SCOPE, SEQUENCE, and COORDINATION

A National Curriculum Project for High School Science Education

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SCOPE, SEQUENCE, and COORDINATION

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National Science Education Standard—Physical Science
Chemical Reactions
Chemical reactions may release or consume energy. Some reactions such as the burning of fossil fuels release large amounts of energy by losing heat and emitting light. Light initiates many chemical reactions, such as photosynthesis, the evolution of urban smog.

Teacher Materials

Learning Sequence Item:

942

Observing Chemical Reactions

March 1996
Adapted by: Michele Mallardi

Energy Transformation in Chemical Reactions. Students should observe changes in temperature or motion (an explosion) or emission of light indicating that chemical reactions either release (exothermic) or absorb energy (endothermic). *(Chemistry, A Framework for High School Science Education, p. 65.)*

Contents

This micro-unit was adapted by **Michele Mallardi** (Jefferson Davis H.S., Houston, Texas)

942

Learning Sequence

Energy Transformation in Chemical Reactions. Students should observe changes in temperature or motion (an explosion) or emission of light indicating that chemical reactions either release (exothermic) or absorb energy (endothermic). *(Chemistry, A Framework for High School Science Education, p. 65.)*

Science as Inquiry	Science and Technology	Science in Personal and Social Perspectives	History and Nature of Science
The Repeating "Exploding" Flask **Activity 1** The Heat Is On **Activity 2** Disc O' Inferno **Activity 3** Caught Red-Handed! **Activity 4** Stuck Between a Beaker and a Hard Place **Activity 5** Chilling Tales **Activity 6** Endothermic or Exothermic? **Assessments 1, 9, 10** Exothermic Indicators **Assessment 2** Combustion **Assessment 3** Endothermic Reactions **Assessment 5** Temperature Change **Assessments 7, 11**	Burning of Fossil Fuels **Assessment 6**	**Hot and Cold Packs** **Reading 1** **Fireside Dreams** **Reading 2** Digestion **Assessment 4** Cleaning Products **Assessment 8**	

Suggested Sequence of Events

Event #1

Lab Activities

1. The Repeating "Exploding" Flask (15-minute demo)
2. The Heat Is On (45 minutes)
3. Disc O' Inferno (25 minutes)

Additional/Alternative Activity

4. Caught Red-Handed (55 minutes)

Event #2

Lab Activities

5. Stuck Between a Beaker and a Hard Place (10-minute demo)
6. Chilling Tales (45 minutes)

Event #3

Readings from Science as Inquiry, Science and Technology, Science in Personal and Social Perspectives, and History and Nature of Science

The following readings are enclosed with the Students Materials:

Reading 1 Hot and Cold Packs
Reading 2 Fireside Dreams

Assessment items are at the back of this volume.

Assessment Recommendations

This teacher materials packet contains a few items suggested for classroom assessment. Often, three types of items are included. Some have been tested and reviewed, but not all.

1. Multiple choice questions accompanied by short essays, called justification, that allow teachers to find out if students really understand their selections on the multiple choice.

2. Open-ended questions asking for essay responses.

3. Suggestions for performance tasks, usually including laboratory work, questions to be answered, data to be graphed and processed, and inferences to be made. Some tasks include proposals for student design of such tasks. These may sometimes closely resemble a good laboratory task, since the best types of laboratories are assessing student skills and performance at all times. Special assessment tasks will not be needed if measures such as questions, tabulations, graphs, calculations, etc., are incorporated into regular lab activities.

Teachers are encouraged to make changes in these items to suit their own classroom situations and to develop further items of their own, hopefully finding inspiration in the models we have provided. We hope you may consider adding your best items to our pool. We also will be very pleased to hear of proposed revisions to our items when you think they are needed.

Teacher Sheet

Science as Inquiry

The Repeating "Exploding" Flask

What causes the explosion?

