

UOttawa Gee Gee's Sports and Health Drinks  
Thermodynamic Design Lab

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## **CHM1311 Section 1**

Lab TA:

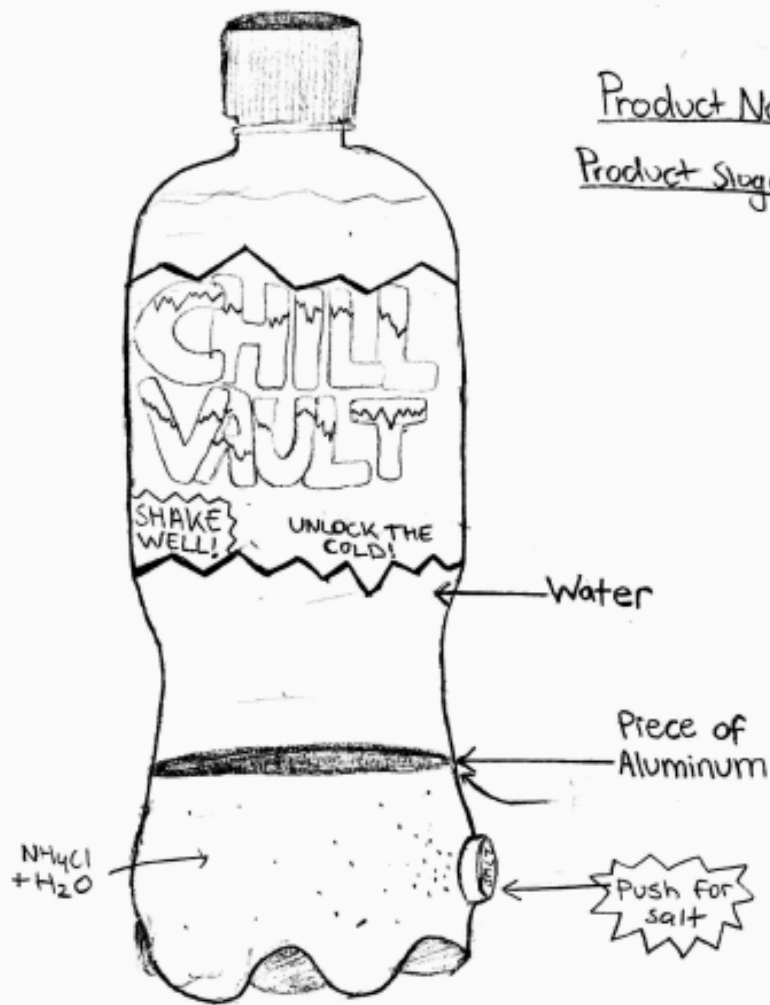
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Product Name: Chill Vault  
Product Slogan: Unlock the cold



### Product Design:

- Bottom section is separated from the top by an aluminum piece.
- "Push for salt" button releases ammonium chloride ( $\text{NH}_4\text{Cl}$ ) into water,
- Since aluminum is a conductive metal, it will decrease the temperature of the water contained in the upper compartment.

## Introduction:

Thermodynamics can be defined as the study of the relationship between heat and other forms of energy. In this lab we will be investigating the relationship between heat and chemical energy. The purpose of this lab was to cool the contents of a calorimeter cup by 5°C in under 5 minutes.

A calorimeter is a device used to measure heat flows that accompany chemical processes. It consists of an insulated container and a thermometer used to measure temperature change. When a chemical reaction occurs inside a calorimeter there is heat flow between the chemicals and the calorimeter and the thermometer rises or falls in response to the heat flow. The heat of the calorimeter can be discovered if we know the mass, specific heat capacity and temperature at a given time. Specific heat capacity can be defined as the heat required to raise the temperature of a given substance by 1 degree.

$$q=mc \Delta T$$

Calorimeters are also insulated so that very little heat is lost to the surroundings and we can assume that the only heat exchange is between the calorimeter and the chemicals.

