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Experiment 2

"...But a Hot Temper Leaps O'er a Cold Degree: A Tall Cold Drink of Water"

Enthalpy of Various Reactions

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Introduction:

Chemical reactions are generally accompanied by the release or absorption of energy in the form of heat. Thermochemistry is the study of energy changes (enthalpy) involved in chemical and physical processes. It is a part of the study of thermodynamics, which is applied by many scientists and engineers through their work. In order for a chemical reaction to take place, reactants and products are involved in the process. Reactions that release heat are known as exothermic reactions, while reactions that trap heat are considered to be endothermic reactions. To determine whether a reaction is exothermic or endothermic, the enthalpy of reaction must be calculated. The enthalpy of a system is related to the energy of a system by the formula:

$$H = U + PV$$

with H the enthalpy of the system, U the internal energy, P the pressure and V the volume. When performing a reaction, the enthalpy change is typically what is calculated as opposed to the enthalpy itself. The enthalpy change that is associated with a reaction is denoted by ΔH.
Assuming pressure is constant, the equation related to enthalpy change is as follows:

$$\Delta H = \Delta U + P \Delta V$$

For exothermic reactions, there is a negative change in enthalpy whereas for endothermic reaction there is a positive change in enthalpy. Calorimetry is used to measure the amount of heat transferred to or from a substance. A calorimeter is a device that is used to measure the amount of heat involved in a chemical reaction. The two most common types of calorimeters are “coffee-cup” calorimeters and bomb calorimeters. A “coffee-cup” calorimeter was used in this lab since it is a simpler device to use for students. Although they are easier devices to use, they allow more heat to be lost to their surroundings, providing less accurate data. A simple calorimeter is typically made with two styrofoam cups within one another, a thermometer and a lid. In this lab, one cup was made from styrofoam and the inner cup was an aluminum can. Each cup is filled with water and the change in temperature of the water inside the calorimeter is measured. This provides us to calculate the heat of the reaction with the following formula:

$$Q = mc_{water} \Delta T$$

with Q the heat of reaction, m the mass of water, c the specific heat capacity of water and ΔT the change in temperature of the water inside the inner cup.

With this background knowledge in thermochemistry, we were able to perform the following experiment. Our goal was to create a product that gives a -5 degree celsius change in temperature in 5 minutes. To accomplish this task, we were given two different salts, ammonium chloride (NH_4Cl) and ammonium nitrate (NH_4NO_3). Considering the Health and Safety implications of each of these salts, we decided to choose ammonium chloride to us in our experiment. Ammonium nitrate is a strong oxidizing agent that can cause irritation to the respiratory tract if it is inhaled. To achieve our goal, we completed multiple trials adjusting the amount of salt that was used each time.

Procedure:

