Lab Report

Dystan Medical Company - Cold Packs and Hot Packs

Colin Hancock

Wolfgang Allred

1225 - #202

18 March 2017

Introduction

In this lab, we are employed by the Dystan Medical Supply Company. Our task is to design an efficient and cost effective hot pack and cold pack for medical usage. We simply must find out: what salt will most effectively increase or reduce heat, and which salt turns back the most profit while doing so? Looking at the equations and the placement of the heat, it seems that LiCl will be the best for heating packs while KCl will be the best for cooling packs.

This experiment is important because it is necessary to determine what materials are to be used in medical-grade hot and cold packs. These packs are very important medically to treat burns or inflammation, as well as in athletics for sports-related injuries. This experiment will effectively allow these packs to be produced, eventually making it to the market and allowing many consumers to treat a variety of injuries. This will be very beneficial to many people, as they now have access to easy medical treatment.

Hot packs and cold packs work by having an internal packet of a salt surrounded by a solvent. When the packet is broken, the salt is dissolved and depending upon the ionic compound it is either an endothermic or exothermic process. If the dissolution is endothermic then the temperature of the solution will drop, and if it is exothermic the temperature of the solution will rise. The cold pack and hot pack must have temperatures of 0°C and 65°C respectively, with 100 mL of water in them each. Calorimetry will be used exclusively in this experiment. Using this technique, we will first find the calorimeter constant by combining hot and cool water in the calorimeter and recording the temperature. After calculating the constant, we can then move on to using the calorimeter to determine the heats of dissolution of each of the salts. This will be done by adding salt to cool water and measuring the temperature, followed by a series of calculations resulting in the heat of dissolution. We will compare these heats to determine which salt will be most effective in each of the packs. Using the data, the exact mass of salt necessary for the desired temperature in a cold pack or hot pack can be calculated. Once we have determined the mass required of each salt, the cost for each pack can be determined using the cost chart provided in the lab manual. The total cost for each pack must be under $5.00 in order to return a profit. We will then compare the prices and use that comparison to decide which salt is the most effective and yet maximizes profits.

Experimental

Following is a table of the chemicals to be used during this experiment. As they are all given as solid salts, molarity will not be applicable.

Reagents
Ammonium Nitrate (NH_4NO_3)
Calcium Chloride ($CaCl_2$)
Lithium Chloride (LiCl)
Potassium Chloride (KCl)

REQUIRED EQUIPMENT

Two styrofoam cups, a lid, a temperature probe, a ring stand, a utility clamp, a two-hole stopper, a stir bar, a magnetic stir plate, a hot plate, and heat-proof gloves.

PART A - DETERMINATION OF A CALORIMETER CONSTANT

Once you have prepared the MeasureNet system to record a thermogram, set up the hot plate at least two feet away from the MeasureNet system and set it to medium heat. Add 45-50 grams of water to the calorimeter, writing down the exact mass, and write down the temperature of the cool water given by the temperature probe.

Add about 100mL of water to a 500mL beaker and place it on the hot plate, closely monitoring its temperature. Once the temperature has reached 80-90℃, use the heat-proof gloves and a graduated cylinder to measure out about 50mL of hot water, writing down the exact volume and converting it to grams. Take the temperature of the hot water using a thermometer and write it down, and then press **Start** on the MeasureNet system. Quickly open the lid of the calorimeter and pour all of the hot water into the calorimeter, replacing the lid afterwards. Once the temperature has stabilized, press **Stop** on the MeasureNet system.

Press **File Options** and **F3** and use the given number keys to assign the data a three-digit code. Write down this code and press **Display** to clear the previous scan. Use a magnetic rod to remove the stir bar, decant the water into the sink, and dry the calorimeter thoroughly. Perform a second trial using the previous steps and write down all relevant information. Afterwards, make sure to email the files to yourself. Follow the **Calculations** instructions following to complete the experiment.

PART B - DETERMINATION OF THE ENTHALPY OF DISSOLUTION OF VARIOUS SALTS

Once you have prepared the MeasureNet system to record a thermogram, choose a salt to perform a thermogram on and measure out about one gram of it, writing down the exact mass. Add 45-50 grams of water to the calorimeter, writing down the exact mass, and write down the temperature of the cool water given by the temperature probe.

Press **Start**, and after a few seconds have elapsed, pour all of the salt into the water-filled calorimeter and quickly close the lid. Once the temperature has stabilized at an equilibrium, press **Stop**. Press **File Options** and **F3** and use the given number keys to assign the data a three-digit code. Write down this code and press **Display** to clear the previous scan. Use a magnetic rod to remove the stir bar, decant the solution into the sink, rinse off the temperature probe, and dry the calorimeter thoroughly. Perform two trials using these instructions for each of the salts, writing down all relevant information, and once you have done so make sure to email all of the files to yourself. Follow the **Calculations** instructions following to complete the experiment.

