Where's the Heat?
Investigating Exothermic and Endothermic Processes

About this Lesson
This activity is designed to explore the energy transformations that occur in endothermic and exothermic processes by making observations, collecting measurements and recording qualitative and quantitative data in an experiment.

This lesson is included in the LTF Middle Grades Module 9.

Objectives
Students will:

- Dissolve urea and sodium percarbonate in water to examine endothermic and exothermic processes.
- Make observations, collect measurements, and record qualitative and quantitative data about the mixtures
- Calculate the change in temperature that occurred for each solution and identify the energy transfer

Level
Middle Grades: Chemistry

Common Core State Standards for Science Content

LTF Science lessons will be aligned with the next generation of multi-state science standards that are currently in development. These standards are said to be developed around the anchor document, *A Framework for K–12 Science Education*, which was produced by the National Research Council. Where applicable, the LTF Science lessons are also aligned to the Common Core Standards for Mathematical Content as well as the Common Core Literacy Standards for Science and Technical Subjects.

Code	Standard	Level of Thinking	Depth of Knowledge
(LITERACY) RST.9-10.3	Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.	Apply	II
(MATH) A_CED.4	Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations.	Apply	II

T E A C H E R

Connections to AP*
AP Chemistry:
III. Reactions A. Reaction types

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Materials

Each lab group will need the following:

aprons
balance
goggles
graduated cylinder, 50 mL
paper towels
sodium percarbonate
test tube rack, large
test tube, large
thermometer
urea, solid
water, distilled
2 weigh boats

Additional teacher materials:

cold pack, instant
cold pack, instant
OxiClean®

Assessments

The following assessment is located on the LTF website

- Middle Grades Chemistry: Chemical Reactions Assessment

Teaching Suggestions

Chemistry is often defined as the interaction of matter and energy. Too often our courses focus on the "matter" and neglect the "energy." This activity is designed to explore the energy transformations that occur in endothermic and exothermic processes. These terms are used to describe the direction of thermal energy flow between a system and its surroundings. Exothermic reactions or processes are those that release energy from the system to the surroundings. Endothermic reactions or processes are those that absorb energy into the system from the surroundings. As a result of this energy exchange, a temperature change may also be observed. Exothermic reactions will display an increase in temperature as the energy is released by the system and absorbed by the thermometer. These exothermic reactions will also feel warm to the touch as the energy leaves the reaction vessel and transfers to your hand. Endothermic reactions will display a decrease in temperature as the energy is removed from the surroundings and the thermometer to go into the system. These endothermic reactions will feel cold to the touch as the energy is removed from your hand for transfer into the system.

It is important to note that the energy changes students are exploring in this activity are of two different varieties. The energy change in the urea + water combination is the result of the physical dissolution that occurs (enthalpy of solution) whereas the energy change for the sodium percarbonate is the result of a chemical reaction (enthalpy of reaction). The reaction is shown below:

$$2Na_2CO_3 \bullet 3H_2O_2 \rightarrow 2Na_2CO_3 + 3H_2O + 1.5\ O_2 + \text{Heat}$$

The terms endothermic and exothermic can also be used to describe changes of state. When water changes from a liquid to a gas, energy is absorbed and the process is said to be endothermic. When water condenses from a gas to a liquid, energy is released and the process is said to be exothermic.

Instant cold packs provide the urea, uric acid, or ammonium nitrate that is needed for the endothermic solution. They can be purchased at your local discount store, drug store, or sporting goods store. One cold pack should provide enough solute for several classes. You may wish to purchase an extra cold pack to demonstrate the application of this concept by activating the cold pack as directed on the package. Instant hand warmers may also be demonstrated as an example of an exothermic process.

The students are instructed to carry out the reactions in a test tube. If you do not have test tubes a small beaker may be substituted. However, be sure that the thermometer can be adequately submerged in the liquid without touching the bottom of the beaker.