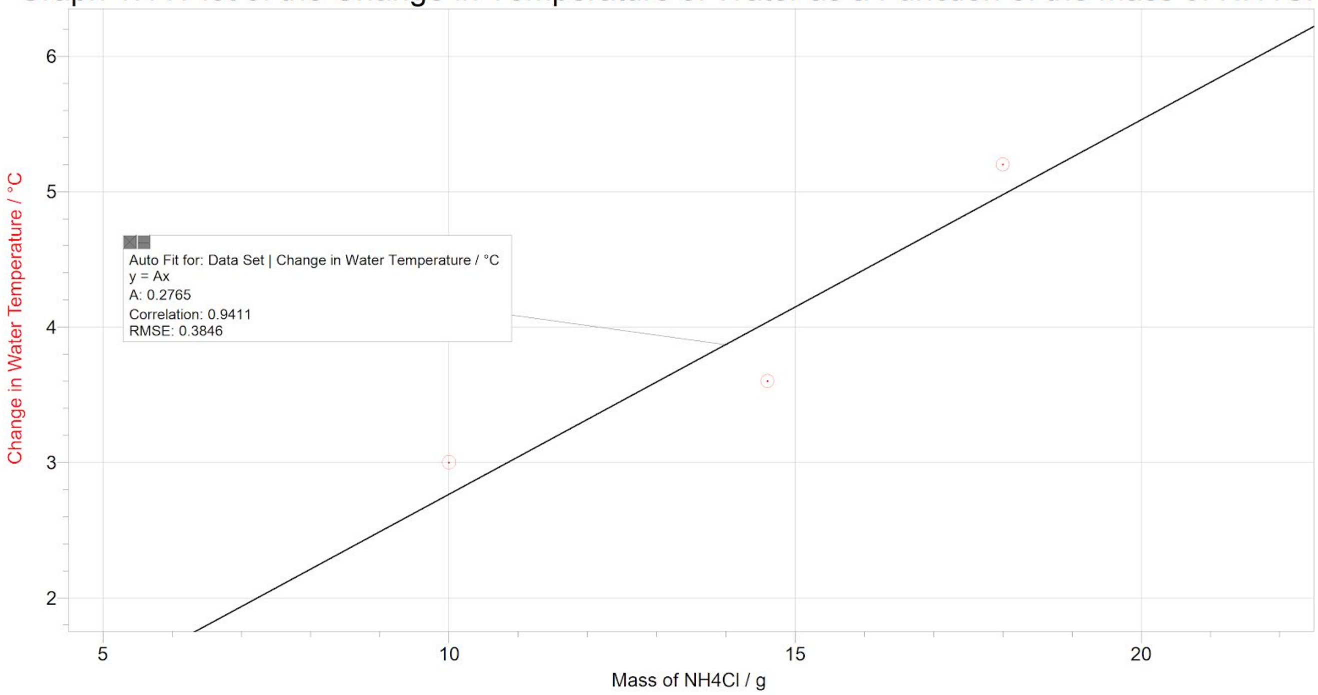
1. Weigh the empty Aluminium can using an electronic balance.
2. Weigh 10.0g of NH_4Cl using an electronic balance.
3. Using a graduated 100mL cylinder, measure out 100mL of water and pour it into the can. Record the initial temperature, T_1.
4. Using the same graduated cylinder, measure out a total of 120mL of water and pour it into the cup. (*to add in discussion: possible source of error)
5. Add the weighed 14.6g of NH_4Cl in the water in the cup. Quickly place the can in the cup and cover with lid.
6. Record the temperature, T_2 after 5 mins.
7. Repeat experiment with 14.6g and 18.0g of NH_4Cl.
8. Plot a graph of ΔT against M.

Tables and Graphs:

Table 1: The Measurement of Water Temperature Before and After the addition of NH_4Cl

Mass of NH_4Cl, m (g)	Initial Temperature, T_1 (°C)	Final Temperature, T_2 (°C)	Change in Temperature, ΔT (°C)
10.0	22.4	19.4	-3.0
14.6	22.3	18.7	-3.6
18.0	22.6	17.4	-5.2

Graph 1: A Plot of the Change in Temperature of Water as a Function of the Mass of NH4Cl



<u>Calculations and Observations:</u>

<u>Sample Calculation for change in temperature, ΔT</u>

$\Delta T = T_2 - T_1$; For M= 10.0g, ΔT = 19.4 - 22.4 = -3°C

<u>Mass of NH4Cl theoretically required for a decrease of 5°C</u>

Heat required to heat water, $Q = mc\Delta T$; [density of water = 1 ; m= V]

= 220 * 4.18 * 5

= 4.598 kJ

ΔH (NH_4Cl) = 17 kJ/mol [from prelab]

Molar mass NH_4Cl = 14.01 + 4(1.001) + 35.45 = 53.482

Therefore, mass of NH_4Cl needed to need water = (1/(17kJmol)) * 4.598 kJ * 53.482 g/mol

= 14.5g

Heat required to heat Al (can), Q = 7.94 * 0.900 * 5 ; [mass of empty Al can = 7.95g]

= 0.03573 kJ

Therefore, mass of NH_4Cl needed to heat Al can = (1/(17kJmol)) * 0.03573 kJ * 53.482 g/mol

= 0.112g

=> Total mass of NH_4Cl needed = 14.5g + 0.112g = 14.6g

Mass of NH_4Cl experimentally required for a decrease of 5°C

Based on Graph 1, $\Delta T = Am$

Therefore $m = \Delta T/A$

$\Delta T = -5°C$ A= -0.2765

m = 18.083 g

Therefore the mass of NH_4Cl needed to decrease the temperature of the drink by 5°C is 18 g

