Exothermic, Endothermic, & Chemical Change
A Lab Investigation

Summary

In this investigation, students classify chemical reactions as exothermic or endothermic. Next, students explore the relationship between an observed change in temperature and the classification of a change as chemical or physical.

Objective

Students will explore energy changes during chemical reactions, heat of reaction (ΔH), and the connection between energy changes and chemical changes.

Safety

- Be sure you and the students wear properly fitting goggles.
- Acetic acid (vinegar) vapors can be irritating. Work in a well-ventilated area. In the event of eye contact, flush with water. The concentration of acetic acid in this experiment does not present any significant hazards.
- Calcium chloride can be an irritant to body tissues. In the event of contact, wash affected areas with water. Dispose of calcium chloride solutions according to local regulations.

Materials for Each Group

- Vinegar
- Baking soda
- Calcium chloride
- Water
- Thermometer
- 4 small clear plastic cups
- 1 cup measuring cup
- Measuring spoons (1 tablespoon, ½ teaspoon)

Time Required

One class period, approximately 45–50 minutes.

Lab Tips

After students explore one example of an endothermic change and one example of an exothermic change, they are then asked to explore the connection between energy changes and chemical reactions. To do this, students may need some guidance to arrive at the idea that temperature changes may also accompany dissolving.

Students will have an easier time devising a fair test if they are well versed in the definitions of physical changes and chemical changes. Students should propose an experiment to you before they test their hypothesis. To observe a temperature change during a physical change, students should devise a procedure such as:

Add 10 mL of water to a small plastic cup and place a thermometer in the water. Record the initial temperature (T_i).

Add ½ teaspoon of calcium chloride to the water and swirl the cup. After it has stopped changing, record the final temperature (T_f).

Pre-Lab Discussion

This investigation introduces the concepts of enthalpy (heat) of ΔH in the context of exothermic and endothermic reactions. To give students a deeper grounding in the basics and reinforce basic concepts covered previously, you may wish to review the mechanics of chemical changes, how to write balanced chemical equations, and the law of conservation of energy.

Incorporating into the Curriculum

This investigation could be incorporated into a unit on chemical changes or thermochemistry.

TEACHER'S KEY

Analyzing Evidence

Please note that initial and final temperature readings may vary slightly from student to student. The baking soda and vinegar reaction should produce a termpature decrease of approximately 7 °C. The baking soda and calcium chloride reaction should produce a temperature increase of approximately 15–20 °C.

Process	T_i	T_f	ΔT	Exothermic or endothermic?	ΔH (+/–)
Baking soda + vinegar	~22 °C	15 °C	–7 °C	Endothermic	+
Baking soda solution + calcium chloride	~22 °C	42 °C	+20 °C	Exothermic	–

1. Based on your observations of the baking soda and vinegar reaction, is the reaction exothermic or endothermic? Apply your knowledge of energy changes in chemical reactions to complete the table above.

   Endothermic, see table above.

2. Based on your observations of the baking soda solution and calcium chloride reaction, is this chemical reaction exothermic or endothermic? Apply your knowledge of energy changes in chemical reactions to complete the table above.

   Exothermic, see table above.

Interpreting Evidence

1. In the chemical reaction between baking soda and vinegar, what did you observe other than a temperature change? What might this tell you about one of the products of this chemical change?

   The reaction mixture bubbled, so one of the products must have been a gas. By considering the reactants, students may be able to infer that carbon dioxide was produced.

2. In the chemical reaction between baking soda solution and calcium chloride, what did you observe other than a temperature change? What might this tell you about one of the products of this chemical change?

   The reaction mixture bubbled, so one of the products must have been a gas. By considering the reactants, students may be able to infer that carbon dioxide was produced.