CALCULATIONS

Use the following equation to calculate calorimeter constant, where $C_{warm\ water}$ and $C_{cool\ water}$ are equal to 4.18J/g°C. ΔT is the change in temperature depending on which water is required. The mass is also required and is shown as “m”.

$$\square_{[illegible]} = \frac{-(\square_{[illegible]} \times \square_{[illegible]} \times \square\square_{[illegible]}) - (\square_{[illegible]} \times \square_{[illegible]} \times \square\square_{[illegible]})}{\square\square_{[illegible]}}$$

Use the following equations for the calculation of molar heat for each of the salts.

$$\Delta\square_{[illegible]} = \frac{-((\square_{[illegible]} \times \square_{[illegible]} \times \square\square_{[illegible]}) + (\square_{[illegible]} \times \square\square_{[illegible]}))}{[illegible]}$$

The mass and cost will be found by rearranging the previous equation for the change of heat of reaction to solve for grams of salt, excluding the calorimeter portion, and adding \$1.28 for labor, overhead cost, and plastic bag cost.

$$[illegible] = \frac{-100 \times \square_{[illegible]} \times [illegible] \times \square\square_{[illegible]}}{\square_{[illegible]} \times [illegible] \times \square\square_{[illegible]} + \square\square_{[illegible]}}$$

$$[illegible] = [illegible] \times \frac{[illegible]}{[illegible]} + \$1.28$$

Results

Following is a table for the first portion of the experiment: the determination of a calorimeter constant.

Trial	Mass of Cool Water	Temperature of Cool Water	Mass of Hot Water	Temperature of Hot Water	Final Temperature
1	45.9 g	23.44 °C	50.0 g	71.78 °C	44.48 °C

2	45.5 g	22.58 °C	50.0 g	75.00 °C	45.75 °C

Work for Finding Calorimeter Constant for Both Trials:

$$C_{calorimeter} = \frac{-(m_{warm\ water} \times c_{warm\ water} \times \Delta T_{warm\ water}) - (m_{cool\ water} \times c_{cool\ water} \times \Delta T_{cool\ water})}{\Delta T_{cool\ water}}$$

$$C_{calorimeter\ trial\ 1} = \frac{-(50.0\ g \times 4.186\ J/g°C \times (44.48\ °C - 71.78\ °C)) - (45.9\ g \times 4.186\ J/g°C \times (44.48\ °C - 23.44}{44.48\ °C - 23.44\ °C}$$

$$C_{calorimeter\ trial\ 2} = \frac{-(50.0\ g \times 4.186\ J/g°C \times (45.75\ °C - 75.00\ °C)) - (45.5\ g \times 4.186\ J/g°C \times (45.75\ °C - 22.58}{45.75\ °C - 22.58\ °C}$$

Calorimeter Constant for Trial 1: ___79.4J/°C___

Calorimeter Constant for Trial 2: ___73.8J/°C___

Average Calorimeter Constant: ___76.6J/°C___

Following is a set of tables for the second part of the experiment: the determination of the enthalpy of dissolution of various salts.

Ammonium Nitrate

Trial	Mass of DI Water	Temperature of DI Water	Mass of Salt	Final Temperature

1	45.0 g	23.48 °C	1.0030 g	22.17 °C
2	45.0 g	24.84 °C	1.0027g	23.19 °C

Work for Finding Heat of Dissolution for Both Trials:

$$\Delta\square_{\square\square\square\square\square\square\square\square\square\square} = \frac{-((46.0030\ \square \times 4.186\square/\square°\square \times (22.17\ °\square - 23.48\ °\square)) + (76.6\square/°\square \times (22.17\ °\square - 23.48\ °\square)))}{0.012531\ \square\square\square\square\square\ \square\square\square\square}$$

$$\Delta\square_{\square\square\square\square\square\square\square\square\square\square} = \frac{-((46.0027\ \square \times 4.186\square/\square°\square \times (23.19\ °\square - 24.84\ °\square)) + (76.6\square/°\square \times (23.19\ °\square - 24.84\ °\square)))}{0.012527\ \square\square\square\square\square\ \square\square\square\square}$$

$$\square\square\square\square = \frac{-100 \times 4.186\square/\square°\square \times 80.04\square/\square\square\square \times -25°\square}{4.186\square/\square°\square \times 80.04\square/\square\square\square \times -25°\square + 1000 \times 31.80\square\square/\square\square\square}$$

$$\square\square\square\square = \square\square\square\square \times \frac{\$26.20}{500\ \square} + \$1.28$$