Objective:

Demonstrate an exothermic combustion reaction that releases energy in the form of motion (sound).

Materials:

Demonstration per class:

two 500-mL Erlenmeyer flasks
50–75 mL of methanol (preferred) or ethanol
galvanized sheet, 0.3–0.5 mm thick (basically an inert metal sheet)
catalytic coil (10–15 cm in length; 0.3–1 mm diameter)
(The catalytic wire can be platinum (preferred), palladium (preferred), or nickel when using methanol; the catalytic wire must be platinum or palladium when using ethanol.)
copper wire (an inert piece of wire)
Bunsen burner
hot plate
damp cloth (safety)

Procedure:

Be sure to read the safety precautions for this exciting demo.

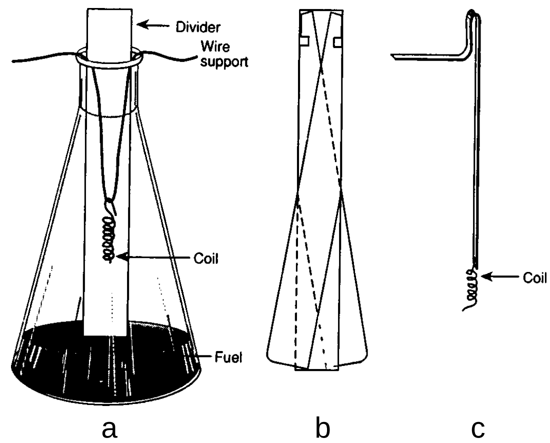
Cut the galvanized sheet so that it is longer than the depth of the reaction flask and the width of the sheet allows it to just pass through the neck of the Erlenmeyer flask. Place the sheet in the reaction flask so it serves as a divider. See diagram below.

Coil the catalytic wire so that it is 2–4 cm in length. Attach the coil to the center of the copper wire. The copper wire is acting as the support wire and should be molded so that the catalytic coil is hanging in the center of the flask. Set the coil and wire to the side.

Pour 50–75 mL of methanol or ethanol into another flask (not the reaction flask). Heat the alcohol until it boils; this will produce alcohol fumes that will serve as a reactant. Quickly pour the alcohol into the reactant flask.

After the alcohol has been poured into the reactant flask, the coil, suitably suspended from the inert V-shaped copper wire, is heated in a Bunsen flame and quickly suspended in the reaction flask. Remember, the position of the coil is important and you should suspend the coil about halfway down the flask.

Within minutes the “bangs” should begin. It takes longer for the explosions to begin with ethanol as compared to methanol.



a. Erlenmeyer flash with simple divider and coil suspended from wire loop.
b. Alternate divider with wings.
c. Alternate coil holder with long handle. Coil is held in place with a set screw.

Occasionally the explosions do not start. This may be due to:

a. the solvent not being hot enough;
b. the coil not being initially hot enough; or
c. insufficient oxygen in the flask.

The first two can be remedied by reheating. To overcome the last problem, use a piece of tubing and carefully blow air into the back half of the flask.

Background:

This is an exothermic combustion reaction. The reactions using methanol are as follows:

- the catalytic oxidation reaction

$CH_3OH\ (g) + ½\ O_2\ (g) \rightarrow CH_2O\ (g) + H_2O\ (g)$

- the combustion reaction

$2CH_3OH\ (g) + 3O_2\ (g) \rightarrow 2CO_2\ (g) + 4H_2O\ (g)$

The reactions using ethanol are:

- the catalytic oxidation reaction

$C_2H_5OH\ (g) + ½\ O_2\ (g) \rightarrow CH_3CHO\ (g) + H_2O\ (g)$

- the combustion reaction

$C_2H_5OH\ (g) + 3O_2\ (g) \rightarrow 2\ CO_2\ (g) + 3H_2O\ (g)$

The metal used as the coil catalyzes vapor phase reactions. In particular, it catalyzes the oxidation of alcohol. When such a wire is suspended over vapors in a flask, a regular “bang” accompanies the reaction. The series of bangs can last several hours. The loudness of the bang and the length of period depend on the type of metal, the alcohol, and the size of the flask used in the demonstration. The explosion is due to the exothermic combustion of the alcohol vapor in the flask. The exothermic oxidation of the alcohol on the surface heats the metal coil between explosions.

