

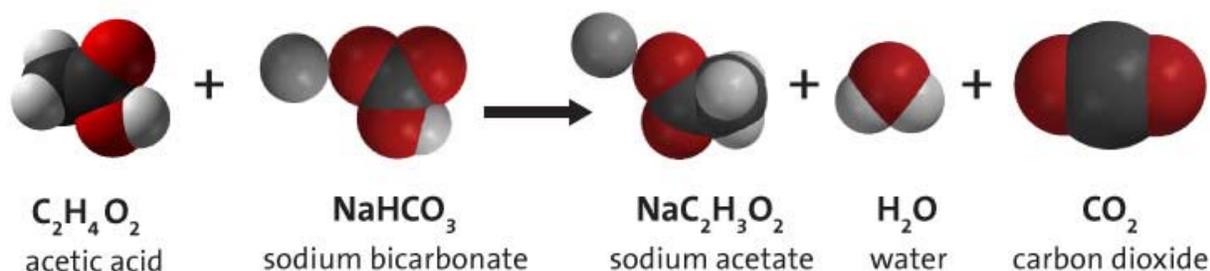
## PREPARING TO INVESTIGATE

### *Energy Changes in Chemical Reactions*

In this activity, you will explore the energy changes that accompany chemical reactions. To understand the energy implications of chemical reactions, it's important to keep in mind two key ideas:

1. It takes energy to break bonds.
2. Energy is released when bonds are formed.

To understand this, consider the chemical reaction between vinegar (also known as acetic acid to chemists) and baking soda (known as sodium bicarbonate). Before the atoms of acetic acid and sodium bicarbonate can be rearranged to form the products, the bonds between the atoms in those molecules must be broken, and because the atoms are attracted to one another, it takes energy to pull them apart.



Then, when the products are formed (sodium acetate, water, and carbon dioxide) energy is released because atoms that have an attraction for one another are brought back together. Not every bond between atoms in the reactants is necessarily broken during a chemical reaction, but some bonds are.

By comparing the energy used when bonds in the reactants are broken with the energy released when bonds in the products are formed, you can determine whether a chemical reaction releases energy or absorbs energy overall.

Chemical reactions that release energy are called exothermic. In exothermic reactions, more energy is released when the bonds are formed in the products than is used to break the bonds in the reactants. Chemical reactions that absorb (or use) energy are called endothermic. In endothermic reactions, more energy is absorbed when the bonds in the reactants are broken than is released when new bonds are formed in the products. If a chemical reaction absorbs as much energy as it releases, it is called isothermic—there is no net energy change.

But because we can't observe bonds breaking or being formed, how can we distinguish between exothermic and endothermic chemical reactions?

## Identifying Exothermic & Endothermic Reactions

There are two methods for distinguishing between exothermic and endothermic reactions.

### 1. Monitor temperature change

When energy is released in an exothermic reaction, the temperature of the reaction mixture increases. When energy is absorbed in an endothermic reaction, the temperature decreases. You can monitor changes in temperature by placing a thermometer in the reaction mixture.

### 2. Calculate the enthalpy of reaction ( $\Delta H$ )

To classify the net energy output or input of chemical reactions, you can calculate something called the enthalpy change ( $\Delta H$ ) or heat of reaction, which compares the energy of the reactants with the energy of the products.

Enthalpy is a measure of internal energy. So, when you calculate the difference between the enthalpy of the products and the enthalpy of the reactants, you find the enthalpy change ( $\Delta H$ ), which can be represented mathematically as:

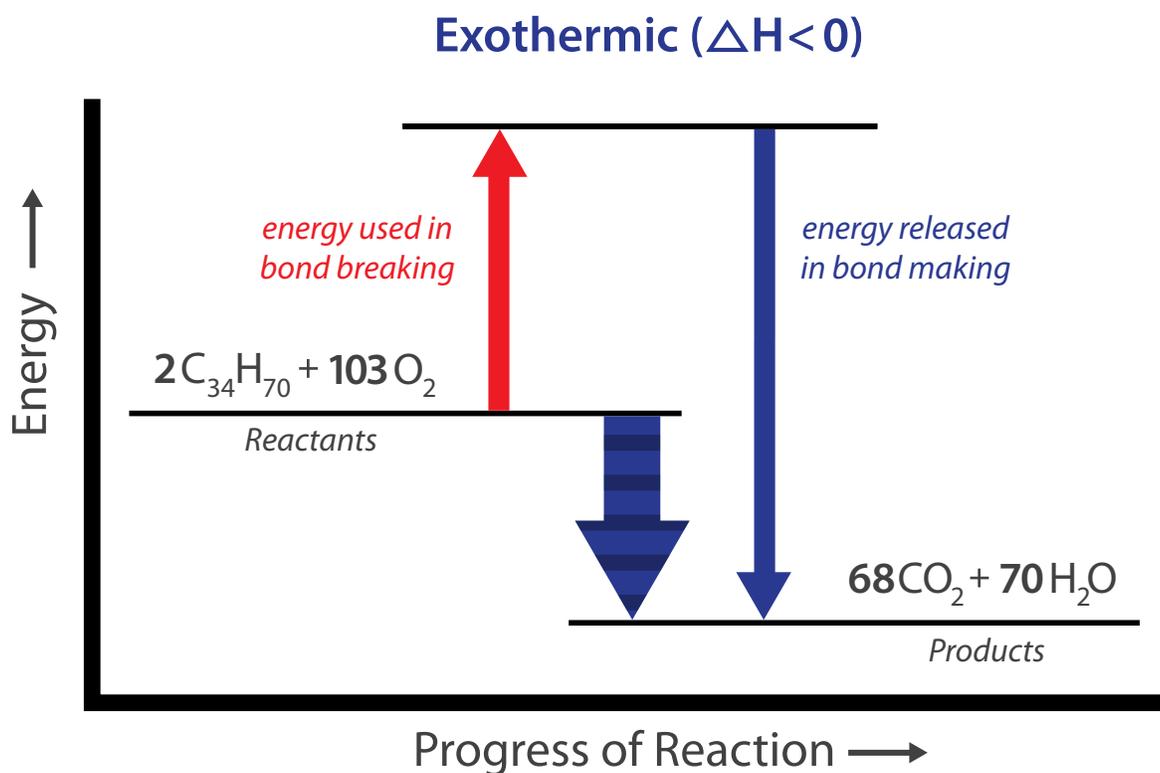
$$\Delta H = \text{energy used in reactant bond breaking} + \text{energy released in product bond making}$$

