Controlling Chemical Reactions

Reading Preview

Key Concepts

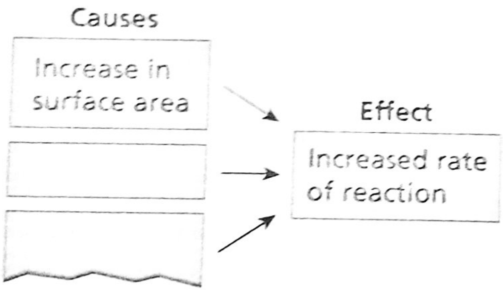
- How is activation energy related to chemical reactions?
- What factors affect the rate of a chemical reaction?

Key Terms

- activation energy
- concentration
- catalyst
- enzyme
- inhibitor

Target Reading Skill

Relating Cause and Effect As you read, identify the factors that can cause the rate of a chemical reaction to increase. Write the information in a graphic organizer like the one below.



Lab zone

Can You Speed Up or Slow Down a Reaction

1. Put on your safety goggles and lab apron.
2. Obtain three 125-mL solutions of vitamin C and wat one at room temperature, one at about 75°C, and o chilled to between 5°C and 10°C.
3. Add 3 drops of iodine solution to each container an each with a clean spoon. Compare changes you obs in the solutions.
4. Clean up your work area and wash your hands.

Think It Over

Inferring What conclusion can you make about the effect temperature on the reaction of iodine and vitamin C?

With a splintering crash, a bolt of lightning strikes a tre forest. The lightning splits the tree and sets fire to the le the ground below it. The leaves are dry and crisp drought. The crackling fire burns a black patch in the The flames leap to nearby dry twigs and branches ground. Soon, the forest underbrush is blazing, and th of trees start burning. Miles away in an observation t ranger spots the fire and calls in the alarm—"Forest fire

Forest fires don't just happen. Many factors contri them—lightning and drought to name just two. But, eral, wood does not always burn easily. Yet, once woo begin to burn, it gives off a supply of heat and light. W so hard to start and m some chemical reactions?

◀ **Lightning can supply enoug energy to ignite a forest fire**

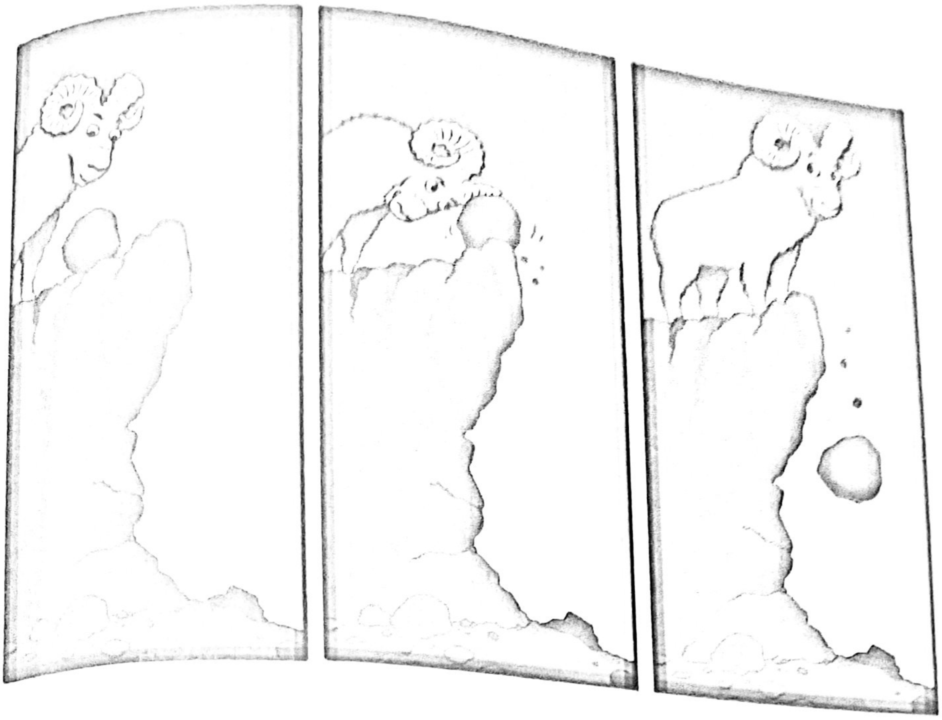


FIGURE 12
Modeling Activation Energy
The rock at the top of this hill cannot roll down the hill until a small push gets it going.
Making Models How is this cartoon a kind of model for the role of activation energy in a chemical reaction?