$$q_{\text{chemicals}} = -q_{\text{calorimeter}}$$

For the temperature of the calorimeter to go down by 5°C an endothermic reaction would need to take place causing the heat of the calorimeter to fall. Both ammonium chloride and ammonium nitrate undergo endothermic reactions when mixed with water. For this experiment we chose to use ammonium chloride instead of ammonium nitrate because ammonium nitrate is a flammable substance while ammonium chloride is not. So it is safer for customers to use as there is no risk of the can exploding. Also if possibly ingested, ammonium chloride<sup>1</sup> does less harm to the body than ammonium nitrate<sup>2</sup>.

Coffee was replaced with water in this lab to simulate the endothermic reaction between coffee and the ammonium chloride because their heat capacities are about the same (4.18J/(g°C)) and water is a lot more accessible in a lab than coffee. A pop can was placed inside the calorimeter and filled with 100mL of water to simulate the contents of the coffee can. Then

80mL of water was placed outside of the pop can. More water was placed inside the can than outside to make sure that the can did not float and so that the endothermic reaction would occur on the sides of the can with equal distribution rather than spread around the can with unequal heat distribution. Afterwards, the salt will be spread around the calorimeter so that the endothermic reaction can take place.

Reference: <http://chemistry.about.com/od/thermodynamics/a/coffee-cup-bomb-calorimetry.htm>,  
Anne Marie Helmenstein, Ph.D., About Education

### Material List

- Ammonium Chloride (10g, 15g)
- Pop can
- Calorimeter (Styrofoam cup)
- 100mL beaker (for gathering water)
- 50mL beaker (for the ammonia chloride)
- Thermometer
- Distilled water
- Small graduated cylinder
- Electronic balance

### Lab Procedure (Groups 1&2)

1. Gather all materials needed for the experiment that are given in the materials list above.
2. The lab will be separated into different groups, each group testing a different mass range of ammonia chloride being used.
3. Set LabQuest Settings to: Duration: 6 min, Interval: 0.5 min.
4. Group one will be using the mass range of 5-10 g of ammonia chloride.
5. Group two will be using the mass range of 10-15 g of ammonia chloride.
6. Group three will be using the mass range of 15-20 g of ammonia chloride.

7. Gather 5 g of the ammonia chloride in a beaker, assure to record the initial weight of the beaker before the ammonia chloride is placed inside.
8. Record the mass of the pop can.
9. Place 100mL of distilled water inside the pop can.
10. Place the pop can inside the calorimeter, ensuring to not spill any water over the sides.
11. Place the salt ammonia chloride in the space between the pop can and the calorimeter.
12. Fill the calorimeter with about 80 ml of distilled water, just enough to submerge the salt that is placed around the can.
13. If the can begins to rise place more water in the space between the can and the calorimeter.
14. Place the lid of the calorimeter on quickly.
15. Once the lid is on tightly, place the thermometer inside the water of the pop can.
16. Record the temperature for five minutes after the thermometer has been placed inside.
17. Shake the calorimeter to ensure that all the salt is dissolved in the distilled water (in a circular motion).
18. The goal is to achieve a 5 degrees decrease in temperature within a 5 minute or less time range.
19. Record the change of temperature with the mass used.
20. Repeat steps 6 through 17 using the masses of 5g & 10g.

Tables & Data:

Table 1. Important measured amounts used in the experiment with mass 5g of salt.

Volume of water Inside the can	100mL
Volume of water outside the can	80mL
Mass of can	8.22g

Table 2. Important measured amounts used in experiment with 10g of salt.

Volume of water Inside the can	100mL
Volume of water outside the can	80mL
Mass of can	7.91g

Table 3. Data for trial 1 with mass 5.003g of  $\text{NH}_4\text{Cl}$ .

Time (min)	Temperature (C)
0:00	20.5
0:30	20.3
1:00	20.4
1:30	20.4
2:00	20.3
2:30	19.8
3:00	19.8
3:30	19.4
4:00	19.4
4:30	19.4
5:00	19.2

Table 4. Data for trial 2 with mass 5.004g of  $\text{NH}_4\text{Cl}$ .

