An Investigation into the Chemistry of Hot and Cold Packs

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Jared Compaleo Section 17M

Academic Honesty Statement

I have read and agree to the terms of the Academic Honesty Statement.

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Introduction

This report investigates the use of a calorimeter to measure enthalpy change and differentiate between exothermic and endothermic processes quantitively and determine what properties would constitute a “better” hot or cold pack. This report investigates the process of calorimetry which is the measurement of heat absorbed or released by something; specifically, the heat of solution of various salts which is the enthalpy change when the salt is dissolved (Libretexts, 2019). Calorimetry is done in a calorimeter, which is a device where the heat released or absorbed by a reaction is measured (Sanders, 2019). However, because heat is measured in a calorimeter, it is the surrounding that is directly measured, making the head of reaction the negative of the heat measured (Sanders, 2019). In this experiment, heat is calculated using the equation Heat = mcp∆T where heat is measured in joules, mass (m) is measured in grams, specific heat capacity (cp) is J/g\*˚C and change in temperature (∆T) is measured in degrees centigrade (Sanders, 2019). However, heat calculated using the equation Heat = mcp∆T changes with the amount measured, the heat is divided by the moles of reactants and turned into enthalpy which does not change with amount used (Libretexts, 2019).

In this experiment, salts are dissolved first in small test tubes to determine if they are exothermic or endothermic; then the salts that have been subjectively determined to release the most heat and absorb the most heat are tested for amount of heat released per mole (Sanders, 2019). The hypotheses are if the salt is endothermic, then it is suited for cold packs; if the salt is exothermic, then it is suitable for hot packs; and if there is more salt, then the heat change will be greater.

Methods

Students were assigned sets of salts to study; in my case, set A (ammonium chloride, sodium nitrate, magnesium sulfate) was assigned (Sanders, 2019). Roughly 2cm of each salt was separately dissolved in 5-6 mL of deionized water and touched to test for temperature change (Sanders, 2019). The information was recorded in table 12.2 with the remaining data coming from groups assigned different sets of salt (Sanders, 2019).

A Styrofoam cup (calorimeter) was massed before 25mL of deionized water added and massed again (Sanders, 2019). Approximately 1g the salt from the assigned set that was deemed the most exothermic is massed then added into the calorimeter with water and stirred with a temperature probe until the salt was fully dissolved and the highest temperature was reached (Sanders, 2019). All the information was recorded in the combined table 12.3 & 12.5 (Sanders, 2019). The procedure was then repeated with 2g of the same hot salt, 1g of the salt from the assigned set that was deemed the most endothermic, and 2g of the same cold salt (Sanders, 2019).

Results

Table 12.1 Cost and Impacts of Salts Used in This Experiment

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Salt | Formula of Salt (Anhydrous) | Price per gram | Environmental considerations from SDS | GHS designation | Most likely issue for our situation | Production or disposal issues | References |
| Ammonium Chloride | NH4Cl | $ 0.07 | Harmful to aquatic life | irritant, environmentally damaging | eye irritation | none | beta-static.fishersci.com |
| Sodium Nitrate | NaNO3 | $ 0.15 | Don't empty into drains | oxidizing, irritant | eye irritation | none | beta-static.fishersci.com |
| Magnesium Sulfate | MgSO4 | $ 0.04 | None | not hazardous | may cause irritation | none | beta-static.fishersci.com |
| Calcium Chloride | CaCl2 | $ 0.09 | None | irritant | eye irritation | none | beta-static.fishersci.com |
| Magnesium Chloride | MgCl2 | $ 0.03 | None | irritant | skin irritation | none | beta-static.fishersci.com |
| Potassium Nitrate | KNO3 | $ 0.09 | May migrate into ground water | oxidizing, irritant | skin irritation | none | beta-static.fishersci.com |
| Magnesium Nitrate | Mg(NO3)2 | $ 0.04 | None | oxidizing, irritant | eye irritation | none | beta-static.fishersci.com |
| Potassium Chloride | KCl | $ 0.06 | When ingested, causes dehydration | irritant | skin irritation | none | beta-static.fishersci.com |

Table 12.2 Quantitative Results

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Salt | Chemical Formula | Temp Change | Is heat released from the system to its surroundings? | Is heat absorbed by the system from its surroundings? | q system |
| Ammonium Chloride | NH4Cl | cooler | No | Yes | > 0 |
| Magnesium Sulfate | MgSO4 | warmer | Yes | No | < 0 |
| Calcium Chloride | CaCl2 | no change | No | No | no change |
| Magnesium Chloride | MgCl2 | warmer | Yes | No | < 0 |
| Potassium Nitrate | KNO3 | cooler | No | Yes | > 0 |
| Magnesium Nitrate | Mg(NO3)2 | warmer | Yes | No | < 0 |
| Potassium Chloride | KCL | cooler | No | Yes | > 0 |
| Sodium Nitrate | NaNO3 | cooler | No | Yes | > 0 |