There are several precautions that must be taken during the demonstration.

a. If the alcohol is too hot, the alcohol vapor may ignite when the coil is lowered and burn at the mouth of the flask. The flame can be quickly and simply extinguished by placing a damp cloth over the top of the flask to smother the flame.
b. Be sure to handle the support wire with a damp cloth.
c. The flask gets hot very quickly. Breakage is extremely rare, but you should have a fire extinguisher handy.
e. If you experience a buildup of formaldehyde fumes (especially in a small room), you should conduct the demonstration under the hood.

Further Variations:

This should be done as a demonstration. Turning out the lights makes the effect more dramatic.

Adapted from Battino, R., Letcher, T.M., Rivett, D.E.A., and Krause, P. *Journal of Chemical Education* 70 (12):1029–30, 1993.

Teacher Sheet

Science as Inquiry

The Heat Is On

How does the temperature vary during a reaction?

Overview:

Calculate the water temperature increase during an exothermic reaction (release of energy).

Materials:

Per lab group:

1 Styrofoam™ cup
10–15 g of calcium chloride
(barium oxide can replace calcium chloride)
thermometer (Celsius)
1 100-mL graduated cylinder
1 balance (0.01 g)
1 stirring rod

Procedure:

Have students measure 100 mL of water and pour it into the Styrofoam cup. They then record the temperature of the water. They should measure 10–15 g of calcium chloride and quickly pour it into the water. They record the temperature of the reactants every minute until the temperature levels off.

Students should then graph their data, the x-axis representing time and the y-axis representing temperature.

Background:

The reaction caused by mixing calcium chloride with water is exothermic. Exothermic reactions release energy. In this lab the energy is released in the form of heat, which can be observed through temperature readings and touch. The exothermic heat of solution for calcium chloride is 117 calories per 100 mL of water:

$$CaCl_2 \text{ [s]} + H_2O \text{ [l]} \rightarrow Ca^{2+} \text{ [aq]} + 2Cl^{-} \text{ [aq]} + \text{heat}$$

The temperature should increase about 12 degrees Celsius. The Styrofoam cup will give more accurate measurements.

Further Variations:

Note that barium oxide can replace calcium chloride. Teachers may want to buy a hot pack to show the students, especially as an introduction to the hot pack activity.

Adapted from Summerlin, L.R. and Ealy, James L., *Chemical Demonstrations*, Volume I. Washington, D.C.: American Chemical Society, 1988.

Teacher Sheet

Science as Inquiry

Disc O' Inferno

How can water cause a reaction?

Objective:

Students perform an exothermic reaction inside a soda cap.

Materials:

Per lab group:

soda cap
5-inch square of aluminum foil
square of metal (to protect student desks)
1 tsp. of ammonium nitrate
1 pinch of zinc dust
1 pinch of iodine
1 dropper
2 spatulas
1 tongs
1 250-mL beaker
1 damp cloth
water

Procedure:

This reaction is potentially dangerous and students should wear safety glasses. You may wish to do this as a demo. If students perform this as an activity, you could premeasure the ammonium nitrate to control the quantity used.

Have students place a soda cap on a 5-inch square of aluminum foil, which should be resting on some sort of metal sheet. Make certain that the foil does not rest on wood or on the desk. They then pile the ammonium nitrate in the soda cap, and using a spatula, sprinkle some zinc dust on top. Using another spatula, they sprinkle iodine on top of this. They now add three drops of water. *(Warning: this is when the mixture may catch fire.)*

Have students use tongs to dump the soda cap into a beaker of water after the reaction ceases.