Energy and Reactions

To understand why it can be hard to start some chemical reactions, look at Figure 12. The rock at the top of the hill can fall over the cliff, releasing energy when it crashes into the rocks at the bottom. Yet it remains motionless until it's pushed over the small hump.

Activation Energy Every chemical reaction is like that rock. A reaction won't begin until the reactants have enough energy to push them "over the hump." The energy is used to break the chemical bonds of the reactants. Then, the atoms begin to form the new chemical bonds of the products. The **activation energy** is the minimum amount of energy needed to start a chemical reaction. **All chemical reactions need a certain amount of activation energy to get started.**

Consider the reaction in which hydrogen and oxygen form water. This reaction gives off a large amount of energy. But if you just mix the two gases together, they can remain unchanged for years. For the reaction to start, a tiny amount of activation energy is needed—even just an electric spark. Once a few molecules of hydrogen and oxygen react, the rest will quickly follow because the first few reactions provide activation energy for more molecules to react. Overall, the reaction releases more energy than it uses. Recall from Section 1 that this type of reaction is described as exothermic.

Reading Checkpoint **What is the function of a spark in a reaction between hydrogen gas and oxygen gas?**

Exothermic and Endothermic Reactions Every chemical reaction needs activation energy to get started. Whether or not a reaction needs still more energy from the environment to keep going depends on if it is exothermic or endothermic.

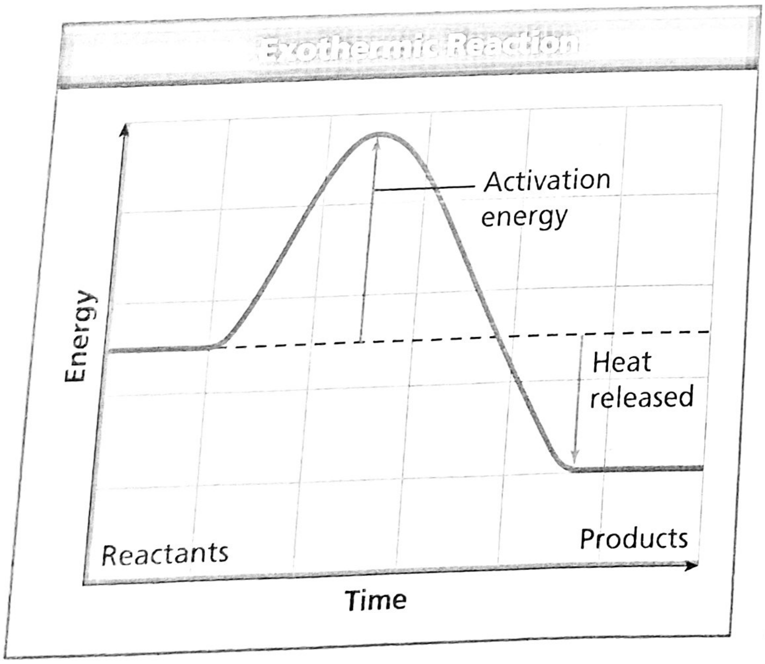
Exothermic reactions follow the pattern you can see in the first diagram in Figure 13. The dotted line marks the energy of the reactants before the reaction begins. The peak in the graph shows the activation energy. Notice that at the end of the reaction, the products have less energy than the reactants. This difference results in a release of heat. The burning of fuel, such as wood, natural gas, or oil, is an example of an exothermic reaction. People can make use of the heat that is released to warm their homes and cook food.