3. Write the chemical equation for:
   - the chemical reaction between baking soda and vinegar

     $C_2H_4O_2 + NaHCO_3 \longrightarrow CO_2 + H_2O + NaC_2H_3O_2$

   - the chemical reaction between baking soda and calcium chloride

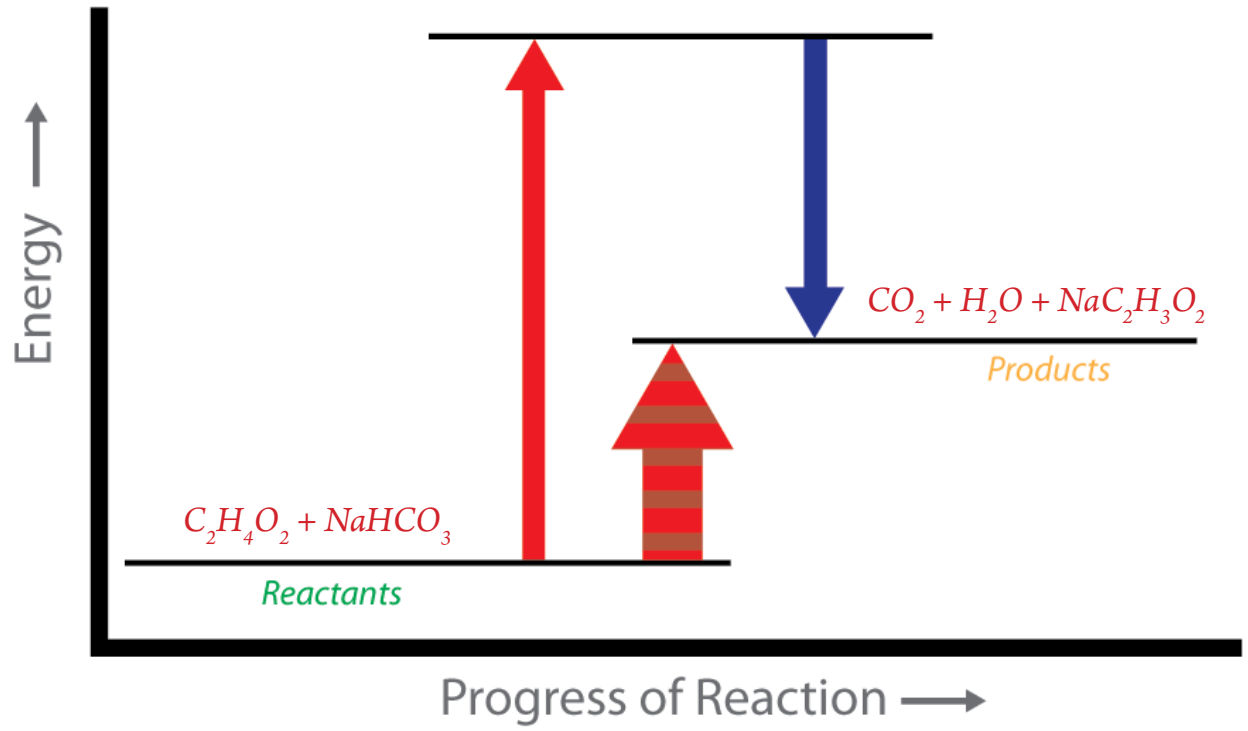
     $2NaHCO_3 + CaCl_2 \longrightarrow 2NaCl + CaCO_3 + H_2O + CO_2$

4. Using the language of breaking and making bonds, explain the net energy change for the chemical reaction between baking soda and calcium chloride.

