Experiment 2
A Tall Cold Drink of Water

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Introduction

The objective of this experiment was to determine the ideal amount of a substance (NH_4Cl or NH_4NO_3) in order to reduce the temperature of a drink contained in an aluminium can by 5 °C. This amount can be determined by applying Hess' law and calorimetry.

Hess' law states that when the enthalpy changes of individual chemical changes in a reaction are added together it will give the total enthalpy change of the reaction. The dissolution of a salt is defined as the enthalpy of solution. This depends on two factors: lattice energy and hydration energy. The lattice energy is the energy required to vaporize one mole of a salt in order to form gaseous ions. The lattice energy is always endothermic meaning energy is absorbed. Therefore the value for the lattice energy is always positive. The other factor, hydration energy, is the energy released when one mole of ions in the gaseous state are dissolved in water to form aqueous ions. The hydration energy is exothermic meaning that this value is always negative. The sum of these two values gives the enthalpy of solution. If hydration energy is greater than the lattice energy the resultant is negative and vice-versa. The enthalpy of solution can be shown by the equation $\triangle H = (-\,heat\ loss\ of\ water) + (heat\ loss\ of\ salt)$. It can also be calculated by $\triangle H = \frac{q}{n} = \frac{-mc\triangle T}{n}$ [1]. (*Enthalpy of various reactions, n.d)*

"q=mc△T" in the previous equation is the formula for heat of formation. It is used to find the amount of energy that is required to raise or lower the temperature of a substance by a certain amount. "m" represents the mass of the substance, "c" represents the specific heat capacity of the substance and "△T" represents the change in temperature. This equation must be applied for the water and the metal in the system (in this case aluminium) since it will all be losing/gaining energy. In order to find the required amount of moles of salt in order to achieve the equation [1] can be rearranged to become $n = \frac{q}{\Delta H}$. The "q" is the desired total (q of water + q of metal) energy change and $\triangle H$ is the enthalpy of solution of the salt.

Calorimetry can be used to measure the amount of energy lost or gained (or temperature change in this case). In order to do this an apparatus called a calorimeter is used. A calorimeter is an isolated system where volume is constant and there is no heat loss. The calorimeter can be used to measure the temperature before and after to see the change in the system.

The two available salts for this experiment were NH_4Cl and NH_4NO_3. Theoretically speaking, to achieve the 5 °C temperature change about a 1.66$ would need to be spent on NH_4Cl and about 1.75$ on NH_4NO_3 for the same temperature change. Obviously the more economical option is NH_4Cl. On top of that NH_4NO_3 is highly explosive (National Center for Biotechnology Information, n.d), therefore NH_4Cl was determined to be the safer and more ideal option pricewise.

Procedure:

1. Measure the mass of the can using a balance then determine the required mass of NH_4Cl required to achieve a change in temperature of 5°C
2. Measure 100mL of water using a graduated cylinder and pour it into the styrofoam cup
3. Measure 100mL of water and add it to the aluminium can and place it in the styrofoam cup
4. Set up the thermometer with the lab quest for 5 minutes of recording and new data points every 30 seconds
5. Place the lid on the styrofoam cup and insert a thermometer into the hole in the lid
6. Record the initial temperature
7. Mass 13.28 grams of NH_4Cl using a balance and pour it into the water surrounding the can and replace the lid
8. Start recording the temperature as soon as the lid has been replaced
9. After 5 minutes discard the contents into the designated waste bucket and clean the equipment
10. Repeat steps 2-9 3 more times with 15, 17 and 19 grams of NH_4Cl

Data/Observations

Pg #3

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Procedure

1. Measure mass of aluminium can and find q for can
2. Put 100 mL of water into the can and styrofoam cup
3. Calculate q for water and add to q of aluminium.
4. Using this value find the mass of NH_4Cl needed for a -5°C temp change.
5. Place thermometer into ~~the~~ water and record initial temp.
6. Measure mass of NH_4Cl and place in styrofoam cup.
7. Leave thermometer probe in for 5 mins
8. After 5 mins discard solution and water and redue steps 1-7 for 3 other mass