Time (min)	Temperature (C)
0:00	20.3
0:30	20.0
1:00	19.6
1:30	19.6
2:00	19.6
2:30	19.4
3:00	19.4
3:30	19.3
4:00	19.5
4:30	19.3
5:00	19.1

Table 5. Data for trial 1 with 10.01g of  $\text{NH}_4\text{Cl}$

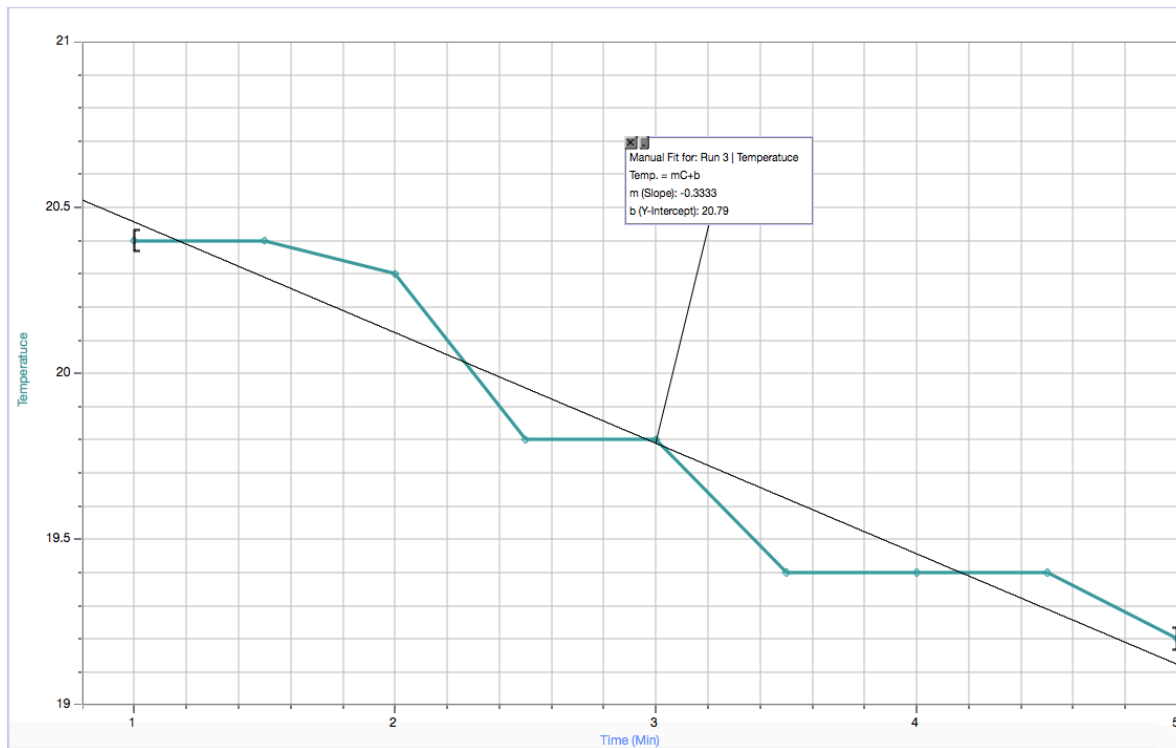
Time (min)	Temperature ©
0:00	20.8
0:30	19.6
1	19.7
1:30	19.2

2:00	19.1
2:30	18.3
3:00	18.3
3:30	18.3
4:00	17.9
4:30	18.0
5:00	18.3
5:30	18.5
6:00	18.3

