Lab 28. Designing a Cold Pack: Which Salt Should Be Used to Make an Effective but Economical Cold Pack?

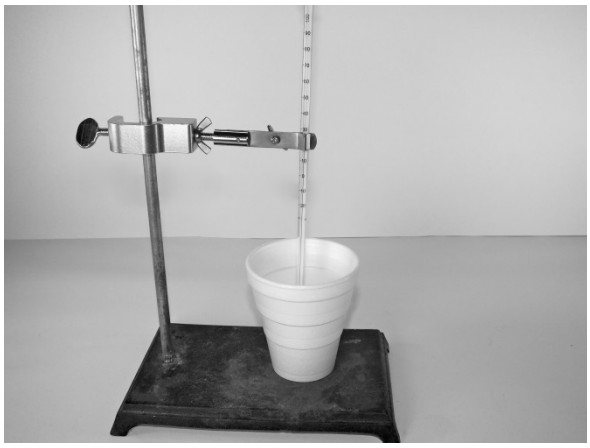
Introduction

An instant cold pack is a first aid device that is used to treat injuries. Most commercial instant cold packs contain two plastic bags. One bag contains an ionic compound, and the other bag contains water. When the instant cold pack is squeezed hard enough, the bag containing the water breaks and the ionic compound and water mix. The dissolution of the ionic compound in the water results in an enthalpy change and a decrease in the overall temperature of the cold pack. In this investigation, you will explore the enthalpy changes that are associated with common salts and then apply what you have learned about these enthalpy changes to design an effective but economical instant cold pack.

The enthalpy change associated with the dissolution process is called the *heat of solution* (ΔH_{soln}). At constant pressure, the ΔH_{soln} is equal in magnitude to heat (q) lost to or gained from the surroundings. In the case of a salt dissolving in water, the overall enthalpy change is the net result of two key processes. First, an input of energy is required to break the attractive forces that hold the ions in the salt together and to disrupt the intermolecular forces that hold the water molecules in the solvent together. The system *gains* energy during this process. Second, energy is released from the system as attractive forces form between the dissociated ions and the molecules of water. The system *loses* energy during this process. The ΔH_{soln} can therefore be either endothermic or exothermic depending on the net energy change in the system. The ΔH_{soln} is exothermic when the system releases more energy into the surroundings than it absorbs and endothermic when the system absorbs more energy than it releases.

FIGURE L28.1

Example of a calorimeter



A chemist can determine the molar ΔH_{soln} for a specific salt by mixing a sample of it with water inside a *calorimeter*. A calorimeter is an insulated container that is designed to prevent or at least reduce heat loss to the atmosphere (see Figure L28.1). Once the salt and water are mixed, the chemist can record the temperature change that occurs inside the calorimeter as a result of the dissolution process. The magnitude of the heat energy change is then calculated using the following equation:

$$q = m \times s \times \Delta T$$

where q = heat energy change (in joules), m = total mass of the solution (solute plus solvent), s = the specific heat of the solution (4.18 J/g•°C), and ΔT = the observed temperature change. The chemist can then calculate the molar ΔH_{soln} for the salt by dividing q by the number of moles of the salt (n) that he or she mixed with the water.

Your Task

Investigate different salts for potential use in a cold pack. Using the empirical data you collect along with the cost data provided in Table L28.1, determine which salt in what quantity should be used to produce an effective but economical cold pack.

TABLE L28.1

Prices of salts

Salt	Amount (in grams)	Price
NH_4Cl	1,000	$13.90
NH_4NO_3	500	$8.95
$MgSO_4$	100	$1.17
$Na_2S_2O_3$	500	$8.55

The guiding question of this investigation is, **Which salt should be used to make an effective but economical cold pack?**

Materials

You may use any of the following materials during your investigation:

Consumables	Equipment
• Ammonium chloride, NH_4Cl • Ammonium nitrate, NH_4NO_3 • Magnesium sulfate, $MgSO_4$ • Sodium thiosulfate, $Na_2S_2O_3$ • Distilled water	• Graduated cylinder (100 ml) • Spatula • Calorimeter • Temperature probe with sensor interface • Electronic or triple beam balance

Safety Precautions

Follow all normal lab safety rules. Ammonium chloride, ammonium nitrate, sodium thiosulfate, and magnesium sulfate are all tissue irritants and moderately toxic by ingestion. Your teacher will explain relevant and important information about working with the chemicals associated with this investigation. In addition, take the following safety precautions:

- Wear indirectly vented chemical-splash goggles and chemical-resistant gloves and apron while in the laboratory.
- Handle all glassware with care.
- Wash your hands with soap and water before leaving the laboratory.

Investigation Proposal Required? ☐ Yes ☐ No

Getting Started

The first step in your investigation is to determine the heat energy change associated with each salt. To accomplish this task, you will need to determine what type of data to collect, how you will collect the data, and how you will analyze the data.