~~Procedure~~

~~1. Mass the~~

$c_{al} = 0.0009$

$q_w = mc\Delta t$
$= (200)(0.00418)(5)$
$= 4.18$

$q_a = mc\Delta t$ 0.9
$= (9.27)(0.0009)(5)$
$= 0.041715$

$\Delta_s H^\circ = \frac{q_s}{n}$

$n = \frac{m}{MM}$

$n = \frac{q_s}{\Delta_s H^\circ}$
$= \frac{q_w + q_a}{\Delta_s H^\circ}$
$= \frac{4.18 + 0.041715}{17}$
$= \frac{4.221715}{17}$
$= 0.2483$

$m = n \times MM$
$= (0.2483)(53.49)$
$= 13.28$ g

Trial	G of NH_4Cl	Initial Temp °C	Final Temp °C	Time
1	13.29	23	18.5	5 mins
2	15.03	23.2	18.2	5
3	17.01	23	18	5
4	19.11	23.5	17.5	6

Sample Calculations

$$q = mc\triangle T$$
$$q = (200\ g)(0.00418\ KJ/g\ °C)(5°C)$$
$$q = 4.18\ KJ$$

Sample calculation 1: Finding the enthalpy change of water with a 5 °C temperature change

$$\triangle sH = \frac{q}{n}$$
$$n\ = \frac{q}{\triangle sH}$$
$$n\ = \frac{q(water) + q(aluminium)}{\triangle sH}$$
$$n\ = \frac{4.18 + 0.041715}{17}$$
$$n\ = \frac{4.2217515}{17}$$
$$n\ = 0.2483$$

Sample calculation 2: Finding number of moles of NH_4Cl needed to achieve calculated enthalpy change

$$m = nMM$$
$$m = (0.2483\ mol)(53.49\ g/mol)$$
$$m = 13.28\ g$$

Sample calculation 3: Converting moles of NH_4Cl needed to grams

$$price\ per\ gram = \frac{62.4}{500}$$
$$price\ per\ gram = 0.1248$$

Sample calculation 4: Finding price/g for NH_4Cl

$$Total\ price = (13.28\ g)(0.1248)$$
$$Total\ price = 1.66\$$$

Sample calculation 5: Finding total price for NH_4Cl

$$\%\ error = \left|\frac{Actual - Theroretical}{Actual}\right| \times 100\%$$
$$\%\ error = \left|\frac{13.28 - 15.59}{13.28}\right| \times 100\%$$
$$\%\ error = 17\%$$

Sample calculation 6: Percent error calculation

$y = 0.2342x + 1.349$

$5 = 0.2342x + 1.349$

$3.651 = 0.2342x$

$3.651 = 0.2342x$

$x = 15.59$

Sample calculation 7: Determining the x value for the 5 degree temperature change from equation of graph

Discussion:

The calculations done to determine the theoretical mass of NH_4Cl required to achieve a change in temperature of 5°C gave an answer of 13.28 grams. When this mass was tested in the calorimeter, the heat change was only 4.5°C , so the mass was increased to determine how much salt would experimentally work.

Table #1: Impact of the mass of NH_4Cl on the temperature of the water in the can over a 5 minute period

Trail #	Mass of NH_4Cl (g)	Initial temperature (°C)	Final temperature (°C)	Change in temperature (°C)
1	13.29	23	18.5	4.5
2	15.03	23.2	18.2	5
3	17.01	23	18	5
4	19.11	23.5	17.5	6

By increasing the mass of salt as seen in table 1 a temperature change of 15°C occured when the mass of NH_4Cl was both 15.03 and 17.01 grams. This theoretically should not be able to happen since the number of moles of salt in solution have increased which would directly increase the heat of formation.