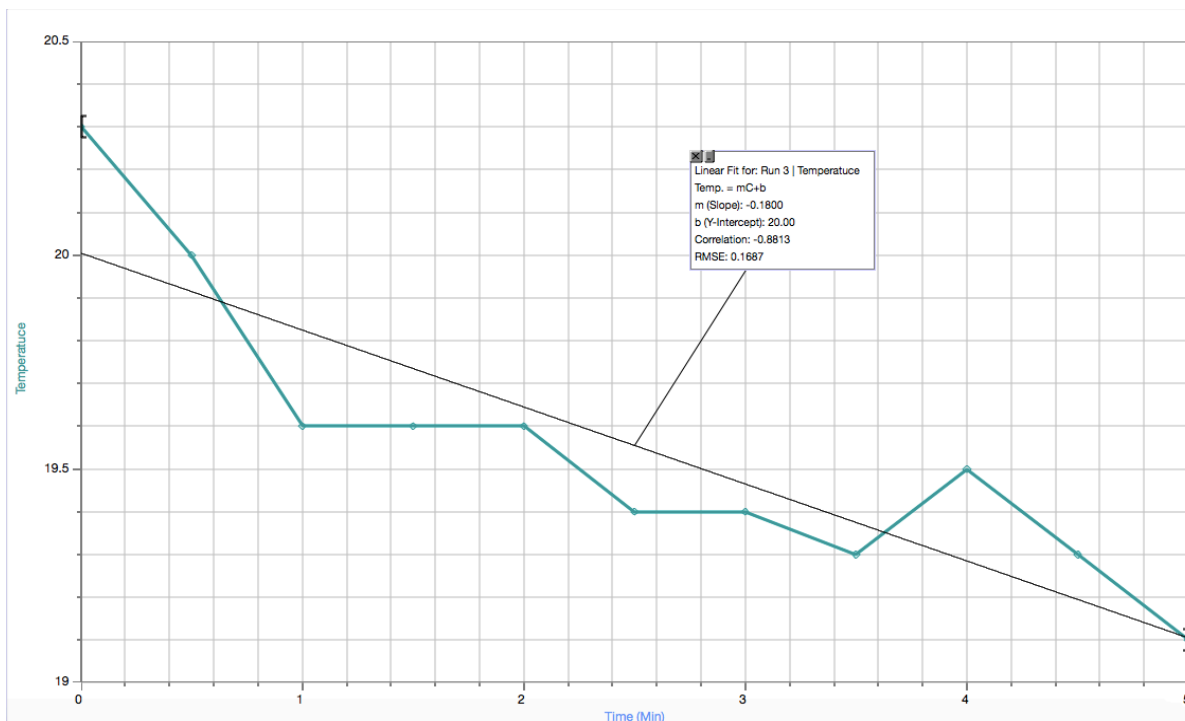
Table 6. Data for the temperature change with each mass of  $\text{NH}_4\text{Cl}$  tested.

<b>Trial</b>	<b>Mass of Salt (g)</b>	<b><math>\Delta T</math> (C)</b>	<b>Mass Can (g)</b>
1	5.003	1.3	8.22
2	5.004	1.2	8.22
3	10.03	3.1	7.912
4	10.01	3.1	7.912
6	10.11	3.1	7.73
7	15.08	5.2	8.35
12	20.04	6.5	8.09