Heat of Dissolution for Trial 1: ___28.14kJ/mol___

Heat of Dissolution for Trial 2: ___35.45kJ/mol___

Average Heat of Dissolution: ___31.80kJ/mol___

Mass For 0.0°C: ___35.69g___

Cost For 0.0°C: ___$3.15___

Calcium Chloride

Trial	Mass of DI Water	Temperature of DI Water	Mass of Salt	Final Temperature

1	45.0 g	24.64 °C	1.012 g	27.04 °C
2	45.8 g	24.58 °C	0.9500 g	26.94 °C

Work for Finding Heat of Dissolution for Both Trials:

$$\Delta\square_{\square\square\square\square\square\square\square\square\square\square} = \frac{-((46.012\ \square \times 4.186\square/\square{}^{\circ}\square \times (27.04\ {}^{\circ}\square - 24.64\ {}^{\circ}\square)) + (76.6\square/{}^{\circ}\square \times (27.04\ {}^{\circ}\square - 24.64\ {}^{\circ}\square)))}{0.009119\ \square\square\square\square\square\square\ \square\square\square\square}$$

$$\Delta\square_{\square\square\square\square\square\square\square\square\square\square} = \frac{-((46.75\ \square \times 4.186\square/\square{}^{\circ}\square \times (26.94\ {}^{\circ}\square - 24.58\ {}^{\circ}\square)) + (76.6\square/{}^{\circ}\square \times (26.94\ {}^{\circ}\square - 24.58\ {}^{\circ}\square)))}{0.008560\ \square\square\square\square\square\square\ \square\square\square\square}$$

$$\square\square\square\square = \frac{-100 \times 4.186\square/\square{}^{\circ}\square \times 110.98\square/\square\square\square \times 40{}^{\circ}\square}{4.186\square/\square{}^{\circ}\square \times 110.98\square/\square\square\square \times 40{}^{\circ}\square + 1000 \times -72.96\square\square/\square\square\square}$$

$$\square\square\square\square = \square\square\square\square \times \frac{\$31.70}{500\ \square} + \$1.28$$

Heat of Dissolution for Trial 1: ___-70.85kJ/mol___

Heat of Dissolution for Trial 2: ___-75.07kJ/mol___

Average Heat of Dissolution: ___-72.96kJ/mol___

Mass For 65.0°C: ___34.17g___

Cost For 65.0°C: ___$3.45___

Lithium Chloride

Trial	Mass of DI Water	Temperature of DI Water	Mass of Salt	Final Temperature

1	44.9 g	24.84 °C	1.004 g	28.29 °C
2	44.9 g	25.07 °C	1.001 g	28.94 °C

Work for Finding Heat of Dissolution for Both Trials:

$$\Delta\square_{\square\square\square\square\square\square\square\square\square} = \frac{-((45.904\ \square \times 4.186\square/\square°\square \times (28.29\ °\square - 24.84\ °\square)) + (76.6\square/°\square \times (28.29\ °\square - 24.84\ °\square)))}{0.02368\ \square\square\square\square\square\ \square\square\square\square}$$

$$\Delta\square_{\square\square\square\square\square\square\square\square\square} = \frac{-((45.901\ \square \times 4.186\square/\square°\square \times (28.94\ °\square - 25.07\ °\square)) + (76.6\square/°\square \times (28.94\ °\square - 25.07\ °\square)))}{0.02361\ \square\square\square\square\square\ \square\square\square\square}$$

$$\square\square\square\square = \frac{-100 \times 4.186\square/\square°\square \times 42.39\square/\square\square\square \times 40°\square}{4.186\square/\square°\square \times 42.39\square/\square\square\square \times 40°\square + 1000 \times -41.60\square\square/\square\square\square}$$

$$\square\square\square\square = \square\square\square\square \times \frac{\$65.00}{500\ \square} + \$1.28$$

Heat of Dissolution for Trial 1: ___-39.16kJ/mol___

Heat of Dissolution for Trial 2: ___-44.05kJ/mol___

Average Heat of Dissolution: ___-41.60kJ/mol___

Mass For 65.0°C: ___20.57g___

Cost For 65.0°C: ___$3.95___

Potassium Chloride

Trial	Mass of DI Water	Temperature of DI Water	Mass of Salt	Final Temperature
1	45.0 g	25.31 °C	1.004 g	24.05 °C
2	45.1 g	25.88 °C	1.085 g	24.56 °C

Work for Finding Heat of Dissolution for Both Trials:

$$\Delta\square_{\square\square\square\square\square\square\square\square\square} = \frac{-((46.004\ \square \times 4.186\square/\square°\square \times (24.05\ °\square - 25.31\ °\square)) + (76.6\square/°\square \times (24.05\ °\square - 25.31\ °\square)))}{0.01347\ \square\square\square\square\square\ \square\square\square\square}$$

$$\Delta\square_{\square\square\square\square\square\square\square\square\square} = \frac{-((46.185\ \square \times 4.186\square/\square°\square \times (24.56\ °\square - 25.88\ °\square)) + (76.6\square/°\square \times (24.56\ °\square - 25.88\ °\square)))}{0.01455\ \square\square\square\square\square\ \square\square\square\square}$$

$$\square\square\square\square = \frac{-100 \times 4.186\square/\square°\square \times 74.55\square/\square\square\square \times -25°\square}{4.186\square/\square°\square \times 74.55\square/\square\square\square \times -25°\square + 1000 \times 24.83\square\square/\square\square\square}$$

$$\square\square\square\square = \square\square\square\square \times \frac{\$28.19}{500\ \square} + \$1.28$$

Heat of Dissolution for Trial 1: ___25.18kJ/mol___

Heat of Dissolution for Trial 2: ___24.49kJ/mol___

Average Heat of Dissolution: ___24.83kJ/mol___

Mass For 0.0°C: ___45.82g___

Cost For 0.0°C: ___$3.86___

Discussion

These results clearly show that calcium chloride is the best salt for the Dystan hot packs, while ammonium nitrate is the best salt for the cold packs. This is shown by the price of each salt. Of the endothermic salts, ammonium nitrate is the least expensive when attempting to reach 0.0°C, at only $3.15. Of the exothermic salts, calcium chloride is the least expensive when attempting to reach 65.0°C, at only $3.45. Regardless, for every salt, Dystan medical company would return a profit, at a maximum of $1.85 profit and a minimum of $1.05, assuming the price is $5.00.