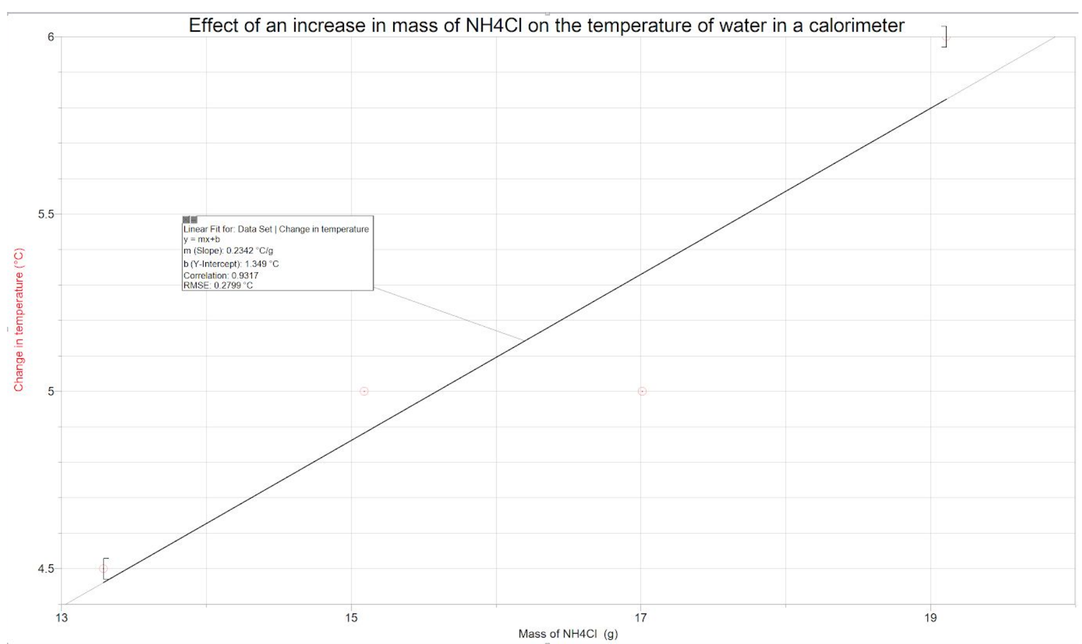

Figure 1: Graph representing the temperature change for the various masses of dissolved NH_4Cl

Using the equation of the graph, y=0.2342x+1.349, where y is the change in temperature and x is the mass of NH_4Cl, a mass of 15.59 grams would provide a change of 5°C. The percent difference between the two values is 17%. This difference is caused by a couple of possible errors. One error is that the system was not completely isolated. The lid of the styrofoam cup did not securely fasten to the cup allowing both heat and some solution to leave the system, the hole in the lid which the thermometer was stuck through also had extra space allowing heat to leave the system. The amount of heat that is kept in the system is now varying since there is no way to control it leading to some values being higher and others lower. By better insulating the system with a sealable lid and air tight thermometer all the heat can be kept in the system giving more accurate results. Another error with the experiment is that the $NH_4Cl_{(s)}$ was not fully dissolved into the water. During the experiment the calorimeter was swirled to mix the salt but this method of stirring is not very effective. This would explain why more $NH_4Cl_{(s)}$ was needed than the theoretical value to give a temperature change of 5°C. To ensure that the $NH_4Cl_{(s)}$ is fully mixed the calorimeter can be inverted multiple times to add kinetic energy and help with the dissolution. A final source of error in the lab is that the room temperature was not constant throughout the trials. Since the system was not fully isolated some heat was transferred into the surroundings, the room, and from the room to the system. Having a varying temperature will either increase or decrease, depending on if the temperature is above or below the system, the amount of heat going into the can. A way to fix this is the same as the first error, by properly isolating the system and also keeping the room temperature constant.

Conclusion:

As a result for this experiment it was determined that 15.59 g of NH_4Cl is the ideal amount in order to reduce the temperature of a drink by 5 °C as compared to the theoretical amount of 13.28 g.

References:

National Center for Biotechnology Information. PubChem Database. Ammonium nitrate, CID=22985, https://pubchem.ncbi.nlm.nih.gov/compound/Ammonium-nitrate (accessed on Oct. 2, 2019)

(n.d). *Enthalpy of various reactions*

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

TA Name: Sarah Osterholm		Names of Students in Group:	a. Saleema Adinoyi
			b. Ayesha Syed
			c. Cameron Steinke
			Linjie He Guomi He
		Date:	
Criteria:	Marks	Assessment	
	Possible	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.	0.5	✓	
3. Plan to vary only one independent variable at a time.	1	✓	
4. Controls on other variables are clearly stated.	0.5	✓	
5. Measurement errors are minimized by appropriate procedures or apparatus.	0.5	✓	
6. No invalid assumptions are made.	0.5	✓	
7. Reagents that need accurate measurement are identified.	0.5	✓	
8. Lab trials and repeats are clearly stated.	0.5	✓	
TOTAL:	5	5	5

Note: This grade will count towards your prelab grade.