

Designing a Hand Warmer

AP® Chemistry Big Idea 5, Investigation 12

An Advanced Inquiry Lab

Introduction

Put your chemistry skills to commercial use! From instant cold packs to flameless ration heaters and hand warmers, the energy changes accompanying physical and chemical transformations have many consumer applications. The backbone of these applications is calorimetry—measuring heat transfer. Investigate the energy changes accompanying the formation of solutions for common laboratory salts, and then apply the results to design a hand warmer that is reliable, safe and inexpensive.

Concepts

- Enthalpy change
- Heat of solution
- Exothermic versus endothermic
- Calorimetry
- Specific heat
- System and surroundings

Background

Hand warmers are familiar cold weather gear used to quickly provide warmth to frigid fingers. Many commercial hand warmers consist of a plastic package containing a solid and an inner pouch filled with water. When the pack is activated, the solid dissolves in water and produces a large temperature change.

The energy or *enthalpy change* associated with the process of a solute dissolving in a solvent is called the *heat of solution* (ΔH_{soln}). At constant pressure, this enthalpy change, ΔH_{soln} , is equal in magnitude to the heat loss or gain, q , to the surroundings. In the case of an ionic solid dissolving in water, the overall energy change is the net result of three processes—the energy required to break the attractive forces between ions in the crystal lattice ($\Delta H_1 = +C$ kJ/mole), the energy required to disrupt intermolecular forces between water molecules ($\Delta H_2 = +D$ kJ/mole), and the energy released when the dissociated (free) ions form ion-dipole attractive forces with the water molecules ($\Delta H_3 = -F$ kJ/mole). The overall process can be represented by the following equations.



If the amount of energy *released* in the formation of hydrated ions (ΔH_3) is greater than the amount of energy *required* to separate the solute and solvent particles ($\Delta H_1 + \Delta H_2$), then the sum (ΔH_{soln}) of the energy changes will be negative and the solution process exothermic (releases heat). If the amount of energy released in the formation of hydrated ions is less than the amount of energy required to separate the solute and solvent particles, then the sum of the energy changes will be positive and the solution process endothermic (absorbs heat).

Heats of solution and other enthalpy changes are generally measured in an insulated vessel called a *calorimeter* that reduces or prevents heat loss to the atmosphere outside the reaction vessel. The process of a solute dissolving in water may either release heat into the resulting aqueous solution or absorb heat from the solution, but the amount of heat exchanged between the calorimeter and the outside surroundings should be minimal. When using a calorimeter, the reagents being studied are mixed directly in the calorimeter and the temperature is recorded both before and after the reaction has occurred. The amount of heat transfer (q) may be calculated using the heat energy equation:

$$q = m \times s \times \Delta T \qquad \text{Equation 1}$$

where m is the **total mass of the solution** (solute plus solvent), s is the specific heat of the solution, and ΔT is the observed temperature change. The specific heat of the solution is generally assumed to be the same as that of water, namely, 4.18 J/g·°C.

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Table of Contents Chemfax Designing A Hand Warmer

1. Understanding the eBook Chemfax Designing A Hand Warmer
 - The Rise of Digital Reading Chemfax Designing A Hand Warmer
 - Advantages of eBooks Over Traditional Books
2. Identifying Chemfax Designing A Hand Warmer
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Chemfax Designing A Hand Warmer
 - User-Friendly Interface
4. Exploring eBook Recommendations from Chemfax Designing A Hand Warmer
 - Personalized Recommendations
 - Chemfax Designing A Hand Warmer User Reviews and Ratings
 - Chemfax Designing A Hand Warmer and Bestseller Lists

5. Accessing Chemfax Designing A Hand Warmer Free and Paid eBooks
 - Chemfax Designing A Hand Warmer Public Domain eBooks
 - Chemfax Designing A Hand Warmer eBook Subscription Services
 - Chemfax Designing A Hand Warmer Budget-Friendly Options
6. Navigating Chemfax Designing A Hand Warmer eBook Formats
 - ePub, PDF, MOBI, and More
 - Chemfax Designing A Hand Warmer Compatibility with Devices
 - Chemfax Designing A Hand Warmer Enhanced eBook Features
7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Chemfax Designing A Hand Warmer
 - Highlighting and Note-Taking Chemfax Designing A Hand Warmer
 - Interactive Elements Chemfax Designing A Hand Warmer
8. Staying Engaged with Chemfax Designing A Hand Warmer
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Chemfax Designing A Hand Warmer
9. Balancing eBooks and Physical Books Chemfax Designing A Hand Warmer
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Chemfax Designing A Hand Warmer
10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
11. Cultivating a Reading Routine Chemfax Designing A Hand Warmer
 - Setting Reading Goals Chemfax Designing A Hand Warmer
 - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of Chemfax Designing A Hand Warmer
 - Fact-Checking eBook Content of Chemfax Designing A Hand Warmer
 - Distinguishing Credible Sources
13. Promoting Lifelong Learning

- Utilizing eBooks for Skill Development
- Exploring Educational eBooks

14. Embracing eBook Trends

- Integration of Multimedia Elements
- Interactive and Gamified eBooks

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