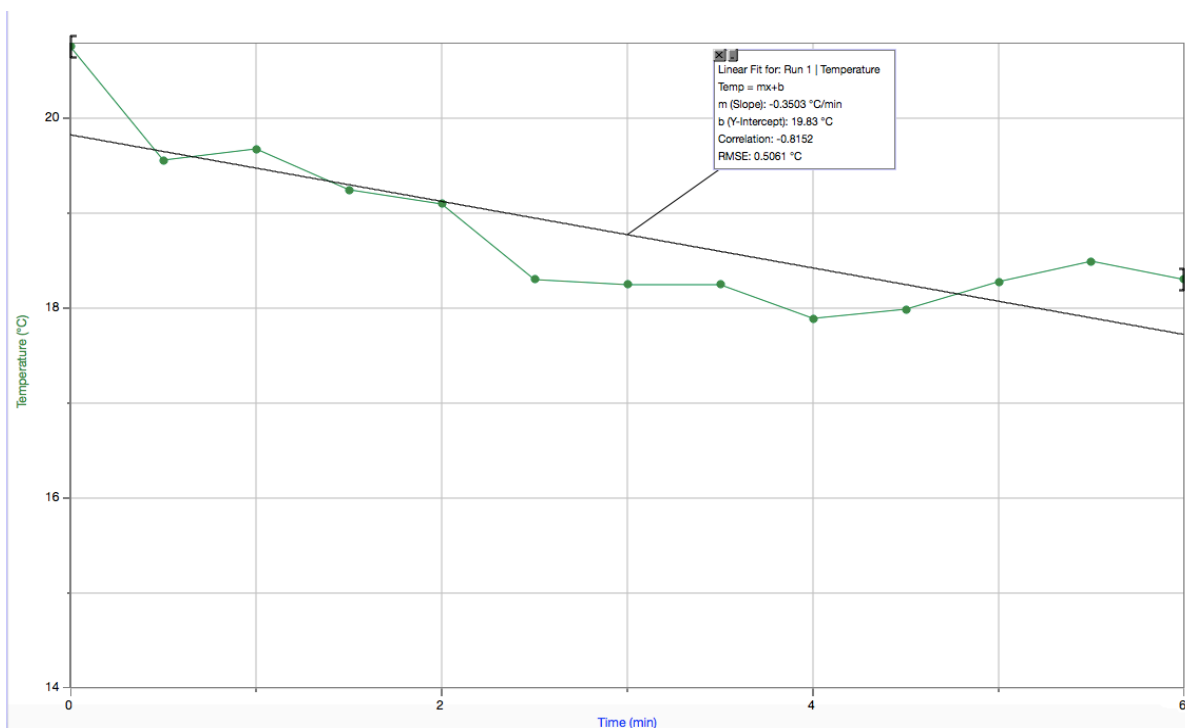
## Graphs:



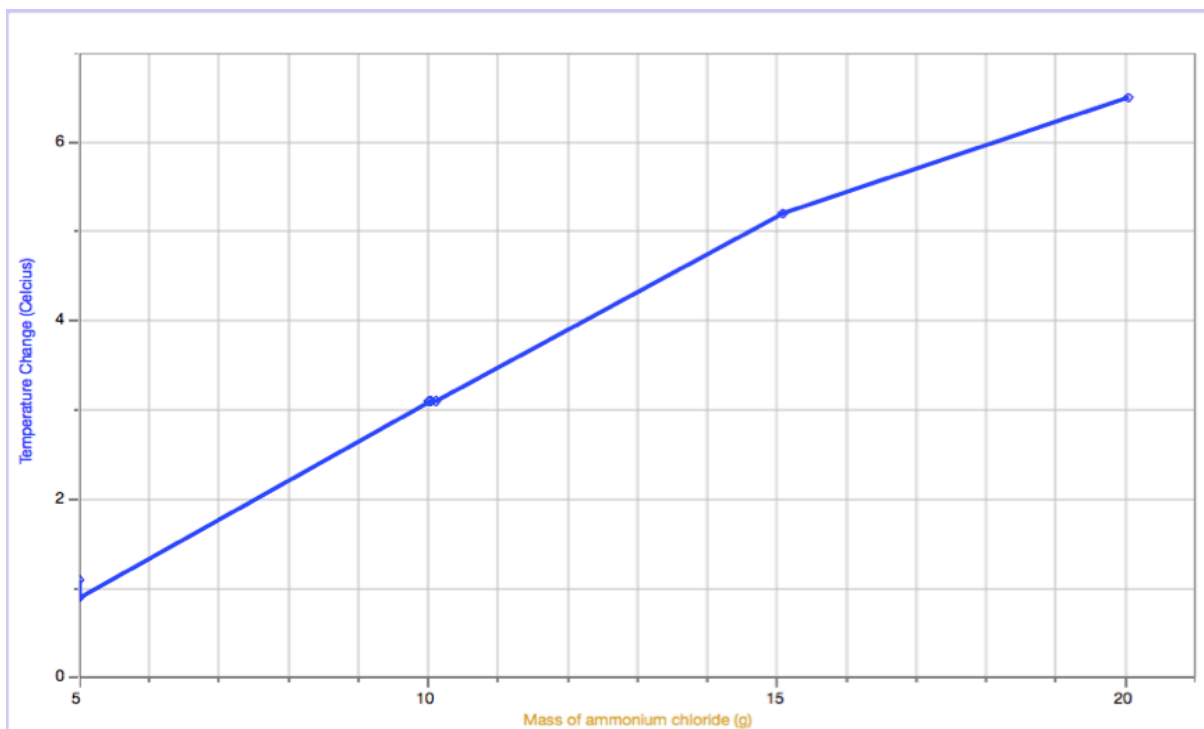
**Figure 1.** Trial 1 with mass 5.003g of  $\text{NH}_4\text{Cl}$ . Temperature in ( $^{\circ}\text{C}$ ) as measured by the thermometer and labQuest 2, versus time in an interval of 30 seconds.



