AP CHEMISTRY

Designing a Hand Warmer

(130 Points)

Name, Date and Lab Partner (5 Points)

Procedure (10 Points)

Complete, step-by-step account

of actions performed

Data (30 Points)

Observation Table (10 Points)

Reagent Masses (5 Points)

Reagents Volumes (5 Points)

Temperature Tables (10 Points)

Analysis/Calculations (30 Points)

Conclusion (40 Points)

Overall Neatness and Organization (5 Points)

Safety (10 Points)

This part is determined by proper lab safety which includes having your goggles and lab coat on properly at all times. Each reminder by the instructor will result in a deduction of 5 or 10 points. This component of the grade can be negative.

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**INTRODUCTION TO ANALYTICAL CHEMISTRY – LAB**

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**EXPERIMENT VI**

**DESIGNING A HAND WARMER**

**INTRODUCTION**

Energy exchange is associated with most atomic processes; light energy is emitted following electron excitation, sound energy is released during many forms of combustion, but heat energy (units of kJ or cal) acts as the most common and quantifiable medium of energy transfer to and from matter. Heat energy exchange between a system and its surroundings is associated with physical changes, such as phase changes and dissolving, as well as chemical reactions.

Put your chemistry skills to commercial use! From instant cold packs to flameless ration heaters and hand-warmers, the energy changes associated with physical and chemical changes have many consumer applications. The backbone of these applications is calorimetry; a method which allows for the measurement of heat transfer between a system and surroundings.

**THEORY**

During physical changes, heat energy (q) is associated with the breaking and formation of intermolecular forces. The heat exchange of such processes can be mathematically described using the ***latent heat equation*** (a).

q = m∆H (a)

In the case of chemical reactions, heat energy (q) is associated with the breaking and formation of chemical bonds. Since there is no instrument that can directly measure heat, the flow of heat energy is quantified by observing changes in temperature of a substance in a process known as **calorimetry**. The relationship between temperature change and heat exchange is described mathematically using the ***heat capacity equation*** (b).

q = mC∆T (b)

A large amount of potential energy is contained within chemical bonds due to the force of attraction between atomic nuclei and bonding electrons. To a lesser extent, potential energy is also stored in the intermolecular forces of attraction between neighboring molecules.

During a physical change, like dissolution, energy is required to break these forces of attraction between solute/solute and between solvent/solvent. Energy is then given off during the formation of new intermolecular forces between the solvent and solute molecules. Therefore, the overall flow of heat energy that occurs during the dissolution of a solute can be described by determining the energy going into the system to break the initial intermolecular attractions in the solute and solvent versus the energy being emitted during the reformation of intermolecular attraction between the solvent and solute.

In this lab, you will investigate the energy changes associated with common laboratory salts and then apply the results to design a hand-warmer that is reliable, safe, and inexpensive.

The enthalpy change associated dissolution is commonly referred to as the heat of solution (∆Hsoln). Assuming the dissolution is performed in a well-insulated container at constant pressure, this enthalpy change, ∆Hsoln, is equal in molar magnitude to the heat loss or gain, q, to the surroundings.

In the case of the dissolution of an ionic solid in water, the overall energy change is the net result of three processes:

1. The energy required to break the intermolecular forces in the solute
2. The energy required to break the intermolecular forces between the solvent
3. The energy given off due to the formation of intermolecular forces between the solute and solvent

The enthalpy change associated with a phase change is commonly referred to as the heat of fusion, Hf, (melting/freezing) and heat of vaporization, Hv, (boiling/condensation). These enthalpy values provide information on the calorie or joule value associated with pushing one gram of the substance of interest through a phase change. The sign assigned to the value indicates the exothermic or endothermic direction of the phase change.

**Safety and Disposal**

Many of the ionic salts researched in this experiment present multiple health risks. Consult an MSDS report on all of the salts prior to handling them.

