) is increasing as well.

Table 1.3

NH_4Cl mass (g)	8.6g	13.67g	18.67g
Initial temperature (°C)	22.4	20.6	22.5
Final temperature (°C)	19.6	17.4	17.5
ΔT (°C)	-2.8	-3.2	-5

This table shows the data collected through this experiment at all three different masses of NH_4Cl

Discussion

The data provided in figure 1.3 shows the initial, final and change in temperature of the drink over the course of 5 minutes, starting from when the different masses of NH_4Cl was added. The independent value of this experiment was the mass as the change in temperature depended on how much salt we put into the calorimeter. The water was constant in all three trials done, 100mL inside the can and 100mL inside the cup. Through our results, you can see that the experimental value that accomplished this goal was 18.67g, not the theoretically calculated value. Moreover, when tested, the theoretical value failed to achieve our goal of $\Delta T = 5$.

Figure 1.2 shows a positive and linear relationship for the change in temperature as a function of the mass of NH_4Cl. The slope of the graph, shown by the line of best fit, is 0.22. This represents the average change of temperature that occurred throughout the three different trials taken. A function that can be used to describe this graph is $q=0.22t+0.6593$.

When comparing our data with what different literary works show, it shows that our calorimeter was successful. Like other experiments done using calorimeters, it was able to measure the amount of heat involved in this chemical reaction. Nonetheless, it was just not as efficient as others because although it was able to decrease the temperature of the water by 5 °C just like we wanted, it took more salt than what was originally predicted to do so. The percentage error between how much the temperature should have theoretically dropped at 13.67g versus how much it actually did is 36%.

Theoretical limitations as to why this experiment and theory may not sufficiently describe real life is that it is very difficult to create a completely closed system. A completely closed system is a system that doesn't exchange any energy with its surroundings and everything in the system is not affected by its surroundings. This is extremely difficult to achieve in the real world as it is hard to completely isolate something from all that's around it. Even in this lab we were not able to work under the conditions of a completely closed system. Although the theory may still apply and work out, it just won't be 100% accurate.

Discussion (continued)

There are many experimental errors that could have or did occur during this lab. For example, there could have been residue of the crystallized salt on the outsides of the can or on the inside of the styrofoam cup before doing new trials. Even though we cleaned the can and cup before every new trial, there is still a chance that some salt from the previous trials was present. This excess salt would have altered the reaction because it would have taken it would mean that there is extra salt in the calorimeter therefore our mass is inaccurate which would in turn affect the change in temperature because with extra mass, it means more salt it taking energy from the water surrounding the can.

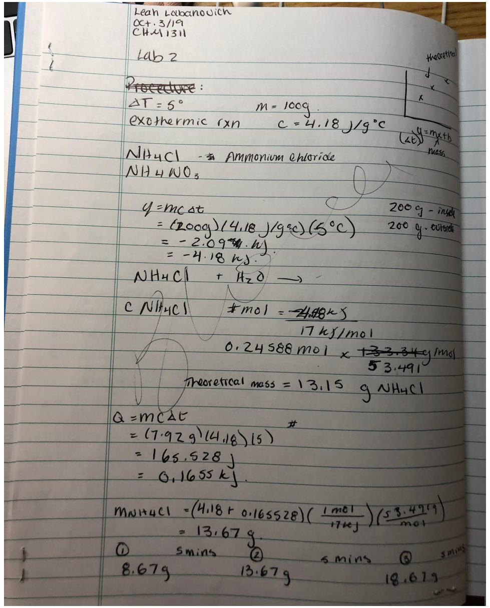
Another experimental error could be due to the fact that the system was not completely closed. Because of the hole made at the top of the styrofoam cup to fit the thermometer, there was space for heat to enter and escape during the 5 minutes that the reaction was taking place. As described in the introduction, for the salt to dissolve in water, it would use energy from the water to break its bonds and so, that would cause the water in the styrofoam cup to get colder. In turn, this would cause the water inside the can to also cool down since it would give some of its heat to the water outside to equalize it. However because heat was escaping and entering, the water in the styrofoam cup didn't cool down as much meaning that the water in the pepsi can also didn't cool down as much so, the final measured temperature for all our trials is slightly higher than what it should actually be. Moreover, this means that our goal was only achieved when we used 18.67g. Even though the water was affected by the heat that entered the cup, because there were more molecules that needed to break their bonds, they took more energy from the water. Although it did result in a change of temperature of 5 °C which was our desired goal, if it were in a completely closed system it most likely would have had a bigger difference in temperature change and therefore we would have required less salt.