**Figure 2.** Trial 2 with mass 5.004g  $\text{NH}_4\text{Cl}$ . Temperature in ( $^{\circ}\text{C}$ ) as measured by the thermometer and labQuest 2, versus time in an interval of 30 seconds



**Figure 3.** Trial 3 performed with 10.01g of  $\text{NH}_4\text{Cl}$ . Temperature in ( $^{\circ}\text{C}$ ) as measured by the thermometer and labQuest 2, versus time in an interval of 30 seconds.



**Figure 4.** Graph of  $\Delta T$  in ( $^{\circ}\text{C}$ ) versus mass of ammonium chloride ( $\text{NH}_4\text{Cl}$ ) in grams. As seen above the optimal mass to produce a decrease in temperature by approximately  $5^{\circ}\text{C}$  is around 15g.

### Observations

- Sizzling sound when salt mixed with the water
- Smelled like a peppermint, strong smell
- Salt appeared to be little white crystals, very grainy and fine

### Calculations: Energy needed to cool 100ml of distilled water

#### **1. Energy of water inside the can**

$$Q = mcT$$

$$Q = (100\text{g})(4.18\text{J/gC})(-5.00\text{C})$$

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

**2. Energy of surrounding water**

$$Q=mcT$$

$$Q= (80\text{g})(4.18\text{J/gC})(-5.00\text{C})$$

$$Q=-1672 \text{ J}$$

**3. Energy of the pop can**

$$Q=mcT$$

$$Q= (8.22\text{g})(0.900\text{J/gC})(-5.00\text{C})$$

$$Q=-36.99 \text{ J}$$

**4. Total Energy**

$$Q_{\text{total}} = (-2090 \text{ J}) + (-1672 \text{ J}) + (-36.99 \text{ J})$$

$$Q_{\text{total}} = -3798.99\text{J}$$

**5.  $Q_{\text{system}} = - Q_{\text{Surroundings}}$**

$$Q_{\text{system}} = -(-3798.99\text{J})$$

$$Q_{\text{system}} = 3798.99 \text{ J}$$

**6. Number of moles of  $\text{NH}_4\text{Cl}$**

$$\text{moles NH}_4\text{Cl} = \frac{3798.99\text{J}}{17\,000 \text{ J}}$$

$$\text{moles NH}_4\text{Cl} = 0.22347 \text{ mol}$$

**7. Mass of  $\text{NH}_4\text{Cl}$**

$$\text{Mass NH}_4\text{Cl} = \text{moles molar mass}$$

$$\text{Mass NH}_4\text{Cl} = 0.22347 \text{ mol } 53.491 \text{ g/mol}$$

$$\text{Mass NH}_4\text{Cl} = 11.954 \text{ grams}$$

$$\text{Mass NH}_4\text{Cl} = 12.00 \text{ grams}$$

## Discussion

The purpose of this experiment was to find the right amount of ammonium chloride, whose function would be to cool 100mL of a liquid, by 5°C in under 5 minutes. To figure out the right mass, an experiment was conducted.