POSSIBLE ANSWERS TO THE CONCLUSION QUESTIONS AND SAMPLE DATA

The data tables below show a sample of data collected from an actual completion of the lab. The results your students collect may not be exact but should show the same trends.

Data Table 1 Urea	
Time (s)	**Temperature of Solution (°C)**
0	23.1
30	19.7
60	18.4
90	17.6
120	14.5
150	13.4
180	13.3
210	12.5
240	11.7
270	11.4
300	11.1

Data Table 2 Sodium Percarbonate	
Time (s)	**Temperature of Solution (°C)**
0	23.0
30	26.2
60	26.5
90	27.4
120	27.6
150	28.5
180	29.7
210	30.2
240	32.1
270	33.4
300	33.6

Data Table 3 Urea/Sodium Percarbonate	
Time (s)	**Temperature of Solution (°C)**
0	23.3
30	23.1
60	23.0
90	22.8
120	22.7
150	22.5
180	22.2
210	21.8
240	21.4
270	21.1
300	20.6

OBSERVATIONS

Urea and Water	Sodium Percarbonate and Water	Urea, Sodium Percarbonate, and Water
• Test tube feels cold • Condensation on outside of test tube • Solution looks clear	• Test tube feels warm • Solution is cloudy	• Test tube feels cold • Solution is cloudy **student answers may vary*

TEACHER

ANALYSIS

Data Analysis Table				
Solution	**Final Temp. (°C)**	**Initial Temp. (°C)**	**Change in Temperature ΔT (°C)**	**Energy Transfer (Absorbed or Released)**
urea + water	11.1	23.1	– 12.0	Absorbed
sodium percarbonate + water	33.6	23.0	10.6	Released
urea + sodium percarbonate + water	20.6	23.3	– 2.7	More absorbed then released

CONCLUSION QUESTIONS

1. For each solution listed below, identify whether the process was endothermic or exothermic and provide evidence for your answer.

Solution	Endothermic or Exothermic	Evidence
urea + water	Endothermic	Heat energy was absorbed and used, and the temperature decreased
sodium percarbonate + water	Exothermic	Heat energy was released, and the temperature increased
urea + sodium percarbonate + water	Endothermic	More heat energy was absorbed then was released and the temperature decreased

2. Compare your observations of solutions 1 and 3. How are they alike?
   - Both solutions felt cool and showed condensation on the outside of the test tube.
   - Student answers may vary.

3. Compare your observations of solutions 2 and 3. How are they alike?
   - Both solutions were cloudy.
   - Student answers may vary.

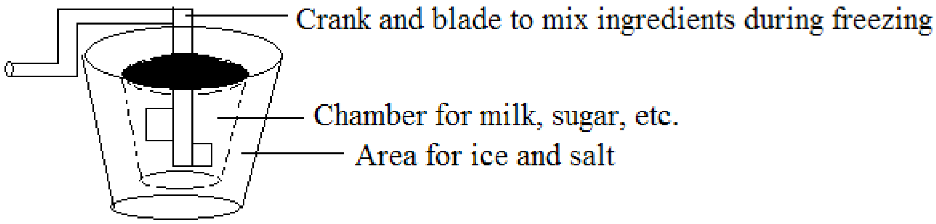
4. Solution 3 combined urea and sodium percarbonate in the same test tube. From your table in the ANALYSIS section, which substance, urea or sodium percarbonate, do you think provided the greatest energy transfer? Justify your answer.
   - The urea dissolving is endothermic and the sodium percarbonate decomposing is exothermic. Since the combined solution felt cold, the urea's dissolving must have absorbed more energy than the sodium percarbonate's decomposition released.

5. How might your results be different if 10 grams of urea (rather than 5 grams) were added to 20 mL of water? Explain your prediction.
   - The solution will most likely feel colder and a larger decrease in temperature would be observed. This may also result in more condensation on the outside of the test tube.