Wait, how can you find a difference by adding? The enthalpy values are added in the equation above because, by definition, energy used in reactant bond breaking is always positive (+) and energy released in product bond making is always negative (-).

If  $\Delta H$  is negative (-) then the chemical reaction is exothermic, because more energy is released when the products are formed than energy is used to break up the reactants. If  $\Delta H$  is positive (+) then the chemical reaction is endothermic, because less energy is released when the products are formed than the energy is used to break up the reactants.

You can also use energy level diagrams to visualize the energy change during a chemical reaction as a result of the energies used and released according to the above equation for  $\Delta H$ . To understand these diagrams, compare the energy level of the reactants on the left-hand side with that of the products on the right-hand side.

The graph below charts the energy change when a candle burns. The wax ( $C_{34}H_{70}$ ) combusts in the presence of oxygen ( $O_2$ ) to yield carbon dioxide ( $CO_2$ ) and water ( $H_2O$ ). Because more energy is released when the products are formed than is used to break up the reactants, this reaction is exothermic, and  $\Delta H$  for the reaction is negative.



In this investigation, you will observe whether energy is absorbed or released in two different chemical reactions and categorize them as exothermic and endothermic. You will also explore the relationship between energy changes and chemical reactions.

## GATHERING EVIDENCE

### *Baking Soda and Vinegar*

1. Pour about 10 mL of vinegar into a small plastic cup. Then, place a thermometer into the vinegar. Record the initial temperature ( $T_i$ ) in the table below.
2. While the thermometer is in the cup, add about  $\frac{1}{2}$  teaspoon of baking soda to the cup.
3. Watch the thermometer for any change in temperature. After it has stopped changing, record the final temperature ( $T_f$ ) and any other observations you made in the table below.



### *Baking Soda and Calcium Chloride*

1. Make a baking soda solution by dissolving about 2 tablespoons of baking soda in 1 cup of water. Stir until no more baking soda will dissolve.
2. Place about 10 mL of baking soda solution in a small plastic cup. Then, place a thermometer into the baking soda solution. Record the initial temperature ( $T_i$ ) in the table below.
3. While the thermometer is in the cup, add  $\frac{1}{2}$  teaspoon of calcium chloride to the cup.
4. Watch the thermometer for any change in temperature. After it has stopped changing, record the final temperature ( $T_f$ ) and any other observations you made in the table below.

Process	$T_i$	$T_f$	$\Delta T$	Exothermic or endothermic?	Other observations?	$\Delta H$ (+/-)
Baking soda + vinegar						
Baking soda solution + calcium chloride						

## ANALYZING EVIDENCE

1. Calculate the temperature change for both chemical reactions. To do this, subtract the initial temperature ( $T_i$ ) from the final temperature ( $T_f$ ), and record the difference in the column labeled  $\Delta T$ . You may see this calculation expressed elsewhere as  $\Delta T = T_f - T_i$ .
2. 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.
3. 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.

## 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?
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?
3. Use your answers from questions 1 and 2 to help you write the chemical equation for:
  - the chemical reaction between baking soda and vinegar
  - the chemical reaction between baking soda and calcium chloride
4. Using the language of breaking and making bonds, explain the net energy change for the chemical reaction between baking soda and calcium chloride.
5. Draw energy profiles for both chemical reactions. Refer to the exothermic energy profile shown previously as an example. Are they the same or different?
6. What is the sign of the heat of reaction ( $\Delta H$ ) for an exothermic reaction? Why?

## REFLECTING ON THE INVESTIGATION

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.
2. Is dissolving calcium chloride in water a chemical change? Explain your reasoning.
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?
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.