The first step was to choose a suitable substance, to cool the water. The two choices were ammonium chloride ( $\text{NH}_4\text{Cl}$ ) and ammonium nitrate ( $\text{NH}_4\text{NO}_3$ ). Although ammonium chloride is more expensive, it is also much safer to use, as ammonium nitrate is highly reactive and can be explosive at times, thus ammonium chloride was the clear choice. It was then calculated how much ammonium chloride was needed to cool the water. This represents an ideal system, of which the experiment was not. In order to count for the error, tests at 5, 10, 15 and 20 grams were done multiple times. The change of temperature was found at 5 minutes, and put in tables. The results were then averaged, and the ideal mass of ammonium chloride was found.

According to Figure 4 the ideal mass would be around 15 g, where the temperature change ranges from 4.7-5.2°C.

This method was chosen because it was the ideal procedure. The different masses were used to test temperature change at each interval, as well as performing multiple experiments at the same mass, to strengthen the sample size. This procedure worked, as the ideal mass was found, with little error. Although the experiment as a whole can be considered as a success, no experiment is without some source of error. A significant source of error in this lab was that the minimal space between the can and the inner wall of the calorimeter did not allow for an even distribution of aluminum chloride, this could have resulted in not all of the aluminum chloride reacting with the water as well as some of the water getting underneath the can causing the can to float which would have given inaccurate results. Another source of error that could have directly impacted the temperature readings was the stirring or shaking of the calorimeter in an attempt to speed up the reaction. The increase in kinetic energy would have also caused an increase in the temperature. One more major source of error in this lab was that it was conducted within a large group of people, the issue being that not everyone is on the same page which can lead to errors and skewed results.

A way that this experiment could be improved is to have the members of the group rotate with every trial of different weight samples of aluminum chloride. This would mean that every member does the experiment with all weight samples ensuring the most accurate and precise results as well as so any outliers can be clearly identified and omitted from the final data. In addition to this it may have been beneficial to have had a larger calorimeter so that there was more room to fit the salt and water outside of the can and that would result in a more thorough chemical reaction.

### Conclusion:

In conclusion, the ideal mass of ammonium chloride that will cool coffee by  $5^{\circ}\text{C}$  was found to be about 15.00g. This mass allows for the contents of the coffee cup to be cooled anywhere from  $5.2-4.7^{\circ}\text{C}$ .

Appendix:

Raw Data

Trial	Mass Salt (g)	$\Delta T$ ( $^{\circ}C$ )	Mass can (g)	Outliers (represented by x)
1	5.003	1.1	8.220	
2	5.004	0.9	8.220	
3	10.03	3.1	7.912	
4	10.01	3.1	7.912	
5	10.13	2.5	7.730	x
6	10.11	3.1	7.730	
7	15.08	5.2	8.350	
8	15.00	4.2	8.250	x
9	15.02	3.6	8.140	x
10	15.05	1.8	8.140	x
11	20.15	4.9	8.09	x
12	20.04	6.5	8.09	
13	20.1	5.1	8.09	x

\* used distilled water.

### Experiment 1

- Initial temp of  $H_2O$  <sup>inside can</sup>  $\rightarrow 20.7^\circ C$
- Initial volume in can  $\rightarrow 100\text{ ml}$
- Initial volume outside can  $\rightarrow 80\text{ ml}$
- Mass of can  $\rightarrow 7.9117\text{ g}$
- Initial mass of  $NH_4Cl$   $\rightarrow 10.032\text{ g}$
- Final Temperature  $\rightarrow 17.6^\circ C$

$$\Delta T = 3.1^\circ C$$

### Experiment 2.

- Initial temp of  $H_2O$  inside  $\rightarrow 21.0^\circ C$
- Initial volume inside  $\rightarrow 100\text{ ml}$
- Initial volume outside  $\rightarrow 80\text{ ml}$
- Mass of can  $\rightarrow 7.9117\text{ g}$
- Initial mass of  $NH_4Cl$   $\rightarrow 10.01\text{ g}$
- Final Temperature  $\rightarrow 17.9^\circ C$

$$\Delta T = 3.1^\circ C$$

Trial #1  
Mass  $\rightarrow$  5.0022 g.