Discussion (Other errors/Improvements)

Some other small errors that could also occurred and limited the results of the experiment include potential inexperience, lack of precision when taking measurements or the equipment not working properly (scale, thermometer, etc.).

It is impossible to completely alleviate all theoretical limitations, however they can be reduced. In order to attain better results in the future, there are a few modifications that can be applied to the experiment. Firstly, while waiting for the reaction to finish, two phones were placed on either side of the thermometer connected to the hole to hold down the styrofoam lid in place in order to minimize the amount of heat escaping and entering the system. While this method may have granted us better results, it was not the most efficient method of trying to keep the system as closed as possible. Therefore to attain more accurate results in future testings, we must try to reduce the amount of heat escaping the cup through the whole. This can be done by maybe placing a cover over the part of the thermometer sticking out so that even if energy does escape through the hole, it won't be able to go into the surroundings. It also reduces the amount of energy entering. Secondly, multiple trials using the same mass should be done for two reasons. Firstly, it gives us more experience when doing the lab and so, that makes us more used to the procedure therefore making us less likely to mess up. Furthermore, if we do multiple trials and get similar results, it makes us more confident that our results aren't just a fluke and so by taking the average of the different trials, we can get the most optimal results.

Raw Data


Leah Labanovich
Oct. 3/19
CHM 1311

Lab 2

~~Procedure~~:

$\Delta T = 5°$ $m = 100g$

exothermic rxn $c = 4.18\ J/g°C$

NH_4Cl — Ammonium chloride

NH_4NO_3

$q = mc\Delta t$

$= (200g)(4.18\ J/g°C)(5°C)$

$= -2.09\ kJ$

$= -4.18\ kJ$

200 g - inside

200 g - outside

$NH_4Cl + H_2O \rightarrow$

c NH_4Cl #mol = ~~4.18~~ kJ / 17 kJ/mol

0.24588 mol × ~~133.34~~ 53.491 g/mol

Theoretical mass = 13.15 g NH_4Cl

$Q = mc\Delta t$

$= (7.92g)(4.18)(5)$

$= 165.528\ J$

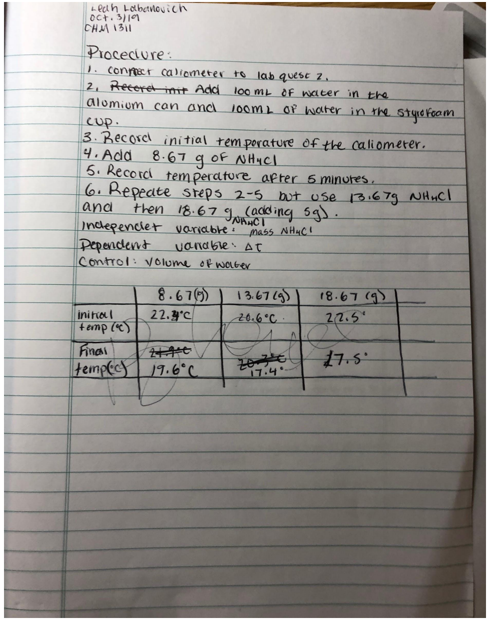
$= 0.1655\ kJ$

$m_{NH_4Cl} = (4.18 + 0.165528)\left(\frac{1\ mol}{17\ kJ}\right)\left(\frac{53.49\ g}{mol}\right)$

$= 13.67\ g$

① 5 mins ② 5 mins ③ 5 mins

8.67g 13.67g 18.67g


Leah Labanovich
Oct. 3/19
CHM 1311

Procedure:

1. connect calimeter to lab quest 2.
2. ~~Record init~~ Add 100 mL of water in the alumium can and 100mL of water in the styrofoam cup.
3. Record initial temperature of the caliometer.
4. Add 8.67 g of NH_4Cl
5. Record temperature after 5 minutes.
6. Repeate steps 2-5 but use 13.67g NH_4Cl and then 18.67 g NH_4Cl (adding 5g).

