

Some Like It Hot, Some Like It Cold

Robert G. Silberman Sciencenter, Ithaca, NY 14850; silberman@cortland.edu

Students combine liquids and solids in a calorimeter and use a thermometer to determine if the reaction mixture gets hot or cold. The goal is to find a combination of a liquid and a solid that could serve as the basis for a cold pack of the type used for athletic injuries. The Activity is done on a small scale but can be modified for a larger scale.

Background

When chemical reactions occur, chemical bonds are broken and formed. Energy is needed to break old bonds and energy is released when new bonds are formed. If the energy released is greater than the energy needed (exothermic), the temperature rises. If the energy needed is greater than the energy released (endothermic), the temperature falls. Sometimes the only reaction that takes place is the conversion of the solid to ions in solution. The heat involved in this reaction is referred to as the heat of solution. In this Activity these reactions are observed:

- $\text{NH}_4\text{NO}_3(\text{s}) \rightarrow \text{NH}_4^+(\text{aq}) + \text{NO}_3^-(\text{aq})$
- $\text{CaCl}_2(\text{s}) \rightarrow \text{Ca}^{2+}(\text{aq}) + 2 \text{Cl}^-(\text{aq})$
- $\text{CH}_3\text{CO}_2\text{H}(\text{aq}) + \text{NaHCO}_3(\text{s}) \rightarrow \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) + \text{Na}^+(\text{aq}) + \text{CH}_3\text{COO}^-(\text{aq})$
- $2\text{H}_2\text{O}_2(\text{aq}) + \text{yeast catalyst} \rightarrow 2\text{H}_2\text{O}(\text{l}) + \text{O}_2(\text{g})$

Commercial cold packs usually use the first reaction. A sharp blow to the pack breaks a water-filled pouch that mixes with the ammonium nitrate in the pack.

Sample Data: Temperature Change and Gas Observed when a Solid Is Mixed with a Liquid

Liquid	Solid			
	baking soda	calcium chloride	ammonium nitrate	yeast
water	-3 °C	+22 °C	-18 °C	+1 °C
vinegar (5%)	-6 °C	+26 °C	-20 °C	+1 °C
hydrogen peroxide (3%)	-3 °C	+24 °C	-18 °C	+13 °C
				gas

Integrating the Activity into Your Curriculum

This Activity focuses on heats of reaction and heats of solution. It can be used as an introduction to thermodynamics and calorimeters. It can be extended to use quantitative data of heats of reactions, heats of solutions, and Hess's law (1).

About the Activity

All of the chemicals except ammonium nitrate are available in grocery or hardware stores. Ammonium nitrate is sold in bulk as fertilizer at some farm supply stores. Calcium chloride is sold as a dehumidifying and ice-melting compound. Yeast is available as dry powder. Small-scale thermometers (0–50 °C) are about 2 1/2-in. long and cost less than three dollars (2). The calorimeter strip is made from a 2 × 2 × 10-in strip of dense polystyrene insulation used in building construction. It comes in large 2-in thick pink sheets and is available in home improvement stores. Scrap pieces for donation are often at building sites. Cut the foam to size with a saw or sharp knife. Make the wells by heating the end of a 22-mm diameter glass test tube with a heat gun (set to ~500 °F). Press it firmly on the foam to melt an inch-deep well; wear goggles and heat-resistant gloves. A 2 × 2 × 10-in strip can have 6 holes spaced 3/4 in. apart. Small-scale calorimeters are also available commercially (2). If small-scale equipment is not available, polystyrene cups and larger thermometers can be used with larger amounts of chemicals [1 teaspoon (5 mL) solid, 1 tablespoon (15 mL) liquid].

This Activity is based on an experiment used in a science museum. Information on this and other experiments designed for science museums is available in this issue of the *Journal* (3).

Answers to Questions

- The yeast/hydrogen peroxide reaction and the vinegar/baking soda reaction both produce a gas, evidence that a reaction other than the formation of a solution is taking place. All other combinations probably involve a heat of solution because there is no evidence of reaction other than a temperature change.
- Some considerations are: if gas is evolved from the reaction, how is it vented; how big does the pack need to be so it is effective on a specific part of the body; what is the cost of ingredients; how toxic are the ingredients and do they present disposal problems; what is the shelf-life of the pack ingredients; and how long will the pack stay cold. Sample data observed in testing are shown in the table above.
- Because both vinegar and 3% hydrogen peroxide are dilute aqueous solutions, the temperature changes are caused by the solvation of the ions in the two solid compounds.