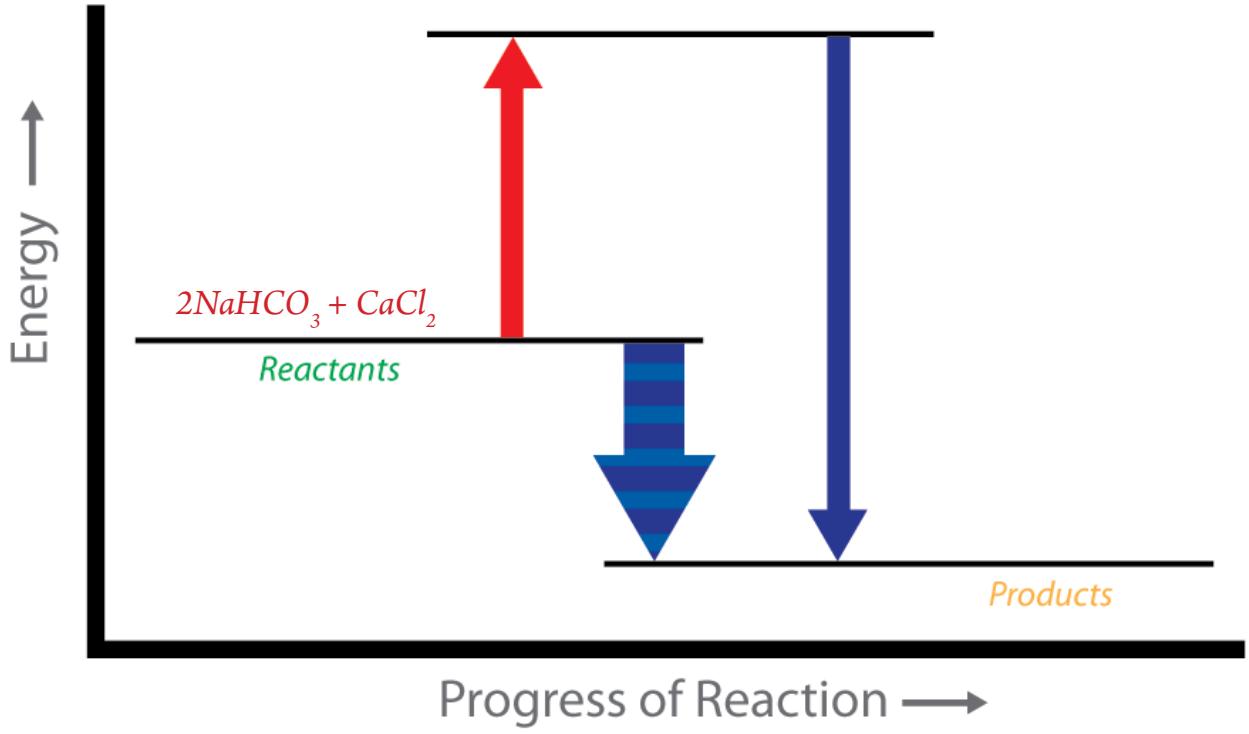
   In the chemical reaction between baking soda and calcium chloride, more energy is released when the products ($2NaCl + CaCO_3 + H_2O + CO_2$) are formed than energy was used to break bonds in the reactants ($2NaHCO_3 + CaCl_2$). There is therefore a net release of energy to the surroundings and the reaction is exothermic.

5. Draw energy profiles for both chemical reactions. Are they the same or different?

Baking soda + vinegar
Endothermic
$\Delta H > 0$



Baking soda + calcium chloride
Exothermic
ΔH<0



6. What is the sign of the enthalpy of reaction (ΔH) for an exothermic reaction? Why?

   The enthalpy (heat) for an exothermic reaction must be negative because more energy is released when the products are formed than is used when the reactants are broken up.

REFLECTING ON THE INVESTIGATION

Students should propose an experiment to you before they test their hypothesis. To observe a temperature change during a physical change, students should devise a procedure such as:

1. Based on your investigation so far, do you think that energy changes only accompany chemical reactions? Using only the materials from the first two reactions, design an experiment that would test this idea. Propose a procedure and have it approved by your teacher before you continue experimenting.

   Students should suggest a procedure like the following:

   Exothermic

   - Add 10 mL of water to a small plastic cup and place a thermometer in the water. Record the initial temperature (T_i).
   - Add ½ teaspoon of calcium chloride to the water and swirl the cup. After it has stopped changing, record the final temperature (T_f).

   Endothermic

   - Add 10 mL of water to a small plastic cup and place a thermometer in the water. Record the initial temperature (T_i).
   - Add ½ teaspoon of sodium bicarbonate to the water and swirl the cup. After it has stopped changing, record the final temperature (T_f).

2. Based on the experiment you conducted in the question above, do you think dissolving is a chemical change? Explain your reasoning.

   Student answers will vary. Some students may argue that nothing chemically distinct is made, so dissolving is a physical change. Other students may see the disruption of intermolecular forces as "bond breaking" (and solvating ions as "bond making") and therefore regard dissolving as a chemical change.

3. Using the language of breaking and making bonds, how can you describe the temperature change you observed when you dissolved calcium chloride in water?

   More energy was released when the calcium and chloride ions were combined with water than was required to break them apart.

4. How might you use exothermic or endothermic processes to solve a real-world problem? Are there any instances when it would be useful to quickly make something hot or cold? Explain how it is useful to know which processes absorb or release energy.

   Exothermic reactions could be harnessed to power machines or heat homes, while endothermic reactions could be used for treating injuries or cooling. By classifying reactions as exothermic or endothermic, we understand which reactions are best suited to meet specific challenges.