Table 12.3 & 12.5 Results of 1 and 2 Grams of Hot and Cold Pack Salts

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Hot Pack Salt (MgSO4) | | Cold Pack Salt (NH4Cl) | |
|  | Trial 1 | Trial 2 | Trial 1 | Trial 2 |
| Mass of Empty Cup | 2.201 | 2.190 | 2.211 | 2.190 |
| Mass of Water | 24.224 | 24.451 | 23.634 | 24.221 |
| Mass of Sample | 1.075 | 2.032 | 1.051 | 2.060 |
| Mass of Solution | 25.299 | 26.483 | 24.685 | 26.281 |
| Initial T (˚C) | 20.0 | 20.7 | 20.9 | 20.6 |
| Final T (˚C) | 24.8 | 31.0 | 18.2 | 14.8 |
| ∆T (˚C) | 4.8 | 10.3 | -2.7 | -5.8 |
| ∆Hsurroundings (kJ) | 4.9E-01 | 1.05E+00 | -2.7E-01 | -5.9E-01 |
| ∆Hsystem | -4.9E-01 | -1.05E+00 | 2.7E-01 | 5.9E-01 |
| Molar Mass of Salt | 120.361 | 120.361 | 53.489 | 53.489 |
| Moles of Salt Dissolved | 8.931E-03 | 1.688E-02 | 1.965E-02 | 3.851E-02 |
| ∆Hsystem (kJ)/Mole | -5.4E+01 | -6.24E+01 | 1.4E+01 | 1.5E+01 |
| Uncertainty in ∆H/mole in kJ/mole | 3.4 | 1.9 | 1.5 | 0.8 |
| ∆T/gram of salt | 4.5E+00 | 5.07E+00 | -2.6E+00 | -2.8E+00 |
| ∆T/$ | 1.1E+02 | 1.27E+02 | -3.7E+01 | -4.0E+01 |

Table 12.4 Class Data Summary

|  |  |  |
| --- | --- | --- |
| Salt | Average ∆T/mass | Average ∆T/$ |
| NH4Cl | -2.8419 | -40.598 |
| KCl | -1.3226 | -22.043 |
| NaNO3 | -1.8576 | -12.384 |
| MgCl2 | 9.2794 | 103.1 |
| KNO3 | 1.4164 | 15.738 |
| CaCl2 | N/A | N/A |
| MgSO4 | 4.7797 | 119.49 |
| LiCl | 5.666 | 60.276 |
| Mg(NO3)2 | N/A | N/A |
|  |  |  |
| price of LiCl | $47.00/500g |  |
| price of LiCl (1g) | 0.094 $/g |  |
| https://www.carolina.com/specialty-chemicals-d-l/lithium-chloride-reagent-grade-500-g/872580.pr | | |

Discussion

As our claims stated, an exothermic salt was a good salt for a hot pack, an endothermic salt was a good salt for a cold pack, and that larger amounts of salt would lead to a greater heat change. The class data suggests that magnesium chloride is the best salt for a hot pack, however literature says calcium chloride, with a lower enthalpy, is a better salt (Stevens, 2018). However, excluding calcium chloride because it was a salt not tested, magnesium chloride would be the best salt for a hot pack temperature wise. Class data suggests that ammonium chloride is the best salt for a cold pack, however literature says that potassium nitrate, with its higher enthalpy, is the best salt for a cold pack (Stevens, 2018). However, class data suggests that potassium nitrate is exothermic. The reason for this error cannot be determined because this salt was not part of the set that was assigned to the group during this experiment. Of the salts with greater testing done by the group, the first trial of the hot salt had a difference of 7.3 kJ/mol which is greater than the uncertainty while the second trial had a difference of 1.1 kJ/mol which falls in the range of the uncertainty (Stevens, 2018). The error from trial two can be determined as caused by the uncertainties of the measurement equipment, however the error in trial one could have potentially been caused by there being less salt, having a higher initial temperature, or having a lower final temperature than recorded; all of which would have made the enthalpy appear greater than it would otherwise have been. Trials one and two of the cold pack salt had a difference of 1.3 and 0.3 kJ/mol respectively, both of which fall within the uncertainty and is both likely caused by the uncertainty of the equipment used for measuring (Stevens, 2018). Any error that occurred could be prevented through a comparison of an average enthalpy with more trials.

References

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