Background:

Ammonium nitrate is a strong oxidizer; it is used in explosives. The reaction that is occurring is:

$$NH_4NO_3 + Zn \rightarrow N_2 + 2H_2O + ZnO$$

The zinc oxide (ZnO) produces the white smoke. Iodine vaporizing during the reaction causes the beautiful purple color.

Further Variations:

The reaction can be performed with and without the iodine so that students can conclude that the iodine is supplemental in the reaction.

Adapted from Alyea, H.N. *Armchair Chemistry, a Programmed Laboratory Manual*, Sixth Edition, 1990.

Science as Inquiry

Caught Red-Handed!

How are hand warmers made?

Objective:

Students make their own hand warmers using an exothermic reaction.

Materials:

Per lab group:

1 small plastic bag with twist tie or zipper lock
25 g of iron powder
1 g of sodium chloride
1 tbsp. of vermiculite

Procedure:

Have students place about 25 g of iron powder in a small plastic bag. They should then add 1 g of sodium chloride, close the bag, and shake to mix the chemicals. They then add one tbsp. of vermiculite and mix again. The hand warmer is now ready to be activated.

To activate, have students add 5 mL of water to the bag, sealing it with the twist tie or zipper lock. They then squeeze and shake the bag to thoroughly mix the contents, being careful not to break the plastic. After a minute or so, a noticeable amount of heat is produced.

Background:

This reaction is basically an oxidation-reduction reaction. Iron is oxidized in an exothermic reaction.

$$4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(s) + \text{heat}$$

heat of formation (Fe_2O_3) = -196.5 kcal/mol

The oxygen is reduced, picking up the electrons lost by iron. Sodium chloride catalyzes the reaction by providing electrolytes. The mineral vermiculite helps insulate the hand warmer and contains the heat, which it distributes throughout the bag. Vermiculite can be purchased in any garden section of a store. The sodium chloride is table salt. One-hundred-mesh iron powder works very well.

If you want to prepare a bag and use it later to produce heat, squeeze out all the air after everything has been added, even the water, and tie it securely. When you want to activate the reaction, open the bag, let in some air, and retie it. When no oxygen is available, there is a reactant missing; therefore, the oxidation cannot occur. Even when you activate the hand warmer, the oxygen will be exhausted before the iron. The reaction can be regenerated by adding more oxygen.

Further Variations:

Buy a hot pack in the store and, using gloves, dissect the chemicals. Transfer the solution into a Styrofoam™ cup. Have students take the temperature of the liquid. They then add the other reactants and continue taking the temperature at one-minute intervals. Have them record the temperature increase and graph their data (time vs. temperature).

Adapted from Summerlin, L.R., Borgford, C. and Ealy, J., *Chemical Demonstrations*, Volume 2. Washington, D.C.: American Chemical Society, 1988.

Science as Inquiry

Stuck Between a Beaker and a Hard Place

What happens when reactions absorb energy?

Overview:

Demonstrate an endothermic reaction that binds together a beaker and wood block.

Materials:

Demonstration per class:

20 g of barium hydroxide crystals
one 50-mL beaker
10 g of ammonium thiocyanate (7 g of ammonium chloride or 10 g of ammonium nitrate may replace the ammonium thiocyanate)
wooden splint
wood block
sulfuric acid or sodium bisulfate (dilute solutions for disposal)

Procedure:

This is suggested as a demonstration! *Instructor should wear safety goggles and disposable gloves—barium hydroxide is toxic.*

Put approximately 20 g of barium hydroxide crystals [$Ba(OH)_2 \cdot 8H_2O$] in a 50-mL beaker. Add 10 g of ammonium thiocyanate to the beaker. Stir the two solids together with a wooden splint. Place the beaker on a wooden box with a small pool of water between the beaker and the block. As the reaction occurs it will freeze the water, binding the beaker to the wood block.