6. Which of the chemical reactants in this experiment would you expect to find in an 'instant cold pack'? Justify your answer.
   - Urea. Its dissolving resulted in the absorption of energy.

7. When making ice cream, salt is added to the ice surrounding the chamber in which the ice cream freezes. The salt lowers the freezing point of the ice, allowing it to melt.

Old Fashion Ice Cream Maker



a. Describe the movement of heat in the ice cream maker as the ice cream freezes and the ice melts.
- Heat is required to melt ice. Heat is removed from the ice cream ingredients as the ice melts, thus allowing the ingredients to freeze.

b. Is the process of freezing the ice cream solution endothermic or exothermic? Justify your answer.
- Exothermic, energy is released to the surroundings.

c. If you started with extremely cold liquid water instead of solid water, would your ice cream freeze as quickly? Justify your answer.
- The heat from the ingredients would still transfer to the cold water but the temperature would not be cold enough to allow the solution to freeze.

T E A C H E R

Where's the Heat?
Investigating Exothermic and Endothermic Processes

Have you ever used an instant cold pack or an instant hand warmer? These helpful products are based on harnessing the energy transfer that takes place during a physical or chemical change. The change can be a physical change like dissolving a solid in water, or it can be a chemical change like the oxidation of iron in air. Whether the package feels hot or cold depends on the direction of the energy transfer.

Exothermic processes are those that release thermal energy from the system to the surroundings. Exothermic processes will feel warm to the touch and show an increase in temperature. For example, when an 'instant hand warmer' is exposed to air a chemical reaction takes place that releases heat. This exothermic chemical reaction can be used to warm a person's hands when they are cold.

Endothermic processes are those that absorb thermal energy from their surroundings. Endothermic processes absorb energy and make their surroundings feel colder. For example, an 'instant cold pack' contains a granular chemical and a sealed bag of water. When the bag of water is broken the water and the solid granules dissolve and the system takes in energy from the surroundings. This dissolving process absorbs energy in the form of heat from its surroundings and can be used to cool an injured area.

PURPOSE

In this activity you will dissolve urea and sodium percarbonate in water to examine endothermic and exothermic processes. You will make observations, collect measurements, and record qualitative and quantitative data about the mixtures.

MATERIALS

Each lab group will need the following:

aprons
balance
goggles
graduated cylinder, 50 mL
paper towels
sodium percarbonate
test tube rack, large
test tube, large
thermometer
urea, solid
water, distilled
2 weigh boats

Safety Alert

Urea and sodium percarbonate should be handled with care. Do not get them near your eyes or mouth. Wash your hands after handling the materials, and wear goggles during the entire lab.

PROCEDURE

1. In the section marked HYPOTHESIS on your student answer page, record a hypothesis about the temperature change that will occur when each of the following chemicals are dissolved in water.
   a. Urea
   b. Sodium percarbonate
   c. A mixture of urea and sodium percarbonate

2. Use a weigh boat to measure out 5 grams of urea.

3. Use a graduated cylinder or syringe to add 20 mL of distilled water to the test tube.

4. Hold a thermometer in the test tube so that the bulb is submerged in the water, but does not touch the sides or bottom of the test tube.

5. Measure the initial temperature of the water and record this value in Data Table 1 on your student answer page. This is the temperature of your solution at time = 0 s. The thermometer will remain submerged in the water; you will continue to take readings as the process progresses.

6. Simultaneously start your stopwatch and add 5 grams of urea to the distilled water in the test tube. Do not use the thermometer to stir the solution. Gently swirl the test tube to disperse the solid. Hold the thermometer so the bulb is directly above the level of the solids at the bottom.

7. Record the temperature of the solution every 30 seconds for a total of 5 minutes. Record your data in Data Table 1 on your student answer page. As the urea dissolves, record at least two qualitative observations about the solution, container, and/or surroundings. Continue to swirl the test tube often so more water comes in contact with the solid solute.

