

Experiment #2

Enthalpy of Various Reactions

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Introduction:

An endothermic reaction occurs as heat is transferred from its surroundings into the chemical system. In order to complete the task given for this experiment, 100ml of water must be cooled by 5°C in 5 minutes, therefore an endothermic product design will be required to do this. The process in which the design of the cup will utilize is the dissolution of a salt which is an ionic compound, in particular NH₄Cl. In order to produce an endothermic reaction, the lattice energy and enthalpy of hydration must sum to form a positive enthalpy of solution value.

$$\text{Lattice energy} + \text{Enthalpy of Hydration} = \text{Enthalpy of Solution}$$

Lattice energy in the case of this reaction is the energy that is required to break the bonds of an ionic solid (NH₄Cl) and convert its components into gaseous ions, given this definition the value of lattice energy will always be positive. ¹ Enthalpy of hydration is the measure the amount of heat released as aqueous ions are hydrated in a solution, this is often a negative value. The molar enthalpy of solution is the total energy released when mole of a substance is dissolved into a solvent. ²

For the purposes of this experiment, Ammonium Chloride was chosen as opposed to ammonium nitrate for two main reason. First, it is the slightly cheaper alternative, ammonium chloride costs \$62.40 per 500g and ammonium nitrate costs \$64.62 per 500g. Secondly and most importantly, ammonium chloride is much safer to use than ammonium nitrate. Ammonium nitrate is classified as a moderately toxic substance and it is dangerous to ingest.³ Since the product to be designed is a drinking cup, the potential of contamination is high, therefore the use of this salt would be a risk. As well, ammonium nitrate is a strong oxidizer and extremely flammable, the design incorporates an aluminum pop can which means that the potential for reaction between the aluminum and ammonium nitrate is unnecessary another risk.

Calculations in the data analysis section of this lab support the fact that the dissolution of ammonium chloride is an endothermic process as the enthalpy of solution is +17kJ/mol. In order to determine theoretically how much ammonium chloride will be needed to cool the solution, the

thermodynamic law of conservation ($Q = mc\Delta T$), and applying relationships known between enthalpy and heat it was determined that in order to cool the solution by 5°C in 5 minutes, 6.58g of ammonium chloride is required.

Procedure:

1. Put all safety equipment on before entering lab area, this includes safety goggles and a lab coat.
2. Calculate the theoretical calculations of the heat energy transfer that is required to cool 100ml of water by 5°C in 5 minutes using NH_4Cl . Calculations shown in lab book figures and data analysis.
3. Obtain required materials for the experiment which include a styrofoam calorimeter, pop can, thermometer, cotton (to insulate calorimeter), balance, graduated cylinder and NH_4Cl salt.
4. Measure out mass of NH_4Cl using balance, and fill the pop can and Styrofoam calorimeter with 100ml of water each using the graduated cylinder.
5. Record the initial temperature of water in the pop can.
6. Add the measured out mass of NH_4Cl into the calorimeter and swirl in order to fully dissolve the salt.
7. Place the lid on top of the calorimeter and pop can and insert thermometer into the hole which is to be insulated with cotton.
8. Record the temperature change after 5 minutes.
9. Repeat steps 4-8 for small masses.
10. Return all equipment and clean lab area.

Data:

Table 1: Data Obtained of the Temperature Change Caused by various Masses of Ammonium Chloride on 100ml of water

Trial	Mass NH ₄ Cl (g)	Initial Temperature (°C)	Temperature After 5 Minutes (°C)	Change in Temperature (°C)
1	6.58 (theoretical)	22.9	20.4	2.5
2	8.00	22.7	19.7	3.0
3	12.00	22.9	18.7	4.2
4	13.15 (actual)	22.9	18.0	4.9
5	13.75	22.9	17.2	5.7
6	14.00	22.9	17.5	5.4

Table 2: Qualitative Observations Recorded During Experiment

Observations:	<ul style="list-style-type: none">- No colour change occurred in solution.- Temperature initially decreased at a quicker rate in all trials then continued to decrease for time interval but at a slower rate.- Small chunks remained in salt, didn't entirely dissolve in all trials.- The more salt added, the bigger the temperature change.
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Graphs:

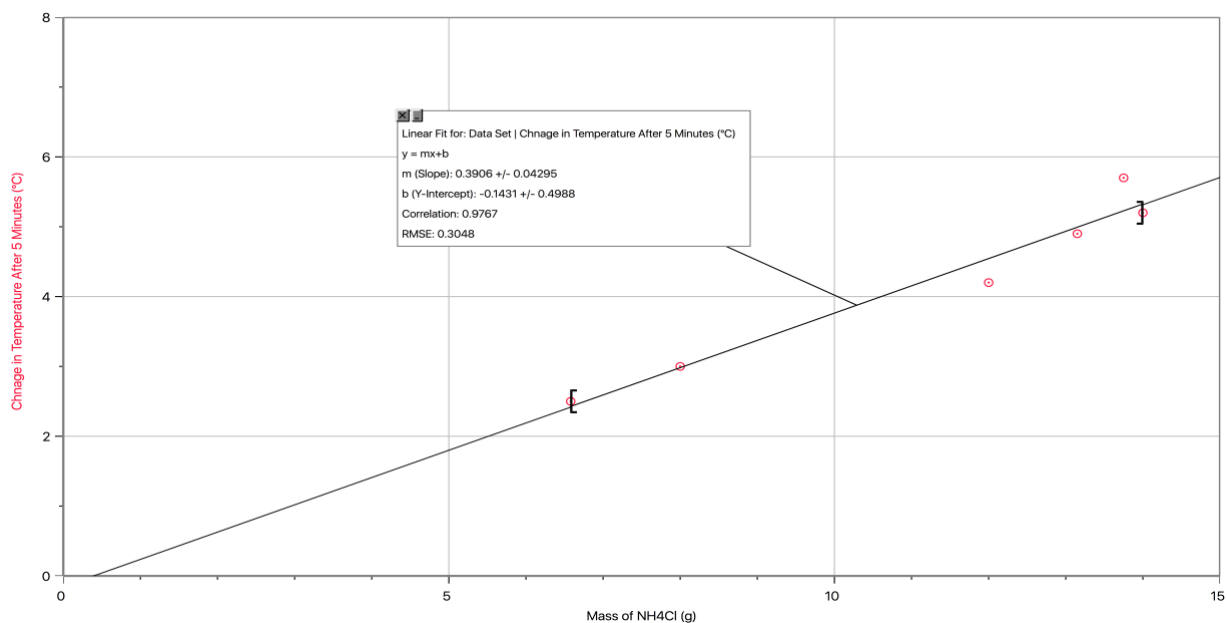


Figure 1: Graph of The Temperature Change In Relation to Mass of Ammonium Chloride

Data Analysis:

- Calculations from Pre-Lab:

ΔH_{sol} = lattice energy + enthalpy of hydration of ion a + enthalpy of hydration of ion b

NH₄Cl:

NH₄NO₃:

$$\Delta H_{sol} = 705 + (-307) + (-381)$$

$$= +17 \text{ kJ/mol}$$

$$= +25 \text{ kJ/mol}$$

- Calculations from Lab Notebook:

$$Q = mc\Delta T$$

$$= (100\text{g})(4.18 \frac{\text{J}}{(\text{g})(\text{C})})(-5^\circ\text{C})$$

$$= -2090 \text{ J}$$

$$= 2.09 \text{ kJ}$$

$$Q_{\text{NH}_4\text{Cl}} = -Q_{\text{H}_2\text{O}}$$

$$\therefore n = -Q_{\text{H}_2\text{O}}$$

$$= -\frac{(-2.090)}{17}$$

$$= 0.1229 \text{ mol}$$

$$0.1229 \text{ mol NH}_4\text{Cl} \times \frac{53.5\text{g}}{\text{mol}} = 6.58\text{g}$$

\therefore The theoretical amount of NH₄Cl required to cool 100g of water by 5°C is 6.58g.