I am fairly confident in these results. Checking with the standard heats of dissolution of each of the salts, we are fairly accurate. Similarly, the results are fairly close to one another and therefore pretty precise. I feel like both accuracy and precision can be approved by doing additional trials. Also, the speed of pouring the salt into the calorimeter can be increased, therefore adding accuracy to the results. Another source of error is leaving excess water in the calorimeter, which could be reduced by thorough drying. Another source is the slowing down of the stir bar, which happened occasionally. This can be prevented by using a more reliable stir plate.

Conclusion

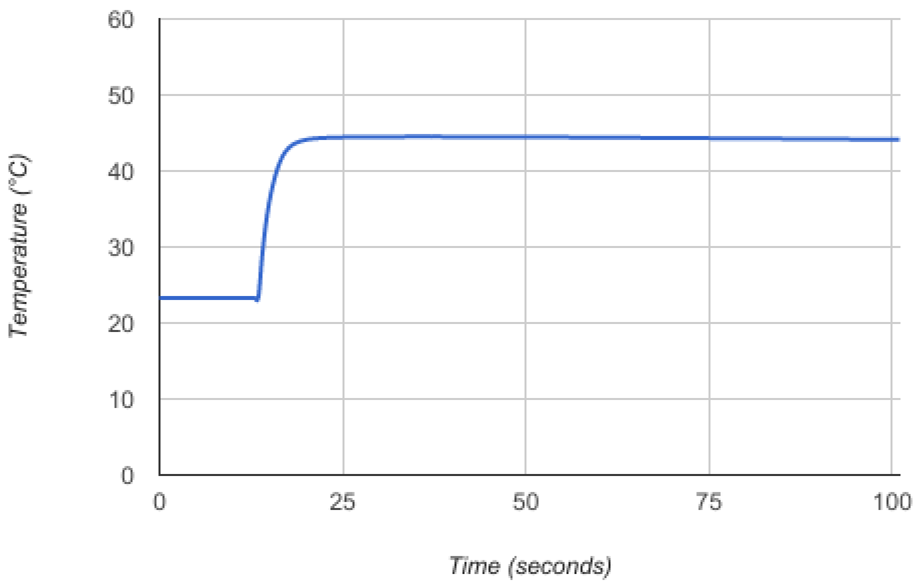
This experiment consisted of first finding a calorimeter constant using hot and cold water. We then poured various salts into the calorimeter as well as water to calculate the heats of dissolution. Once these were found, the mass and then the cost could then be calculated. The most important results of this experiment were that ammonium nitrate was the most efficient and cost-effective salt for the cold packs, while calcium chloride is that for the hot packs. Every salt will still return a profit, however, with ammonium nitrate being the most profitable and lithium chloride being the least, regardless of their hot and cold abilities.

Bibliography

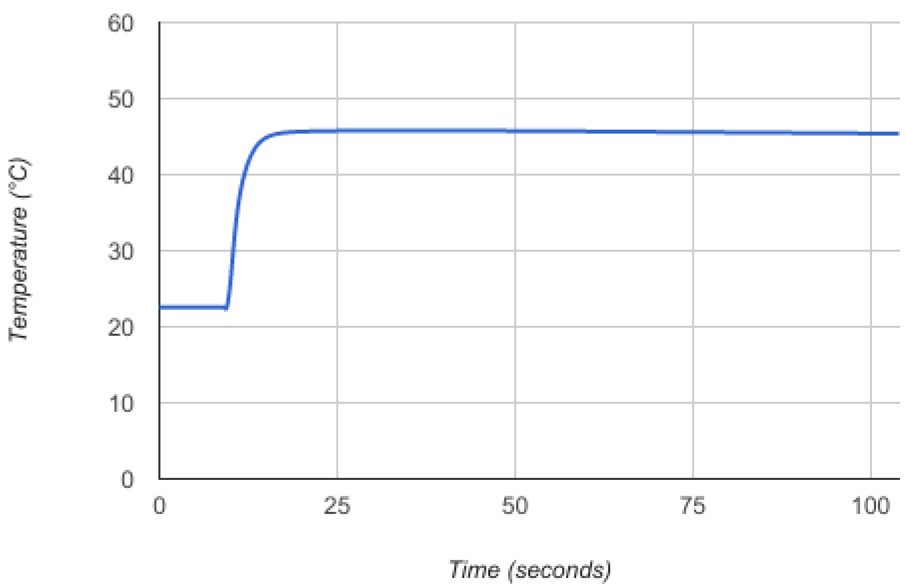
Stanton, B., Zhu, L., & Atwood, C. H. (2006). *Experiments in General Chemistry Featuring MeasureNet*. Belmont, CA: Thomson Brooks/Cole.