8. After five minutes has passed, clean out the test tube and rinse the thermometer. The contents of the test tube may be flushed down the sink with running water.

9. Complete steps 2 through 8 a second time using 5 grams of sodium percarbonate instead of urea and record the resulting temperatures in Data Table 2.

10. Complete steps 2 through 8 a third time using 2.5 grams of urea and 2.5 grams of sodium percarbonate. Use a toothpick to mix the dry sodium percarbonate and dry urea in a weigh boat before adding them to the 20 mL of distilled water. Record the resulting temperatures in Data Table 3.

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HYPOTHESIS

A.

B.

C.

DATA

Data Table 1 Urea	
Time (s)	Temperature of Solution (^oC)
0	
30	
60	
90	
120	
150	
180	
210	
240	
270	
300	

Data Table 2 Sodium Percarbonate	
Time (s)	Temperature of Solution (^oC)
0	
30	
60	
90	
120	
150	
180	
210	
240	
270	
300	

Data Table 3 Urea/Sodium Percarbonate	
Time (s)	Temperature of Solution (^oC)
0	
30	
60	
90	
120	
150	
180	
210	
240	
270	
300	

OBSERVATIONS

Urea and Water	Sodium Percarbonate and Water	Urea, Sodium Percarbonate, and Water

ANALYSIS

1. Using the data tables on the previous page, record the initial and final temperatures for each solution in the Data Analysis Table below.

2. Calculate the change in temperature that occurred for each solution and identify the energy transfer. Record your answers in the table below.

Data Analysis Table				
Solution	**Final Temp. (^oC)**	**Initial Temp. (^oC)**	**Change in Temperature ΔT (^oC)**	**Energy Transfer (Absorbed or Released)**
1. urea + water				
2. sodium percarbonate + water				
3. urea + sodium percarbonate + water				

CONCLUSION QUESTIONS

1. For each solution listed below, identify whether the process was endothermic or exothermic and provide evidence for your answer.

Solution	Endothermic or Exothermic	Evidence
1. urea + water		
2. sodium percarbonate + water		
3. urea + sodium percarbonate + water		

2. Compare your observations of solutions 1 and 3. How are they alike?

3. Compare your observations of solutions 2 and 3. How are they alike?

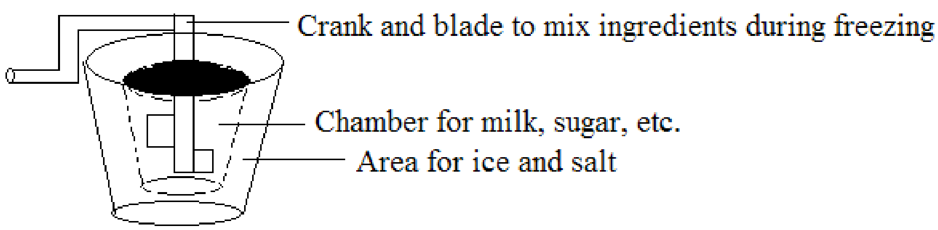
4. Solution 3 combined urea and sodium percarbonate in the same test tube. From your table in the ANALYSIS section, which substance, urea or sodium percarbonate, do you think involved the greatest energy transfer? Justify your answer.

5. How might your results be different if 10 grams of urea (rather than 5 grams) were added to 20 mL of water? Explain your prediction.

6. Which of the chemical reactants in this experiment would you expect to find in an 'instant cold pack'? Justify your answer.

7. When making ice cream, salt is added to the ice surrounding the chamber in which the ice cream freezes. The salt lowers the freezing point of the ice, allowing it to melt.

Old Fashion Ice Cream Maker



   a. Describe the movement of heat in the ice cream maker as the ice cream freezes and the ice melts.

   b. Is the freezing of the ice cream solution endothermic or exothermic? Justify your answer.

   c. If you started with extremely cold liquid water instead of solid water, would your ice cream freeze as quickly? Justify your answer.