- Error Calculation:

$$\%error = \frac{\text{actual} - \text{theoretical}}{\text{theoretical}} \times 100\%$$

$$= \frac{13.15\text{g} - 6.58\text{g}}{6.58\text{g}} \times 100\%$$

$$= 99.84\%$$

Discussion:

Once the experiment was prepared including the calculation and procedure preparation, obtaining the data was quite simple with the use of the thermometer. Different masses of ammonium chloride all corresponded to a different change in temperature. With the exception of trial 5 a linear relationship is evident. Trial 5 was an outlier in the data as a much higher change in temperature occurred than expected for that mass, the trial was still included in figure 1. As expected, as the mass of ammonium chloride was increased, the change in temperature increased as did the rate of increase.

However theoretically, the calculations indicated that only 6.58g of salt would be required to decrease the temperature by 5°C, the experiment however demonstrated that 13.15g would be required. 6.58g of salt only resulted in a change of 2.5°C, only half of what was expected.

The 99.84% error can be explained by several factors, first the system may have not been completely closed. Although we attempted to insulate the thermometer hole as much as possible with cotton, some air could have still escaped, as well the styrofoam lid does not seal meaning that some air could have come in and out of the system affecting the temperature change. Also impurities in both the salt and water may have impacted the results, especially in the case of the water, as tap water was used which isn't always pure and distilled.

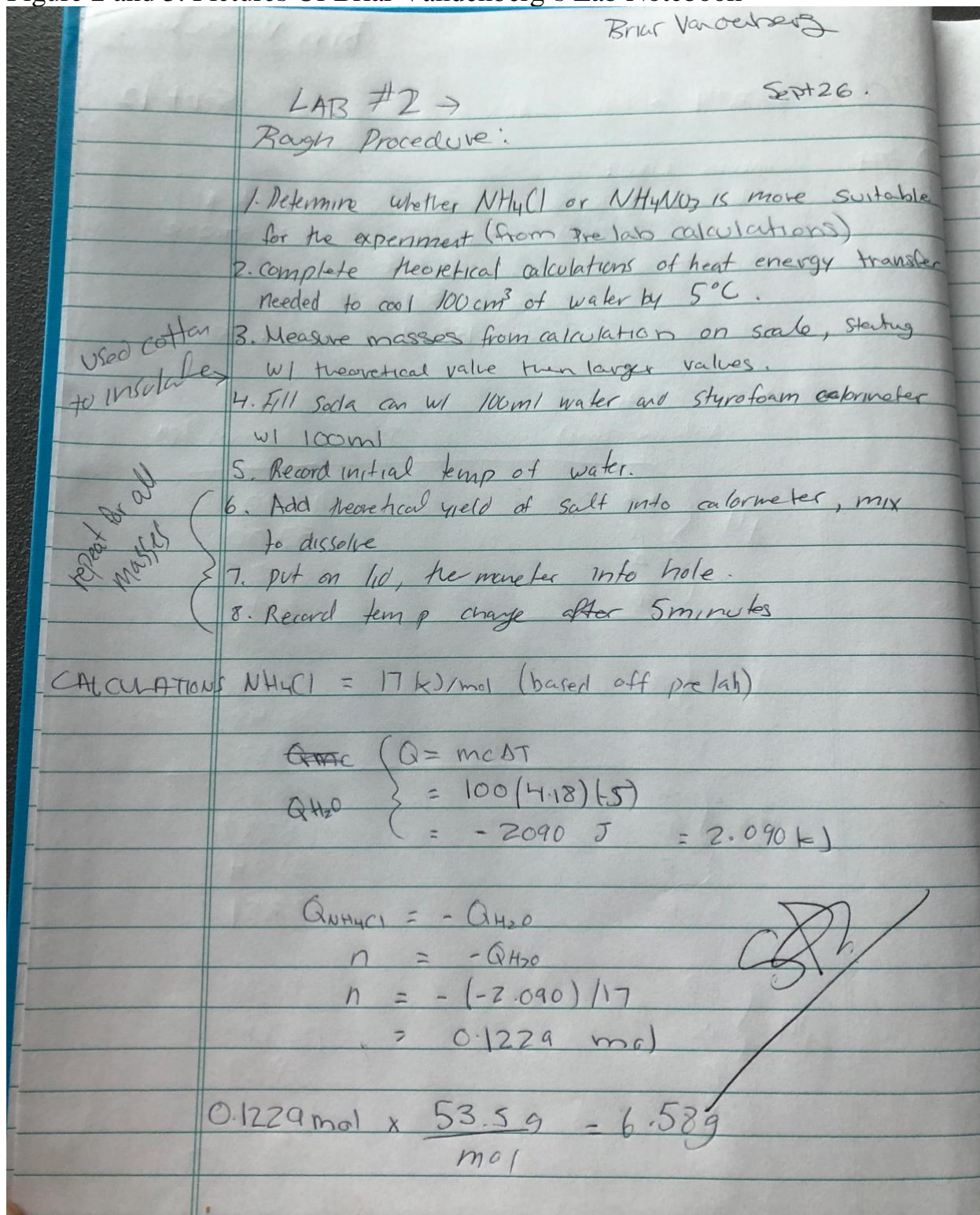
Conclusion:

Conclusively, the six trials performed in this lab disprove the theoretical value, which was 6.58g. Due to limitations and errors mentioned, this value was not obtained. This experiment showed that 13.15g of NH_4Cl is required to cool 100ml of water by 5°C in 5 minutes. However, this lab did prove that as more NH_4Cl is added the temperature change was larger as well it was observed that the temperature decreased at a faster rate.

Works Cited:

1. Libretexts. "Lattice Energy: The Born-Haber Cycle." *Chemistry LibreTexts*, Libretexts, 15 Feb. 2017,
<[chem.libretexts.org/Textbook_Maps/Inorganic_Chemistry/Supplemental_Modules_\(Inorganic_Chemistry\)/Crystal_Lattices/Thermodynamics_of_Lattices/Lattice_Energy%3A_The_Born-Haber_cycle.](http://chem.libretexts.org/Textbook_Maps/Inorganic_Chemistry/Supplemental_Modules_(Inorganic_Chemistry)/Crystal_Lattices/Thermodynamics_of_Lattices/Lattice_Energy%3A_The_Born-Haber_cycle.)>
2. Libretexts. "Hydration." *Chemistry LibreTexts*, Libretexts, 27 Feb. 2018,
<[chem.libretexts.org/Textbook_Maps/Physical_and_Theoretical_Chemistry_Textbook_Maps/Supplemental_Modules_\(Physical_and_Theoretical_Chemistry\)/Thermodynamics/Energies_and_Potentials/Enthalpy/Hydration.](http://chem.libretexts.org/Textbook_Maps/Physical_and_Theoretical_Chemistry_Textbook_Maps/Supplemental_Modules_(Physical_and_Theoretical_Chemistry)/Thermodynamics/Energies_and_Potentials/Enthalpy/Hydration.)>
3. "CDC - AMMONIUM NITRATE - International Chemical Safety Cards - NIOSH." Centers for Disease Control and Prevention, Centers for Disease Control and Prevention, 22 July 2015,
<[www.cdc.gov/niosh/ipcsneng/neng0216.html.](http://www.cdc.gov/niosh/ipcsneng/neng0216.html)>

Figure 2 and 3: Pictures Of Briar Vandenberg's Lab Notebook



DATA:

Mass of NH_4Cl (g)	Temp after 5 minutes	Initial Temp
6.58		2
7.50 8.00	19.7	22.7
8.00 11.00		
8.50 12.00	18.7	22.9

Qualitative Observations:

- no colour change.
- chunks in salt

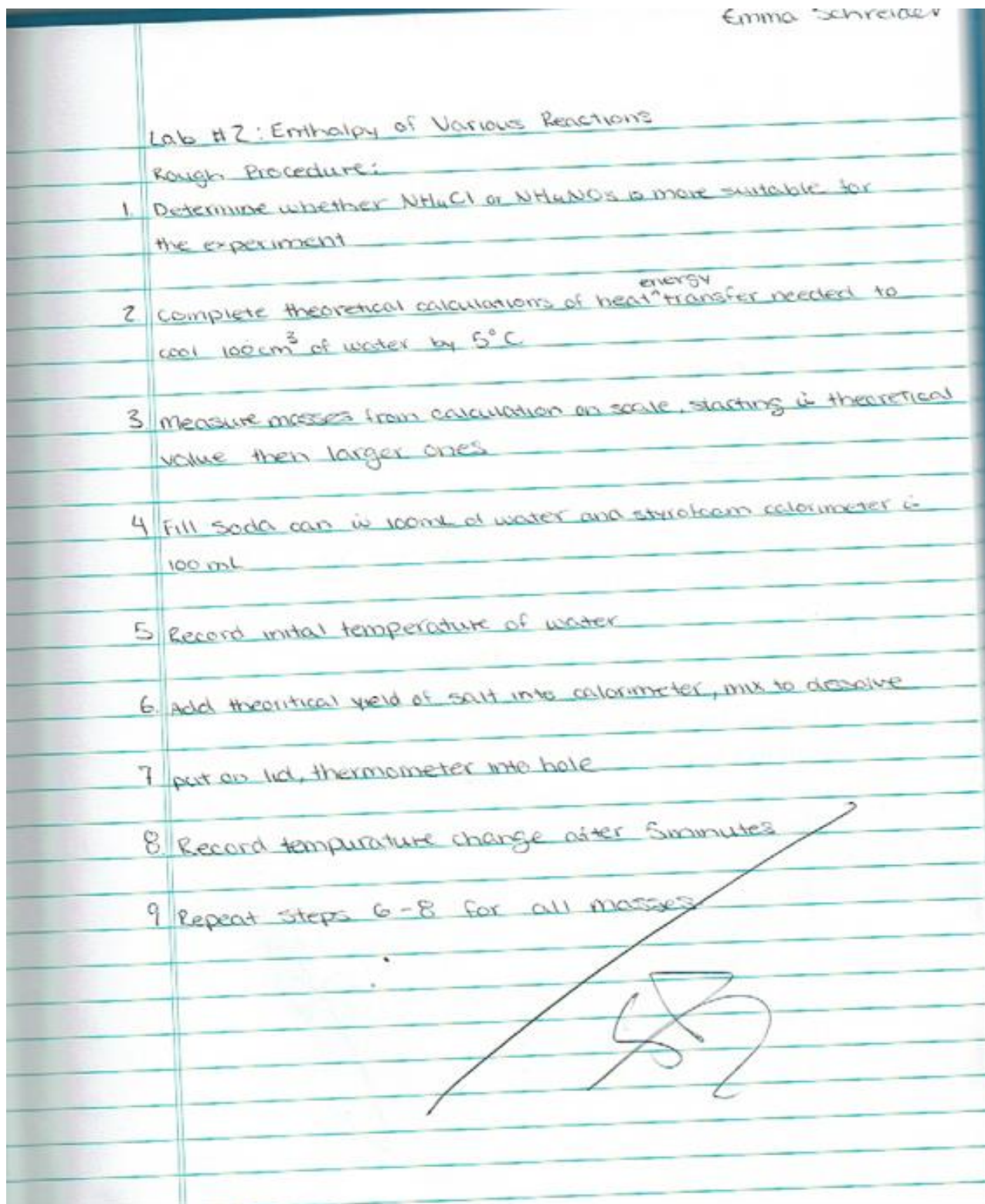
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DATA TABLE

Mass NH_4Cl (g)	Temp initial	After 5 min	diff temperature
6.58	22.9	20.4	2.5
8.00	22.9	19.7	3.0
12.00	22.9	18.7	4.2
14.00	22.9	17.5	5.4
13.75	22.9	17.2	5.7
13.15	22.9	18.0	4.9

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Figure 4, 5, and 6: Pictures of Emma Schreider's Lab Notebook



Calculations:

Finding theoretical yield:

$$\text{NH}_4\text{Cl} = 17 \text{ kJ/mol}$$

$$Q = mc\Delta T$$

$$Q_{\text{NH}_4\text{Cl}} = -Q_{\text{H}_2\text{O}}$$

$$Q_{\text{H}_2\text{O}} = 100 \text{ g} (4.18 \text{ J/kg}) \cdot (-5)$$
$$= -2090 \text{ J}$$

$$n = -Q_{\text{H}_2\text{O}}$$

$$n = (-2090) / 17$$

$$n = 0.1229 \text{ moles NH}_4\text{Cl}$$

$$m = n \cdot M_m$$

$$= 0.1229 \text{ moles} \cdot 53.5 \text{ g/mol}$$

$$= 6.58 \text{ g}$$

Additional masses to use: 8.00g, 7.50g, 8.50g

Additional observations [Qualitative]:

No colour change when NH_4Cl was added to H_2O

Trial 2 \rightarrow salt wasn't fully dissolved

Trial 3 \rightarrow stirred for longer to avoid chunks



Data chart:

mass of NH_4Cl (g)	(H_2O) Temp initial $^{\circ}\text{C}$	(H_2O) Temp Final (after 5 min) $^{\circ}\text{C}$
6) 6.58	22.7	20.4
1) 7.50 8.00	22.7	19.7
3) 8.00 12.022	22.9	17.5
2) 8.50 12.044	22.9	18.7
Volume H_2O	} all values of H_2O were 100ml	
1) 100ml		
2) 100 ml		
3) 100 ml		

Mass of NH_4Cl	Temp: $^{\circ}\text{C}$	Temp Final
4) 13.74	22.9	17.1
5) 13.14	22.9	18.0

Differences in all trials:

- 1 $22.7 - 19.7 = 3$
- 2 $22.9 - 17.5 = 4.2$
- 3 $22.9 - 18.7 = 5.4$
- 4 $22.9 - 17.1 = 5.7$
- 5 $22.9 - 18.0 = 5.1$
- 6 $22.7 - 20.4 = 2.3$




Figure 7: Emma Schrieder's Assessment Criteria

Assessment Criteria for Planning A Tall Cold Drink of Water

TA Name:		Names of Students in Group:	
		a. Emma Schreider	
		b. Briar Vandenberg	
		Date: September 20, 2014	
Criteria:	Marks	Assessment	
	Possible	Self	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.	1	1	1
3. Materials are easily available.	1	1	1
4. Plan to vary only one independent variable at a time.	1	1	1
5. Controls on other variables are clearly stated.	1	1	1
6. Measurement errors are minimized by appropriate procedures or apparatus.	1	1	1
7. The methods are clear enough to be followed by other students.	1	1	1
8. No invalid assumptions are made.	1	1	1
9. Reagents that need accurate measurement are identified.	1	1	1
10. Lab trials are stated.	1	1	1
11. Repeats are stated.	1	1	1
12. Chemistry vocabulary is used correctly.	1	1	1
13. Limitations of the experimental design are described.	1	1	1
TOTAL:	13	13	13

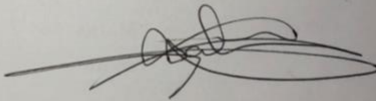


Figure 8: Briar Vandenberg's Assessment Criteria

Assessment Criteria for Planning A Tall Cold Drink of Water

TA Name:		Names of Students in Group:	
		a. <i>Brar Vanderbag</i>	b. <i>Emya Schroeder</i>
		Date: <i>Sept 26th</i>	
Criteria:	Marks Possible	Assessment	
		Self	TA
1. Identify the problem and state it clearly in a way that can be tested.	1		
2. Use proper apparatus, techniques and safety precautions.	1		
3. Materials are easily available.	1		
4. Plan to vary only one independent variable at a time.	1		
5. Controls on other variables are clearly stated.	1		
6. Measurement errors are minimized by appropriate procedures or apparatus.	1		
7. The methods are clear enough to be followed by other students.	1		
8. No invalid assumptions are made.	1		
9. Reagents that need accurate measurement are identified.	1		
10. Lab trials are stated.	1		
11. Repeats are stated.	1		
12. Chemistry vocabulary is used correctly.	1		
13. Limitations of the experimental design are described.	1		
TOTAL:	13	<i>13</i>	<i>13</i>

[Handwritten Signature]