Independent variable: mass NH_4Cl

Dependent variable: ΔT

Control: volume of water

	8.67(g)	13.67(g)	18.67 (g)
initial temp (°C)	22.3°C	20.6°C	22.5°
Final temp(°C)	~~21.9°C~~ 19.6°C	~~20.7°C~~ 17.4°	17.5°

Calculations

Theoretical Mass Calculations:

$\Delta H NH_4Cl = \Delta H lat + \Delta H hyd$
$= (-307 kJ/mol - 381 kJ/mol) + (705 kJ/mol)$
$= 17 kJ/mol$

$q_{can} = mc\Delta T$
$= (7.92 g)(4.184/g°C)(-5°C)$
$= -0.1656864 kJ$

$q_{water} = mc\Delta T$
$= (200 g)(4.184 J/g°C)(-5°C)$
$= -4.180 kJ$

m of $NH_4Cl = (4.180 kJ + 0.1656864 kJ)(1 mol NH_4Cl / 17 kJ)(53.491 g NH_4Cl / 1 mol NH_4Cl)$
$= 13.67 g$

Calculations

Percentage error:

$$\% \text{ error} = (|\text{Approximate Value} - \text{Exact Value}| / |\text{Exact Value}|) \times 100\%$$

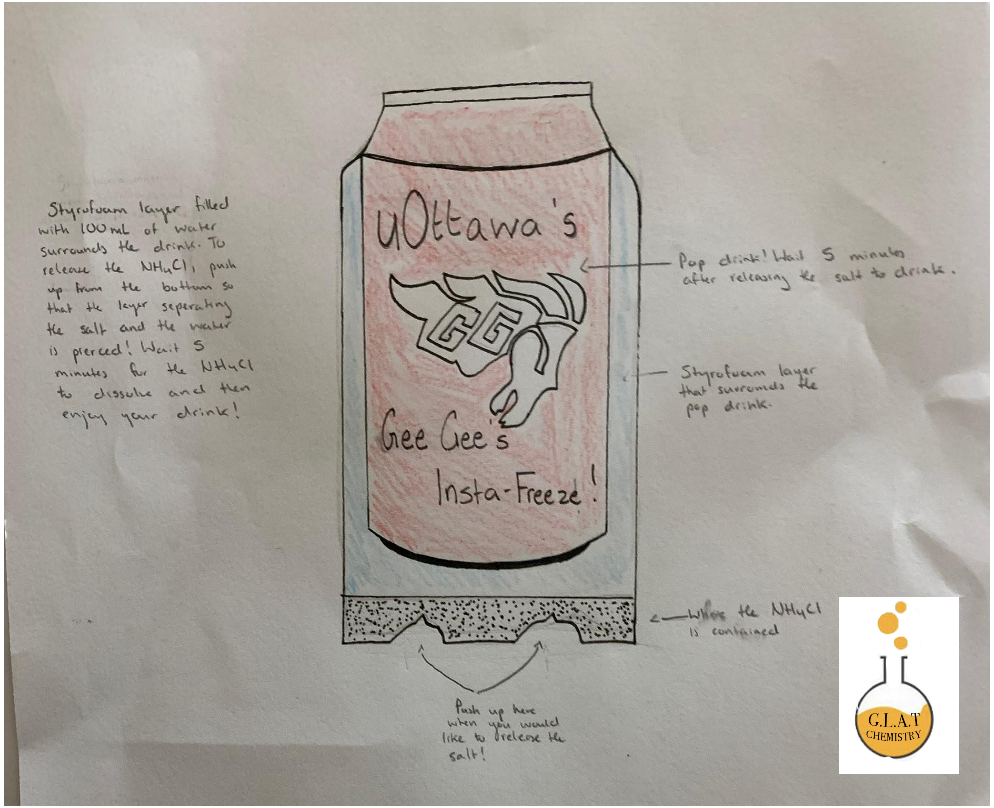
$$= ((|3.2-5|)/|(5)) \times 100\%$$

$$= 36\%$$

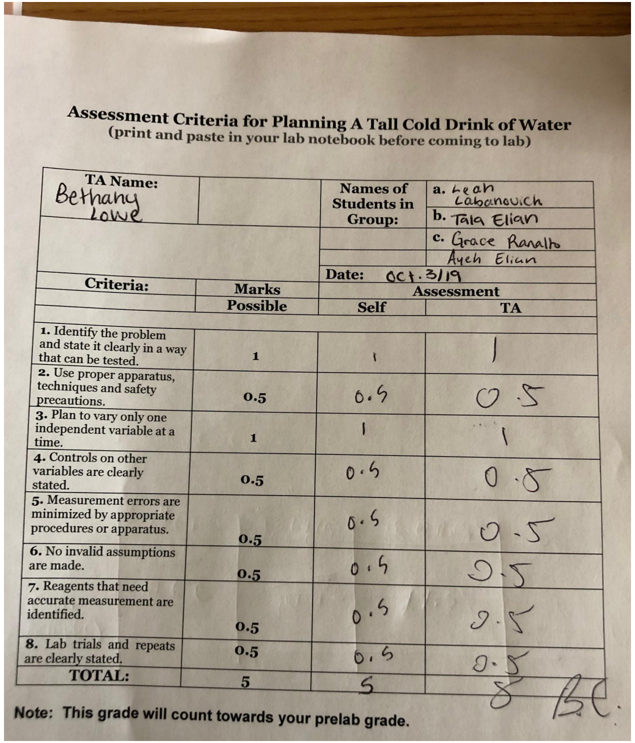
Conclusion

To conclude, the mass of NH_4Cl needed to cool the Gee Gee's sports drink by 5 °C is 18.67g. The percent error of this result was 36%. Given this percent error, we can assume that our results were fairly accurate, but not as precise as they could have been.

Gee Gee's Insta-Freeze!



Assessment Criteria



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

TA Name: Bethany Lowe	Names of Students in Group:	a. Leah Labanovich b. Tala Elian c. Grace Ranallo Ayeh Elian
	Date:	Oct. 3/19

Criteria:	Marks Possible	Assessment: Self	Assessment: TA