Follow proper disposal techniques as described below.

Background:

As noted above, barium hydroxide is toxic—we suggest this as a demonstration to avoid accident. Be sure to use safety precautions when performing this reaction. This is a very good endothermic demonstration because it shows that heats of reaction can occur without the presence of a solution. You may want to try varying the amounts and the size of the beaker for maximum effect. The reaction is:

$$\text{heat} + Ba(OH)_2 \cdot 8H_2O\ (s) + 2NH_4SCN\ (s) \rightarrow Ba(SCN)_2\ (s) + 2NH_3\ (g) + 10H_2O\ (l)$$

The proper disposal for your barium waste is to mix the barium waste with sulfuric acid or sodium bisulfate. This will form a precipitate. Add the sulfuric acid or sodium bisulfate until no more precipitate forms. Filter out the precipitate and dispose of it in your solid-waste basket. The liquid can go down your sink. This is a great activity for one of your best students.

Further Variations:

If you do not have a wood block, you can try to adhere your beaker to another substance.

Adapted from Summerlin, L.R. and Ealy, James L. *Chemical Demonstrations*, Volume I. Washington, D.C.: American Chemical Society, 1988.

Teacher Sheet

Science as Inquiry

Chilling Tales

How are cold packs made?

Overview:

This activity demonstrates an endothermic reaction. Students graph their data.

Materials:

Per lab group:

1 Styrofoam™ cup
15 g of ammonium nitrate
1 thermometer (Celsius)
1 100-mL graduated cylinder
1 balance (0.1 g)
1 stirring rod

Procedure:

Have students pour 100 mL of water into their Styrofoam cups and then take the temperature of the water. They should then measure 15 g of ammonium nitrate and pour the solid into the water. Have them record the temperature of the water at two-minute intervals.

When the temperature levels off students graph their data, the x-axis representing time and the y-axis representing temperature.

Background:

The reaction caused by mixing ammonium nitrate and water is endothermic. Endothermic reactions absorb energy. In this lab the energy in the water is absorbed; therefore, the temperature decreases. Theoretically, 600–900 calories are absorbed per 100 mL of water during this reaction. The Styrofoam container gives better results than a glass beaker. Be sure to destroy the Styrofoam cups after you use them.

Further Variations:

Students could make a cold pack using this reaction. If they mix the contents in a plastic bag, a cold compress can be created. Additionally, you could place the ammonium nitrate in a square of plastic wrap, twist the corners several times to contain the solid, then put the contained crystals into a zippered plastic bag that contains water. Students could then squeeze the closed bag until the crystals explode, initiating the reaction.

You may want to bring in a cold pack so that students can observe the relationship to the commercial world.

Adapted from Summerlin, L.R. and Ealy, James L. *Chemical Demonstrations*, Volume I. Washington, D.C.: American Chemical Society, 1988.

Science as Inquiry

Endothermic or Exothermic?

Item

When ammonium chloride mixes with water, it forms a solution that feels cool. The reaction is:

A. endothermic
B. exothermic
C. both
D. neither

Justification:

Give one reason to explain why you chose your answer. Is more or less energy required to break the bonds?

Answer:

This reaction is endothermic. Heat is a reactant and is required in order for the reaction to occur. We can determine that heat is absorbed because the temperature of the water decreases (the reaction takes energy from the water in the form of heat). Heat must be absorbed to provide the energy necessary to break the chemical bonds. The water continues to cool, indicating that more energy is needed to break the chemical bonds as compared to the energy being created when elements bond together to form the new compounds.

Science as Inquiry

Exothermic Indicators

Item

Which of the following does not indicate an exothermic reaction?

A. Light is given off during the reaction.
B. Matter around the reaction gets warmer.
C. The products of the reaction are cooler than the starting materials.
D. The reaction causes an explosion.

Justification

Explain your answer.