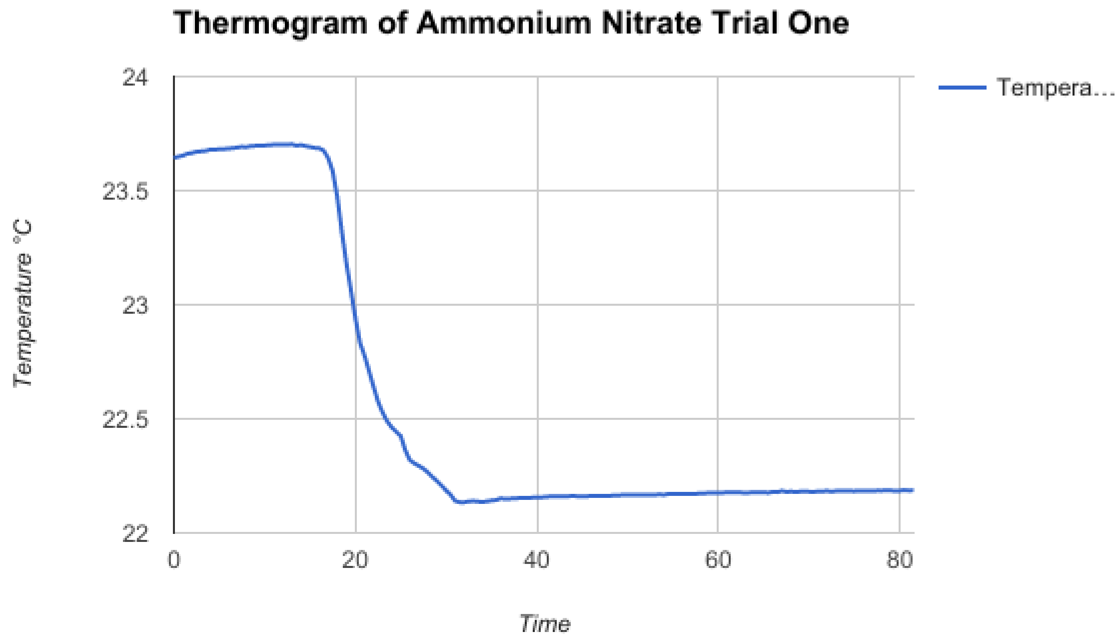
Graphs

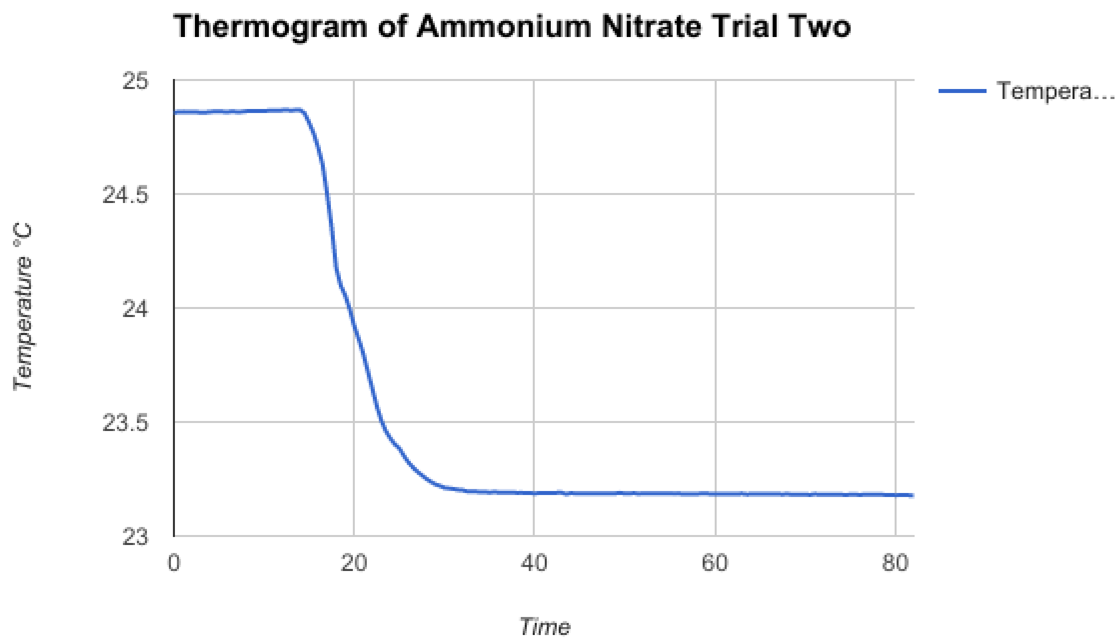
Thermogram for the Calorimeter Constant Trial One