1. Identify the problem and state it clearly in a way that can be tested.	1	1	1
2. Use proper apparatus, techniques and safety precautions.	0.5	0.5	0.5
3. Plan to vary only one independent variable at a time.	1	1	1
4. Controls on other variables are clearly stated.	0.5	0.5	0.5
5. Measurement errors are minimized by appropriate procedures or apparatus.	0.5	0.5	0.5
6. No invalid assumptions are made.	0.5	0.5	0.5
7. Reagents that need accurate measurement are identified.	0.5	0.5	0.5
8. Lab trials and repeats are clearly stated.	0.5	0.5	0.5
TOTAL:	5	5	5 BL.

Note: This grade will count towards your prelab grade.

References

J. Li et al., "Synthesis and Characterization of N,N-Dimethyl Dodecyl-(4-Vinyl Benzyl) Ammonium Chloride", Key Engineering Materials, Vols. 575-576, pp. 71-75, 2014

Ortiz-santaliestra, Manuel, and Adolfo Marco. "Influence of Dissolved Oxygen Conditions on Toxicity of Ammonium Nitrate to Larval Natterjack Toads."*Archives of Env*ironmental Contamination and Toxicology, vol. 69, no. 1, 2015, pp. 95-103. ProQuest, https://search-proquest-com.proxy.bib.uottawa.ca/docview/1685684185?accountid=14701, doi:http://dx.doi.org.proxy.bib.uottawa.ca/10.1007/s00244-014-0126-3.

1-As described in the lab manual (What in the World ISN'T Chemistry, Dr. Rashmi Venkateswaran, 2000, Exp. 1, p. 1).

2- First Law of Thermodynamics. Thermodynamics for Chemical Engineers **2003**.