Initial  
Temp  
water  
inside  
can  
before  $\rightarrow$  20.5

~~Initial  
Temp  
water  
outside  
can  
before~~

Volume  
inside  $\rightarrow$  100ml  
can

~~Mass of~~  
Volume  
outside  $\rightarrow$  80ml  
can

Mass of  
can  $\rightarrow$  8.22grams

Final  
temp of  
water  $\rightarrow$  18.8°C

Trial #2  
Mass  $\rightarrow$  5.0027g

$\rightarrow$  20.3

Trial #3  
 $\rightarrow$  mass  $\rightarrow$  5.0036

0.30  $\rightarrow$  ~~19.4°C~~ 20.0°C

1.00  $\rightarrow$  19.6°C

1.30  $\rightarrow$  19.6°C

2.00  $\rightarrow$  19.6°C

2.30  $\rightarrow$  19.4°C

3.00  $\rightarrow$  19.4°C

3.30  $\rightarrow$  19.3°C

4.00  $\rightarrow$  19.5°C

4.30  $\rightarrow$  19.3°C

5.00  $\rightarrow$  19.1°C

Trial #1	
1min $\rightarrow$ 19°C	1.30min $\rightarrow$ 20°C
2min $\rightarrow$ 19.7°C	2.30min $\rightarrow$ 19.5°C
3min $\rightarrow$ 19.3°C	3.30min $\rightarrow$ 19.4°C
4min $\rightarrow$ 19.0°C	4.30min $\rightarrow$ 19.0°C
5min $\rightarrow$ 19.0°C	19.0°C
30sec $\rightarrow$ 19°C	4.30 $\rightarrow$ 19.0°C
1min $\rightarrow$ 20°C	5.00 $\rightarrow$ 18.8°C
1.30 $\rightarrow$ 19.7°C	
2.00 $\rightarrow$ 19.5°C	
2.30 $\rightarrow$ 19.3°C	
3.00 $\rightarrow$ 19.4°C	
3.30 $\rightarrow$ 19.1°C	
4.00 $\rightarrow$ 19.1°C	

Trial #2	
1min $\rightarrow$ 30sec $\rightarrow$	1.30min $\rightarrow$
2min $\rightarrow$	2.30min $\rightarrow$
3min $\rightarrow$	3.30min $\rightarrow$
4min $\rightarrow$	4.30min $\rightarrow$
5min $\rightarrow$	
0.30 $\rightarrow$ 20.3°C	4.00 $\rightarrow$ 19.4°C
1.00 $\rightarrow$ 20.4°C	4.30 $\rightarrow$ 19.4°C
1.30 $\rightarrow$ 20.4°C	5.00 $\rightarrow$ 19.2°C
2.00 $\rightarrow$ 20.3°C	
2.30 $\rightarrow$ 19.8°C	
3.00 $\rightarrow$	
3.30 $\rightarrow$ 19.4°C	

Trial #1  
Mass → 5.0022 g.

Trial #2  
Mass → 5.0027 g

Initial  
temp  
water →  
inside  
can  
before

→ 20.3

### Observations

- sizzling sound when salt mixed w water
- smelled like a peppermint, strongish smell
- salt, white crystals, grainy.

Initial  
temp  
water →  
outside  
can  
before

Volume  
inside →  
can

~~Mass of~~

Volume  
outside →  
can

Mass of  
can

Initial  
temp of →  
water

1m

2m

3m

4m

5m