References, Additional Related Activities, and Demonstrations

- Rohr, Walter, *An Introduction to Small-scale Thermochemistry*; Flinn Scientific Inc.: Batavia, IL, 2000.
- Flinn Scientific Inc., P.O. Box 219, Batavia, IL 60510; 800/452-1261 (small-scale calorimeters order # AP5928, small-scale thermometers order # AP8712).
- Silberman, Robert G.; Trautmann, Charles; Merkel, Susan M. Chemistry at a Science Museum. *J. Chem. Educ.* 2004, 81, 51–53.

JCE Classroom Activities are edited by Erica K. Jacobsen

Some Like It Hot, Some Like It Cold

Athletic trainers often use cold packs to treat injuries. Cold packs reduce swelling around the injury. The trainer simply hits a cold pack to break an inner pouch, shakes it to mix the contents, and the pack becomes cold almost immediately. What is in these packs?

Many chemical reactions either release energy so that the reaction mixture gets hot (exothermic), or need energy so the reaction mixture gets cold (endothermic). Sometimes the only reaction that takes place is the conversion of a solid to ions in solution. Then the heat involved in the reaction is often referred to as the heat of solution. These reactions can be easily demonstrated with some common chemicals and a calorimeter. A calorimeter is an insulated container that makes it easy to measure a temperature change when a reaction takes place. It can be something as simple as a polystyrene cup or a piece of polystyrene insulation from a home improvement store with wells pressed into it. In this Activity, your challenge is to find the combination of chemicals that could be used to make an instant cold pack.



photo courtesy of the Sciencecenter

Try This

You will need: baking soda, anhydrous calcium chloride (ice melter), ammonium nitrate, dry yeast, water, household vinegar (5%), 3% hydrogen peroxide, small-scale thermometer, measuring spoons, and calorimeter strip.

1. Place 1/4 teaspoon (1.25 mL) of room-temperature liquid (water, vinegar, or 3% hydrogen peroxide) in one well of the calorimeter strip. Place a small-scale thermometer in the well. Measure and record the initial temperature of the liquid. Add 1/8 teaspoon (~0.6 mL) of baking soda to the liquid. Measure and record the most extreme temperature that the solution reaches. Did the temperature change? If so, how? Were there any other changes you observed when the liquid and the solid were combined?
2. Using a clean, dry calorimeter well and a room-temperature thermometer each time, try all possible combinations of a liquid and a solid to find a combination(s) that gets hot or cold. Record the initial and final (most extreme) temperatures for each, along with any other changes you observe. There are four possible solids: baking soda, anhydrous calcium chloride, ammonium nitrate, and dry yeast. There are three possible liquids: water, household vinegar (5%), and 3% hydrogen peroxide. The liquids should be at approximately room temperature.

More Things To Try

1. Determine what ratio of liquid to solid produces the lowest temperature. Determine what ratio of liquid to solid produces the highest temperature.
2. Make a simulated hot pack or cold pack using small plastic bags such as zipper-style freezer bags and sandwich bags.
3. Temperature changes can occur when soluble liquids are mixed. Try mixing glycerin with water.
4. Temperature changes can also occur when reactive solutions are mixed. Try mixing household vinegar with household ammonia.

Questions

1. Which reaction of those you investigated involves heat of reaction, which involves heat of solution? What kind of evidence do you have to support your answer?
2. Suppose you want to use one of these reactions as the basis for a cold pack, what things would you need to consider? Which combination of solid/liquid would be best for a cold pack? Explain why you chose your combination.
3. When calcium chloride or ammonium nitrate are combined with either vinegar or 3% hydrogen peroxide, what reaction is taking place?

Information from the World Wide Web

(accessed October 2003)

Why swelling occurs after injury. http://www.painreliever.com/Ankle/why_swellingoccurs.html

Hot and cold treatment of athletic injuries. http://www.50plus.org/Libraryitems/1_12_Running_Hot_Cold.htm

Be Safe! All of the solutions can be washed down the drain with large amounts of water. Ammonium nitrate is a strong oxidizer and should not be stored near or mixed with reducing agents or flammables. Ammonium nitrate and concentrated acetic acid may ignite if mixed.

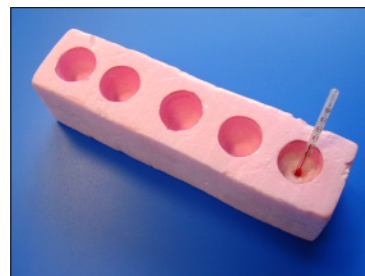


photo courtesy of the Sciencecenter