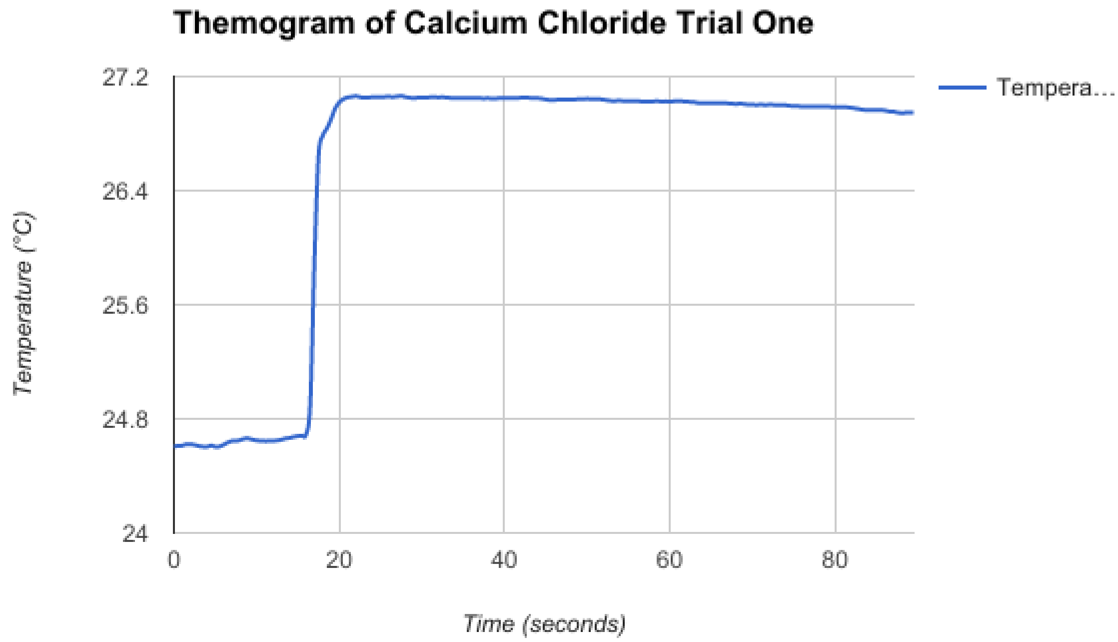


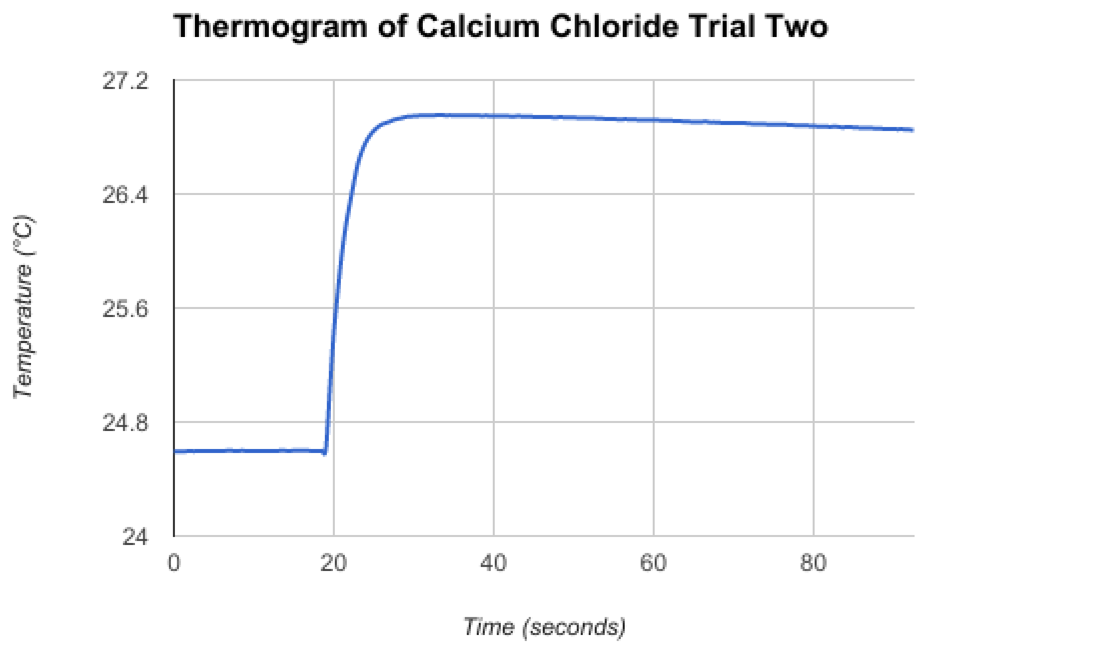
Thermogram for the Calorimeter Constant Trial Two