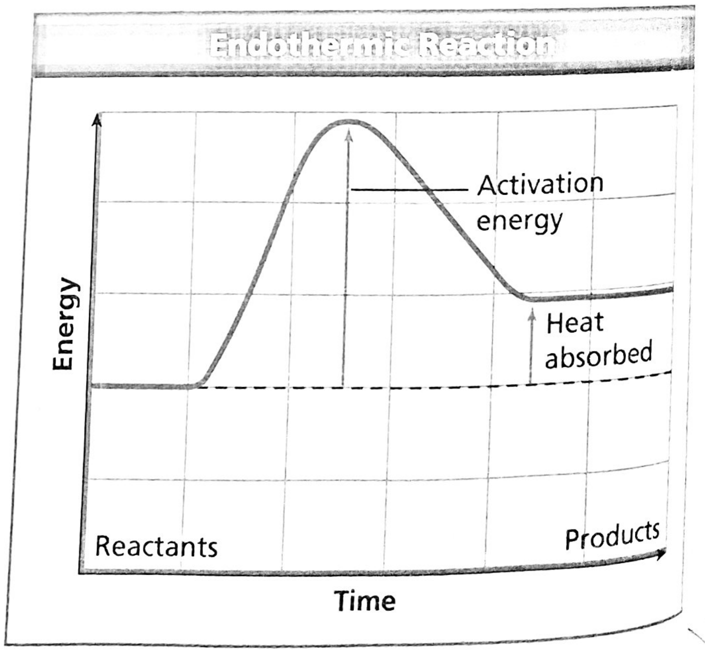
Now look at the graph of an endothermic reaction on the right of Figure 13. Endothermic reactions also need activation energy to get started. But, in addition, they need energy to keep going. Notice that the energy of the products is higher than that of the reactants. This difference tells you that the reaction must absorb energy to continue.

When you placed baking soda in vinegar in the Discover activity in Section 1, the thermal energy already present in the solution was enough to start the reaction. The reaction continued by drawing energy from the solution, making the solution feel colder. But most endothermic reactions require a continuous source of heat to occur. For example, baking bread requires added heat until the baking process is completed.

Reading Checkpoint **In what type of reaction do the reactants have less energy than the products?**

FIGURE 13
Energy Changes in Chemical Reactions
Both exothermic and endothermic reactions need energy to get started. Reading Graphs *What does the peak in the curve in each graph represent?*





Rates of Chemical Reactions

Chemical reactions don't all occur at the same rate. Some, like explosions, are very fast. Others, like the rusting of metal, are much slower. Also, a particular reaction can occur at different rates depending on the conditions.

If you want to make a chemical reaction happen faster, you need to get more reactant particles together more often and with more energy. To slow down a reaction, you need to do the opposite. **Chemists can control rates of reactions by changing factors such as surface area, temperature, and concentration, and by using substances called catalysts and inhibitors.**

Surface Area Look at Figure 14. The wreckage used to be a grain elevator. It exploded when grain dust ignited in the air above the stored grain. Although the grain itself doesn't react violently in air, the grain dust can. This difference is related to surface area. When a chunk of solid substance reacts with a liquid or gas, only the particles on the surface of the solid come into contact with the other reactant. But if you break the solid into smaller pieces, more particles are exposed and the reaction happens faster. Sometimes, speeding up a reaction this way is dangerous. Other times, increasing surface area can be useful. For example, chewing your food breaks it into smaller pieces that your body can digest more easily and quickly.

Lab zone Skills Activity

Interpreting Data

1. Measure the length and width of a face of a gelatin cube.
2. Calculate the area of that face of the cube.

   Area = length × width
3. Repeat for each of the other five faces. Then add the six values to get the total surface area.
4. Using a plastic knife, cut the cube in half. Add the surface areas of the two pieces to get a new total.

5. How did the original total surface area compare with the total area after the cube was cut?
6. Predict the total surface area if you cut each cube in two again. If you have time, test your prediction.

FIGURE 14
Surface Area and Reaction Rate
Grain dust reacts explosively with oxygen. Minimizing grain dust in a grain elevator can help prevent an accident like the one shown here.

Temperature Another way to increase the rate of a reaction is to increase its temperature. When you heat a substance, its particles move faster. Faster-moving particles increase the reaction rate in two ways. First, the particles come in contact more often, which means there are more chances for a reaction to happen. Second, faster-moving particles have more energy. This increased energy causes more particles of the reactants to get over the activation energy "hump."

In contrast, reducing temperature slows down reaction rates. For example, milk contains bacteria, which carry out thousands of chemical reactions as they live and reproduce. At room temperature, those reactions happen faster and milk spoils more quickly. You store milk and other foods in the refrigerator because keeping foods cold slows down those reactions, so your foods stay fresh longer.