Answer

The answer is C. If the products are cooler than the starting material, that means that heat is absorbed to provide the energy that enables the reaction to occur. A, B, and D emit energy, which indicates that the reaction has a net gain of energy (energy was a product of the reaction). See Assessment 1 for further explanation relating to chemical bonds.

Science as Inquiry

Combustion

Item
Combustion or burning:

A. is always an exothermic reaction
B. is always an endothermic reaction
C. may be exothermic or endothermic
D. stores energy in the molecules of the substances reacting

Justification
The burning of wood represents combustion. During this process, what three things are given off? Which of the three things given off during the process is related to exothermic reactions?

Answer:
The answer is A. Combustion is an exothermic reaction because it produces heat. The three products of combustion are water, carbon dioxide, and heat. The heat that is produced during combustion is what indicates that the reaction is exothermic.

Science in Personal and
Social Perspectives

Digestion

Item

An animal's digestive track is like a furnace. When we eat, it is like putting wood inside this digestion-furnace. The process of breaking down our food produces the same products as combustion.

1. What do we call the process of breaking down food in the presence of oxygen?
2. What are three products of this reaction?
3. Explain how our body releases each of these products.
4. Is the process of breaking down food in the presence of oxygen an exothermic or endothermic process? Explain your answer.

Answer:

1. respiration
2. water, carbon dioxide, and energy
3. Our body releases the water by sweating or perspiring. The carbon dioxide is released when we breath out. The energy is used for various metabolic functions.
4. Respiration is an exothermic process because it produces energy.

Science as Inquiry

Endothermic Reactions

Item

Which of the following reactions is endothermic?

A. Liquid water is frozen.
B. Burning gasoline gives off heat.
C. A plant absorbs energy from sunlight.
D. A cup of coffee cools off.

Justification:

Give another example of an endothermic process.

Answer:

The answer is C. The absorption of energy from sunlight by a plant is the primary step in photosynthesis. Some other endothermic processes may include absorption of sunlight by black paper or newspaper, etc., melting ice, and global warming.

Science and Technology

Burning of Fossil Fuels

Item

Which of the following is not normally a product of the burning of fossil fuels?

A. heat
B. water vapor
C. visible light
D. oxygen gas

Justification:

Explain how a car is powered by fossil fuels. Be certain to use the term exothermic in your explanation.

Answer:

The answer is D. Oxygen is a reactant in the process of combustion or the burning of fossil fuels. A car is powered by fossil fuels because when they burn they produce energy—the process is exothermic. This energy is what powers the car.

Science as Inquiry

Temperature Change

Item:
Ammonium sulfate when mixed with water shows a rapid decrease in temperature. Which statement best describes the reason for this temperature change?

A. Energy is released during a chemical reaction.
B. Water acts as a cooling agent on the ammonium sulfate.
C. Energy is absorbed during a chemical reaction.
D. Water evaporates, thereby cooling the substance.

Justification:
How might a pharmaceutical company find this information useful?

Answer:
The answer is C. The decrease in temperature should indicate that the reaction is endothermic; therefore, energy is being absorbed during the chemical reaction. The reaction obtains its energy by absorbing the heat (energy) in the water, which cools the temperature of the water.

Science in Personal
and Social Perspectives

Cleaning Products

Item:
Many chemical reactions occur in the course of everyday life. For the following reaction, tell whether it is exothermic or endothermic and identify it as synthesis or double replacement (displacement): mixing chlorine bleach and some other household cleaning products, causing an explosion and poisonous fumes.

Answer:
The reaction is exothermic because explosions produce heat. Exothermic reactions give off heat; therefore, the reaction is exothermic. This is a double displacement reaction because two or more substances combine to produce two or more different substances. It is evident that new substances are formed because heat is given off as well as gases.

Science as Inquiry

Endothermic or Exothermic?

Item

Given a thermometer, a source of water, a beaker, paper towels, and a few salts (KBr and $CaCl_2$ are relatively safe and give good results), write an experiment to determine whether dissolving of each of the salts is an exothermic or an endothermic reaction.