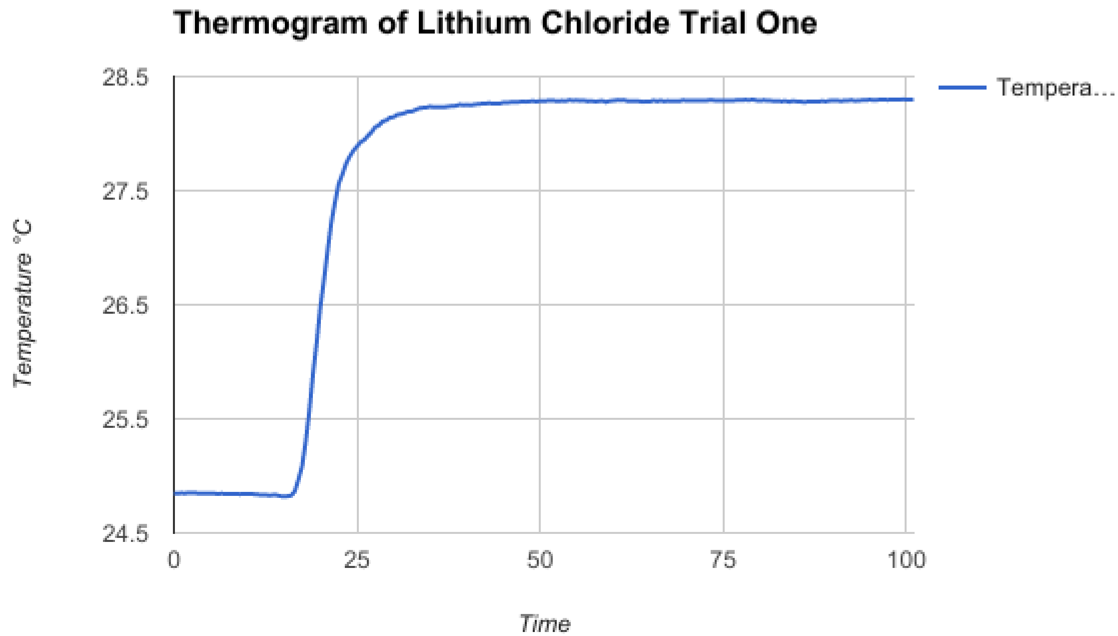


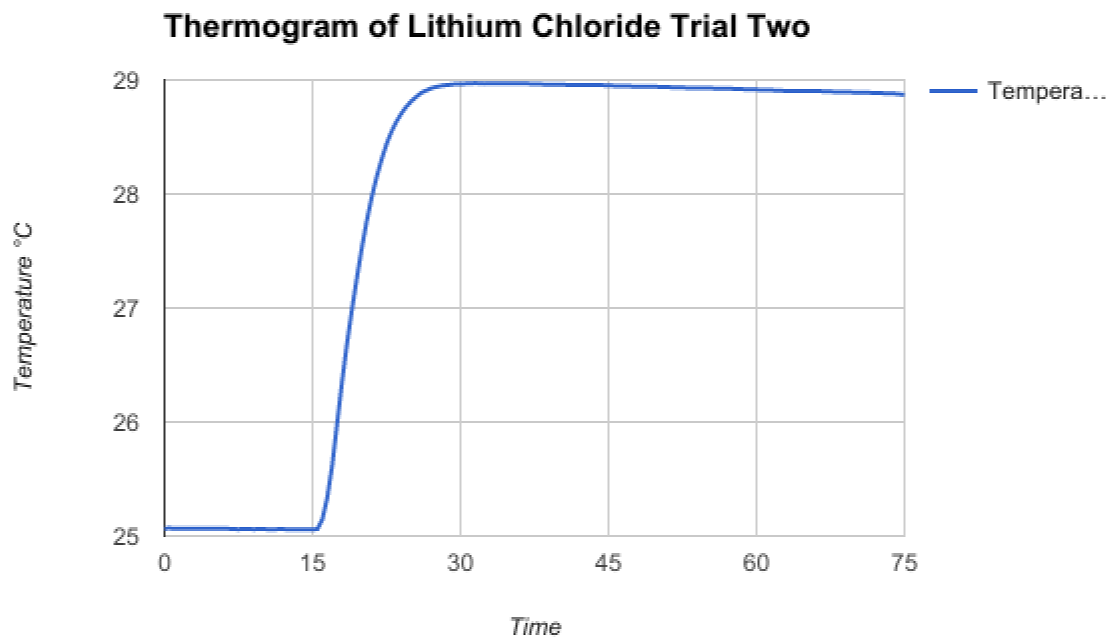

Thermogram of Ammonium Nitrate Trial One
Tempera…
Temperature °C
24
23.5
23
22.5
22
0
20
40
60
80
Time