% Difference between experimental and theoretical mass of NH_4Cl required for a decrease of 5°C

$\%Difference = (m_{theoretical} - m_{experimental})/[(m_{theoretical} + m_{experimental})/2] \times 100\%$

% DIff = (14.6-18)/[(18+14.6)/2] x 100%

= 20%

Discussion:

The NH_4Cl mass required to decrease the temperature by 5°C was experimentally determined to be 18g. This value does not corroborate the theoretically determined mass of 14.6g; the two values have a percent difference of 20%. The difference between the two values is a result of the theoretical value's assumption that the heat lost by the water and can is equal to the heat gained by the NH_4Cl. For this to be true, no energy must be lost to the system's surroundings and the calorimeter, however, the calorimeter and environment would have taken thermal energy from the system because of its contact with the H_2O, NH_4^+, and Cl^- molecules/ions. Thus, the heat lost by the water and can is equal to the heat gained by the NH_4Cl minus the heat absorbed from the surroundings, resulting in a lesser heat loss of water. Given that the water's heat loss is directly proportional to the water's temperature, a NH_4Cl mass's resulting temperature change will be experimentally less than theoretically determined, meaning a greater mass will be required to decrease the temperature by 5°C.

There are numerous errors present in this experiment. Firstly, the can that the experiment utilizes does not have its lid. This causes the mass and heat capacity of the can to be lower in the experiment than it would be in the final product, resulting in a smaller change in temperature for the can and water for a given mass. This error could be removed by utilizing a full can in the experiment, resulting in the mass to more accurately match that of the final product. An additional source of error is due to the assumption that the can's components are entirely aluminum. Tape is added to the can's sharp edges, which possesses a different specific heat capacity than aluminum. As a result, the heat capacity of the can is slightly greater or lower than it was assumed to be, as the tape's specific heat capacity must be added to the calculations. To minimize this error, the tape could be removed from the can so that it consists solely of aluminum. Thirdly, the time between the NH_4Cl being added to the water and the calorimeter's lid being added produces error. The NH_4Cl beings dissolving immediately, however there is a small interval before the lid is added and the calorimeter is sealed. This allows heat to easily transfer into the system from its surroundings, causing the heat transferred from the water and aluminum can to be lesser and the final temperature to decrease. This error could be reduced by having a small hole in the calorimeter's lid that the substrate may be inserted through, and a thermally insulated plug for the hole that can be used after the NH_4Cl is added. The smaller area exposed to the surroundings when the NH_4Cl is added will allow the amount of heat gained from the surroundings to decrease, allowing more of NH_4Cl's gained heat to be from the water and aluminum can.

<u>Conclusion:</u>

In conclusion, the mass of NH_4Cl required to lower the temperature of 240mL of water and an aluminum can by 5 degrees Celsius is 18 grams, with a percent difference of 20% from the theoretically calculated value of 14.6 grams.

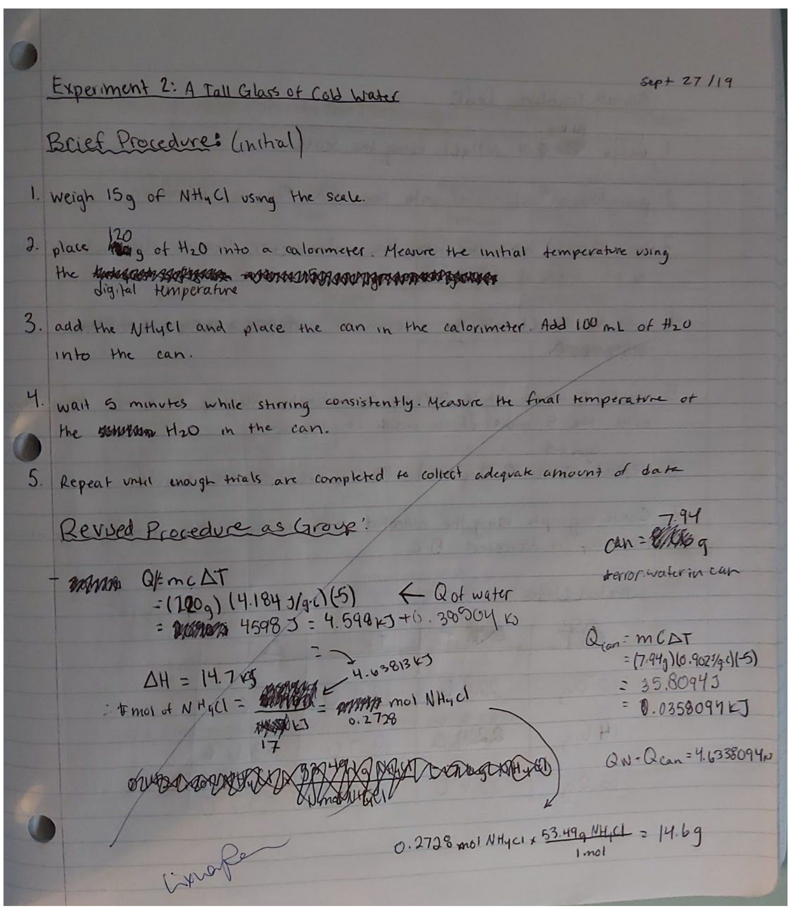
References:

"What in the World ISN'T Chemistry", General Chemistry Laboratory Manual, Dr. Rashmi Venkateswaran, 2019.

"Chemistry", Olmstead, J. Williams, G. Burk, R. (2016). 3rd ed. Toronto: John Wiley and Sons Canada, Ltd.

"Thermochemistry", Chemistry Explained, http://www.chemistryexplained.com/Te-Va/Thermochemistry.html, Michael Eastman, 2019.

Raw Data:



Experiment 2: A Tall Glass of Cold Water

Sept 27/19

Brief Procedure: (initial)

1. weigh 15g of NH_4Cl using the scale.
2. place 120 g of H_2O into a calorimeter. Measure the initial temperature using the digital temperature
3. add the NH_4Cl and place the can in the calorimeter. Add 100 mL of H_2O into the can.
4. wait 5 minutes while stirring consistently. Measure the final temperature of the H_2O in the can.
5. Repeat until enough trials are completed to collect adequate amount of data

Revised Procedure as Group:

can = 7.94 g

error: water in can

$Q = mc\Delta T$

$= (120g)(4.184\ J/g°C)(5)$ ← Q of water

$= 4598\ J = 4.598\ kJ + 0.038094\ kJ$

$= 4.63813\ kJ$

$\Delta H = 14.7\ kJ$

$\therefore$ mol of NH_4Cl = 0.2728 mol NH_4Cl

$Q_{can} = mC\Delta T$

$= (7.94g)(0.902 J/g°C)(-5)$

$= 35.8094\ J$

$= 0.0358094\ kJ$

$Q_W - Q_{can} = 4.6338094$

$0.2728\ mol\ NH_4Cl \times \frac{53.49g\ NH_4Cl}{1\ mol} = 14.6g$

Revised Procedure Con't:

1. weigh 14.6g of NH_4Cl using the scale.
2. pour 100 cm^3 of water into the can. Place in calorimeter.
3. pour 120 cm^3 of water into the calorimeter. Measure the initial temp of the inside of the can.
4. add the NH_4Cl into the calorimeter
5. wait 5 mins while stirring consistently. Measure the final temperature after the 5 mins of the inside of the can.
6. repeat steps 1-5 using 10.0g and 18.0g in separate trials.
7. Create a graph using the collected data to find the actual mass when the temp is decreased 5°C.

Collected Data:

mass	T_i	T_f	ΔT
10.0g	22.4°C	19.4°C	-3°C
14.6g	22.3°C	18.7°C	-3.6°C
18.0g	22.6°C	17.4°C	-5.2°C

Assessment Criteria Sheet:

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

TA Name:	Lixuan Ren	Names of Students in Group:	a. Livia Renaud b. Angela Ferro c. Ben Antaya
		isabella Zabek Nishi Zabek	Maya Jamil
		Date: Sept 27, 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	0.5	
3. Plan to vary only one independent variable at a time.	1	1	
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	0.5	
8. Lab trials and repeats are clearly stated.	0.5	0.5	
TOTAL:	5	5	5

LR

Note: This grade will count towards your prelab grade.