Answer:

Answers may vary.

Science as Inquiry

Endothermic or Exothermic?

Item

Identify each of the following reactions as endothermic or exothermic:

A. ***Dissolving potassium bromide in water.***

Using a balance, measure 10.0 g KBr. Using a graduated cylinder, measure 50.0 mL water and pour it into a 100-mL beaker. Using a thermometer, measure and record the temperature of the water. Add the KBr to the water and stir with a stirring rod. After one minute, measure and record the temperature of the solution. Compare the temperatures before and after the addition of the KBr, and determine whether the reaction is endothermic or exothermic.

water temperature ___________ºC

solution temperature ___________ºC

endothermic or exothermic _________

B. ***Dissolving calcium chloride in water.***

Repeat the procedure from part "A" using calcium chloride, $CaCl_2$.

water temperature ___________ºC

solution temperature ___________ºC

endothermic or exothermic _________

C. ***Neutralization of hydrochloric acid and sodium hydroxide.***

With a graduated cylinder measure 50.0 mL of 0.01 M NaOH and pour it into a labeled 250.0 mL beaker. Measure 50.0 mL 0.01 M HCl and pour it into a labeled 100.0 mL beaker. Measure and record the temperature of each solution. Pour the HCl into the NaOH, stir the mixture with a stirring rod, and measure and record the temperature of the mixture. Compare the temperatures before and after mixing, and determine whether the reaction is endothermic or exothermic.

NaOH temperature ___________ºC

HCl temperature ___________ºC

mixture temperature ___________ºC

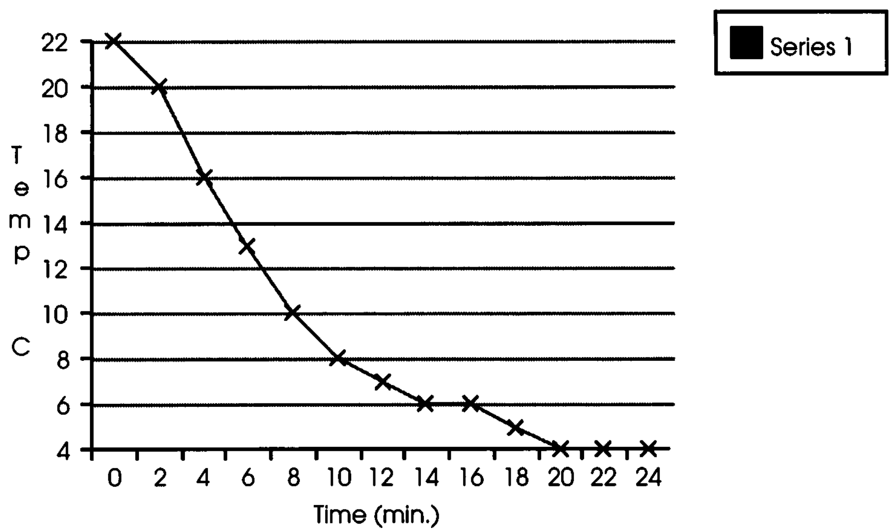
endothermic or exothermic _________

Science as Inquiry

Temperature Change

Item

A chemical reaction was performed in a Styrofoam™ cup. The students recorded the temperature inside the cup every two minutes. They then made a graph of their results. Answer the following questions based on the graph:



1. As the reaction occurred, what happened to the temperature inside the cup?

2. Is the reaction exothermic or endothermic? Explain your answer.

3. If you did not have a thermometer how could you tell if the reaction was endothermic or endothermic?

4. During which two-minute interval was there the greatest change in temperature?

   A. 2 to 4 minutes
   B. 6 to 8 minutes
   C. 10 to 12 minutes
   D. 20 to 22 minutes

5. Explain why you think the greatest change in temperature occurred during that time.