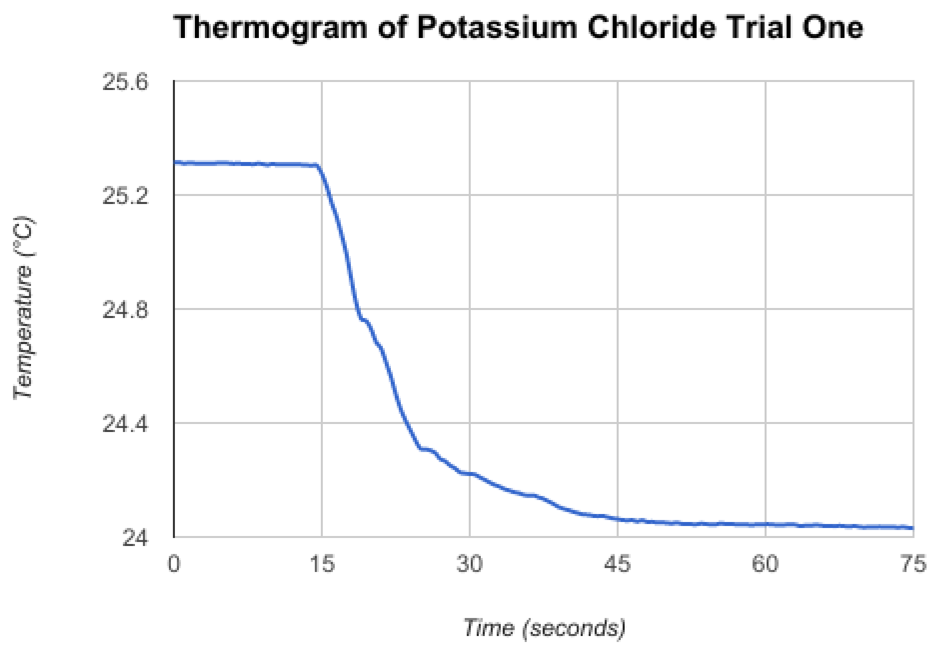

Thermogram of Ammonium Nitrate Trial Two
Tempera…
Temperature °C
25
24.5
24
23.5
23
0
20
40
60
80
Time

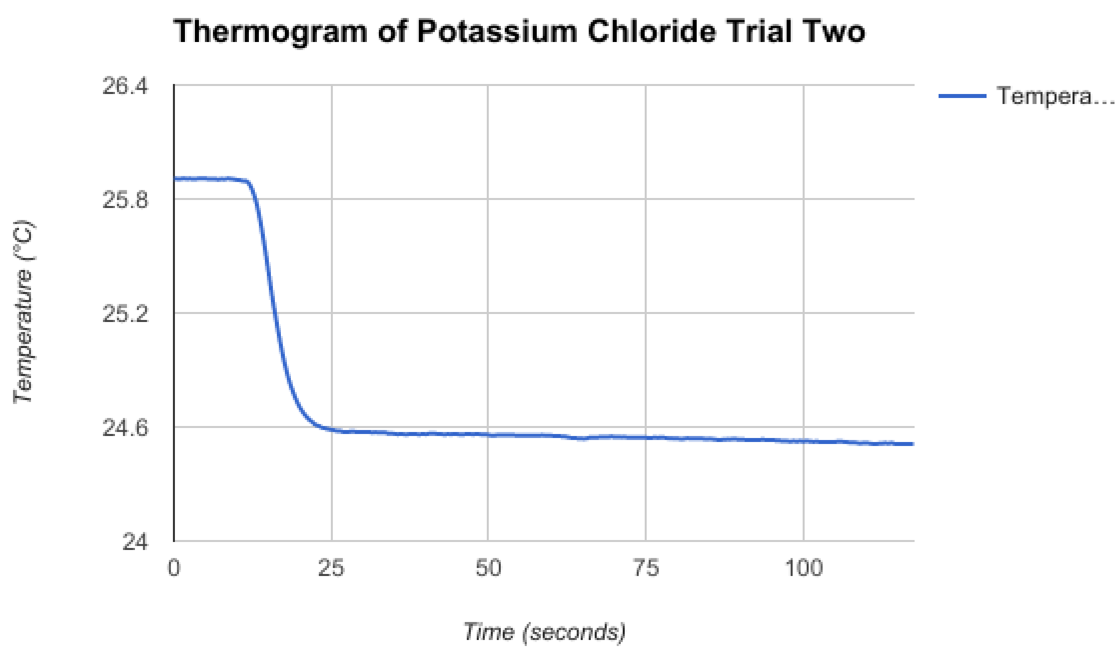

Themogram of Calcium Chloride Trial One
Tempera…
Temperature (°C)
27.2
26.4
25.6
24.8
24
0
20
40
60
80
Time (seconds)


Thermogram of Calcium Chloride Trial Two
Temperature (°C)
27.2
26.4
25.6
24.8
24
0
20
40
60
80
Time (seconds)


Thermogram of Lithium Chloride Trial One
28.5
27.5
26.5
25.5
24.5
Temperature °C
0
25
50
75
100
Time
Tempera…


Thermogram of Lithium Chloride Trial Two
29
28
27
26
25
Temperature °C
0
15
30
45
60
75
Time
Tempera…


Thermogram of Potassium Chloride Trial One
25.6
25.2
24.8
24.4
24
0
15
30
45
60
75
Temperature (°C)
Time (seconds)


Thermogram of Potassium Chloride Trial Two
26.4
25.8
25.2
24.6
24
0
25
50
75
100
Tempera…
Temperature (°C)
Time (seconds)