**Research & Development**

1. Your hand-warmer must utilize a physical change for enthalpic change (ΔH). Discuss the types of physical processes you could perform in lab and decide which process you will initiate inside your hand-warmer. Keep practicality, safety, and ability/ease for calorimetric measurement in mind.
2. What data must be collected to determine the ethalpic change due to a physical process? Discuss how the data collected can be manipulated to represent enthalpic change (ΔH).
3. Design a calorimeter that meets the needs of your enthalpic experiment from (1).
4. To record accurate temperature data, a probe must be equilibrated to the analytic solution, sufficiently submerged in the analyte, and the analyte should be uniform in temperature.
   1. Determine a proper total volume of solution to use in your experiment such that at least ¼ of the probe is submerged. Covert this into a mass value.
   2. How can you assure a uniform physical change/temperature throughout this volume?
5. Using the information provided in the background of this lab, derive an equation that represents the enthalpy values which when summed, represent the heat of solution for an ionic compound being dissolved in water. Watch your signs, include units, and identify whether each variable is an endo or exothermic process.
6. If the enthalpy associated with the hydration of ions is greater than the enthalpy associated with separating the solute and solvent molecules, what can be said about ∆Hsoln?
7. Research the term entropy. Provide a definition below and apply it to your understanding of how dissolution occurs.
8. Recall from our notes that dissolving is always a process that releases ***energy*** (note: I didn’t say enthalpy), as a solute will not dissolve unless the system is moving towards a more energetically favorable state. Explain why a dissolved solution can still feel cold.
9. Calorimeters utilize an insulated container to carry out thermal processes in. The change in temperature experienced by the contents of the container is used to determine the enthalpic change of the system/surroundings. Identify the heat equation that should be used to quantize this type of heat exchange between a system and surroundings.
10. As we saw in our previous thermal lab, our coffee cup calorimeters are not perfect insulators. Describe the steps taken to quantitatively account for this observation and provide an equation that relates the heat of dissolving (qsoln), the heat gained/given by water of the solution (qaq), and the heat absorbed/given by the calorimeter (qcal).

**Investigation**

Prior to performing any experimentation, discuss your research and development conclusions with Mr. Walsh

With the calorimetry experience gained in the Hess’ Law lab, your lab group will be responsible for creating and executing a procedure which covers the following criteria/ideas:

***Calibration of the Calorimeter by Determination of its Heat Capacity***

* This procedural section should cover:
  + Design of the calorimeter
  + Experimental and mathematical determination of Ccal

**Calibration Analysis**

Calculate the Heat Capacity of the Calorimeter.

1. Determine the instantaneous temperature of mixing (Tmix).
2. Calculate the theoretical average temperature (Tave) of the hot and cold water after mixing.
3. Calculate the heat lost by the water (qwater) to the surroundings (calorimeter). (specific heat of water = 4.18 J/g°C)
4. Calculate the heat gained by the surroundings (calorimeter) (qcal).
5. Calculate the heat capacity of the calorimeter (Ccal), which is the heat the calorimeter absorbs each time the temperature of the water changes 1°C. (Tinitial = cold water temp)

Ccal = qcal / (Tmix – Tinitial)

***Designing the Hand-Warmer***

* This procedural section should cover:
  + Candidate ionic salts researched.
    - Form a working group of 4 students. One pair of students should study the 3 solids in Set A and the other pair the solids in Set B.

**Set A Set B**

Ammonium Nitrate Sodium Chloride

Calcium Chloride Lithium Chloride

Sodium Acetate Sodium Carbonate

* + Experimental and mathematical determination of ΔHsoln for each candidate
    - Note: to save on materials, perform trials with 2.0 g of ionic compound
    - Determine amount of solvent to use such that the total mass of your solution matches the optimal value determined in your prelab.
  + Proposal of hand-warmer design, meeting the following criteria:
    - Design of hand-warmer and the proposed salt to be used
    - The hand-warmer must contain 10g of the ionic salt and 40mL of water.
    - A net temperature increase of at least 20.0ºC must be obtained.
    - Discussion of cost, safety, and enthalpic value to support our choice

**Design Analysis**

1. Extrapolating from the data and observations collected, determine which solids would enthalpically be best suited for usage in a hand-warmer while meeting the following requirements:

* The hand-warmer must contain 10g of the ionic salt and 40mL of water.
* A net temperature increase of at least 20.0ºC must be obtained.
  + Include ∆Hsoln calculations to support your selection.

1. Determine the cost per gram (dollars/g) for each ionic salt candidate by researching the cost of 100g bottles of reagent from [www.flinnsci.com](http://www.flinnsci.com)
2. Consult MSDS reports from <http://www.sciencelab.com/msdsList.php> to determine which ionic salts would be best suited for usage in a hand-warmer with respect to safety.

**Conclusion**

* Discuss the concepts of dissolution, heat, enthalpy, entropy, and calorimetry as related to this lab.
* Discuss assumptions made during this experiment and possible sources of error.
* Discuss how your group determined which ionic compound to use in your hand-warmer.
* Draw a step-by-step diagram depicting how your ionic solid is dissolved by water. Include notation that indicates magnitude and direction of heat energy flow during each step.
* Propose an overall engineering design for your hand-warmer that is inexpensive and effective.