To determine *what type of data you need to collect*, think about the following questions:

- What type of measurements or observations will you need to make during your investigation?
- Is it important to know the change in temperature of the solution or just its final temperature?
- How does the amount of salt or the amount of water influence your potential results?

To determine *how you will collect the data*, think about the following questions:

- What will serve as your independent and dependent variables?
- How often will you collect data and when will you do it?
- How will you make sure that your data are of high quality (i.e., how will you reduce error)?
- How will you keep track of the data you collect and how will you organize it?

To determine *how you will analyze the data*, think about the following questions:

- How will you calculate the heat energy change associated with the formation of a solution?
- How will you calculate the molar ΔH_{soln} for each compound?
- What type of graph could you create to help make sense of your data?

The second step of your investigation will be to determine which salt should be used to make the instant cold pack. The company wants to produce small instant cold packs that will easily fit in a portable first aid kit. The instant cold pack they are planning to make will consist of two bags: one containing water and the other containing one of the salts. The bag of water will be placed inside the bag that contains the salt so when the bag of water is ruptured, the salt and water can mix. The company is planning on using 60 ml of water in this cold pack. For the instant ice pack to be effective, its temperature needs to fall to about 2°C once the salt and water are mixed. The company, however, wants to spend as little as possible to produce the instant cold packs. You will therefore need to conduct a complete cost-

benefit analysis for each salt. This will require you to determine how much of each type of salt you will need to use and how much it will cost per instant cold pack. The price of each salt is given in Table L28.1.

Connections to Crosscutting Concepts, the Nature of Science, and the Nature of Scientific Inquiry

As you work through your investigation, be sure to think about

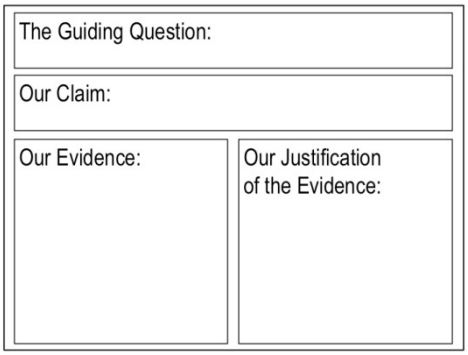
- the importance of recognizing and analyzing patterns,
- how energy and matter flow within a system,
- the role of culture and values in science, and
- the importance of creativity in science.

Initial Argument

Once your group has finished collecting and analyzing your data, you will need to develop an initial argument. Your argument must include a *claim*, which is your answer to the guiding question. Your argument must also include *evidence* in support of your claim. The evidence is your analysis of the data and your interpretation of what the analysis means. Finally, you must include a *justification* of the evidence in your argument. You will therefore need to use a scientific concept or principle to explain why the evidence that you decided to use is relevant and important. You will create your initial argument on a whiteboard. Your whiteboard must include all the information shown in Figure L28.2.

FIGURE L28.2

Argument presentation on a whiteboard



Argumentation Session

The argumentation session allows all of the groups to share their arguments. One member of each group stays at the lab station to share that group's argument, while the other members of the group go to the other lab stations one at a time to listen to and critique the arguments developed by their classmates. The goal of the argumentation session is not to convince others that your argument is the best one; rather, the goal is to identify errors or instances of faulty reasoning in the initial arguments so these mistakes can be fixed. You will therefore need to evaluate the content of the claim, the quality of the evidence used to support the claim, and the strength of the justification of the evidence included in each argument that you see. To critique an argument, you might need more information than what is included on the whiteboard. You might, therefore, need to ask the presenter one or more follow-up questions, such as:

- How did your group collect the data? Why did you use that method?
- What did your group do to analyze the data, and why did you decide to do it that way?
- Is that the only way to interpret the results of your group's analysis? How do you know that your interpretation of the analysis is appropriate?
- Why did your group decide to present your evidence in that manner?
- What other claims did your group discuss before deciding on that one? Why did you abandon those alternative ideas?
- How confident are you that your group's claim is valid? What could you do to increase your confidence?

Once the argumentation session is complete, you will have a chance to meet with your group and revise your original argument. Your group might need to gather more data or design a way to test one or more alternative claims as part of this process. Remember, your goal at this stage of the investigation is to develop the most valid or acceptable answer to the research question!

Report

Once you have completed your research, you will need to prepare an *investigation report* that consists of three sections that provide answers to the following questions:

1. What question were you trying to answer and why?
2. What did you do during your investigation and why did you conduct your investigation in this way?
3. What is your argument?

Your report should answer these questions in two pages or less. The report must be typed and any diagrams, figures, or tables should be embedded into the document. Be sure to write in a persuasive style; you are trying to convince others that your claim is acceptable or valid!