Concentration A third way to increase the rate of a chemical reaction is to increase the concentration of the reactants. **Concentration** is the amount of a substance in a given volume. For example, adding a small spoonful of sugar to a glass of lemonade will make it sweet. But adding a large spoonful of sugar makes the lemonade sweeter. The glass with more sugar has a greater concentration of sugar molecules.

Increasing the concentration of reactants supplies more particles to react. Compare the two reactions of acid and magnesium metal in Figure 15. The test tube on the left has a lower concentration of acid. This reaction is slower than the one on the right, where the acid concentration is higher. You see evidence for the increased rate of reaction in the greater amount of gas bubbles produced.

Reading Checkpoint **Why may an increase in temperature affect the rate of a chemical reaction?**

FIGURE 15
Concentration and Reaction Rate
Bubbles of hydrogren gas form when magnesium reacts with acid.
Relating Cause and Effect *What makes the reaction faster in the test tube on the right?*

Catalysts Another way to control the rate of a reaction is to change the activation energy needed. A **catalyst** (KAT uh list) is a material that increases the rate of a reaction by lowering the activation energy. Although catalysts affect a reaction's rate, they are not permanently changed by a reaction. For this reason catalysts are not considered reactants.

Many chemical reactions happen at temperatures that would kill living things. Yet, some of these reactions are necessary for life. The cells in your body (as in all living things) contain biological catalysts called **enzymes** (EN zymz). Your body has thousands of different enzymes. Each one is specific—it affects only one chemical reaction.

As shown in Figure 16, enzymes provide a surface on which reactions can take place. By bringing reactant molecules close together, the enzyme lowers the activation energy needed. In this way, enzymes make chemical reactions that are necessary for life happen at a low temperature.

Inhibitors Sometimes a reaction is more useful when it can be slowed down rather than speeded up. A material used to decrease the rate of a reaction is an **inhibitor.** Most inhibitors work by preventing reactants from coming together. Usually they combine with one of the reactants either permanently or temporarily. Inhibitors include preservatives added to food products to prevent them from becoming stale or spoiling.

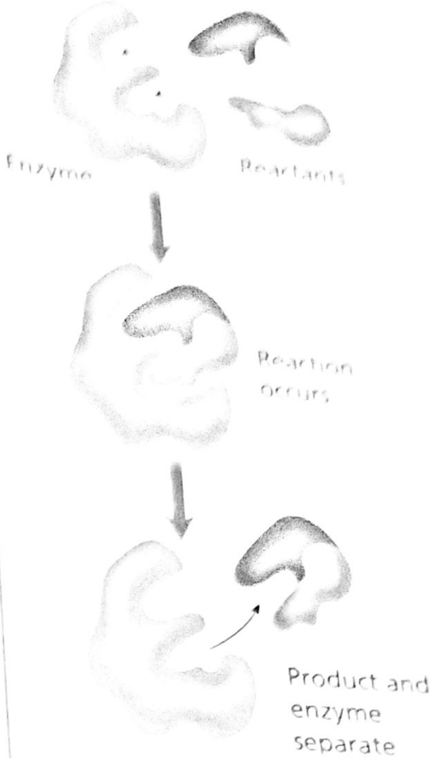


FIGURE 16
Enzyme Action
After a reaction, an enzyme molecule is unchanged.

Section 3 Assessment

Target Reading Skill **Relating Cause and Effect** Use the information in your graphic organizer about speeding up chemical reactions to help you answer Question 2 below.

Reviewing Key Concepts

1. a. **Defining** What is activation energy?
   b. **Describing** What role does activation energy play in chemical reactions?
   c. **Making Generalizations** Look at the diagram in Figure 13, and make a generalization about activation energy in exothermic and endothermic reactions.
2. a. **Identifying** What are four ways that chemists can control the rates of chemical reactions?
   b. **Applying Concepts** Which would react more quickly in a chemical reaction: a single sugar cube or an equal mass of sugar crystals? Explain.

Lab zone At-Home Activity

Comparing Reaction Rates Place an iron nail in a plastic cup. Add enough water to almost cover the nail. Place a small piece of fine steel wool in another cup and add the same amount of water. Ask family members to predict what will happen overnight. The next day, examine the nail and steel wool. Compare the amount of rust on each. Were your family's predictions correct? Explain how surface areas affect reaction rates.