Section 3

Controlling Chemical Reactions

Objectives

After this lesson, students will be able to

L.2.3.1 Explain how activation energy is related to chemical reactions.

L.2.3.2 Identify factors that affect the rate of a chemical reaction.

Target Reading Skill

Relating Cause and Effect Explain that cause is the reason for what happens. The effect is what happens because of the cause. Relating cause and effect helps students relate the reasons for what happens to what happens as a result.

Answers

Students' graphic organizers should show that the factors that can cause an increased rate of reaction include increase in surface area, increase in temperature, increase in concentration of reactants, and use of a catalyst.

All in One Teaching Resources

- Transparency L22

Preteach

Build Background Knowledge L2

Slowing Down Reactions

Ask: **Why do we keep some foods in a refrigerator?** *(To keep them from spoiling)* As you ask how refrigeration helps prevent food from spoiling, lead students to infer that low temperatures slow down the rate of decomposition reactions that spoil food. Tell students that in this section they will learn how temperature and other factors slow down or speed up chemical reactions.

Section 3

Controlling Chemical Reactions

Reading Preview

Key Concepts

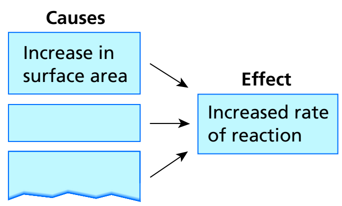
- How is activation energy related to chemical reactions?
- What factors affect the rate of a chemical reaction?

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 Discover Activity

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 water—one at room temperature, one at about 75°C, and one chilled to between 5°C and 10°C.
3. Add 3 drops of iodine solution to each container and stir each with a clean spoon. Compare changes you observe 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 of temperature on the reaction of iodine and vitamin C?

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

Forest fires don't just happen. Many factors contribute to them—lightning and drought to name just two. But, in general, wood does not always burn easily. Yet, once wood does begin to burn, it gives off a steady supply of heat and light. Why is it so hard to start and maintain some chemical reactions?

◀ Lightning can supply enough energy to ignite a forest fire.

Lab zone Discover Activity

Skills Focus Inferring L1

Materials safety goggles, lab apron, 125 mL vitamin C solution at three temperatures, iodine, 3 clear plastic cups, spoon

Time 10 minutes

Tips Prepare vitamin C solution by adding 1 crushed vitamin C tablet to every 480 mL of water. Each group will need 125 mL of solution at each temperature. Chill one third of the total solution in an ice bath and heat one third in a beaker on a hot plate to 75°C. Caution students that iodine can stain skin and clothing.

Expected Outcome Vitamin C reacts with iodine and turns it colorless.

Think It Over At higher temperatures, vitamin C and iodine react faster.

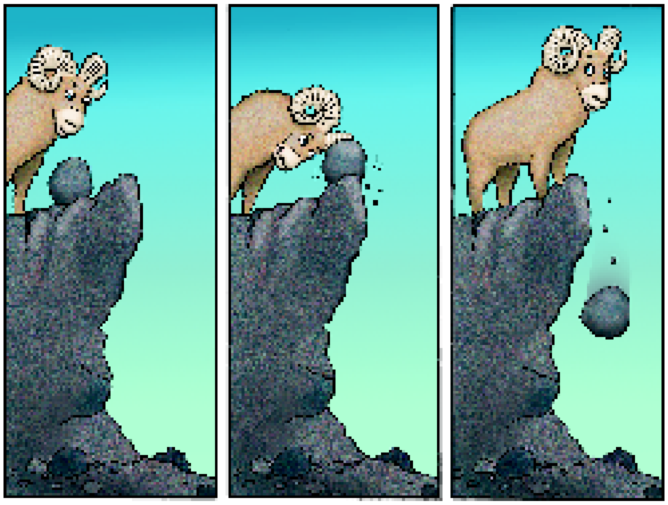


FIGURE 12
Modeling Activation Energy The rock at the top of this hill cannot roll down the hill until a small push gets it going. **Making Models** *How is this cartoon a kind of model for the role of activation energy in a chemical reaction?*

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?

Discovery Channel School

Chemical Reactions
Video Preview
▶ Video Field Trip
Video Assessment

Instruct

Energy and Reactions

Teach Key Concepts L2

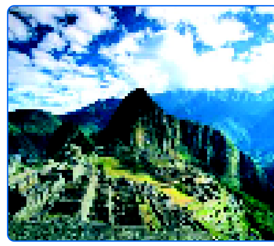
Activation Energy

Focus State that all chemical reactions need a certain amount of energy to get started.

Teach Point out that reactions that release energy, and those that require energy, need activation energy. Use the example of hydrogen and oxygen, which combine to produce water and energy. Ask: **In terms of energy, what type of reaction is this?** *(Exothermic)* Explain that the reaction will not begin without activation energy.

Apply Say that a spark can provide enough energy for a few molecules of hydrogen and oxygen to react. Ask: **What provides the energy for the other molecules to react?** *(Energy released by the reaction of the first few molecules)* **learning modality: verbal**

All in One Teaching Resources
- Transparency L23



Discovery Channel School Video Field Trip

Chemical Reactions

Show the Video Field Trip to give students a chance to see energy-producing chemical reactions. Discussion question: **What chemical reaction takes place inside fireworks?** *(Powder containing potassium nitrate burns quickly and produces gas.)*

Independent Practice L2

All in One Teaching Resources
- Guided Reading and Study Worksheet: *Controlling Chemical Reactions*

Student Edition on Audio CD

Monitor Progress L2

Answers

Figure 12 By showing that a certain amount of initial energy is needed to start the rock falling over the hill

Reading Checkpoint To start the reaction

Differentiated Instruction

Gifted and Talented L3

Modeling Activation Energy Challenge students to think of a way they could use dominoes to model the role of activation energy in a chemical reaction. Encourage them to share their ideas with the class. **learning modality: kinesthetic**

Less Proficient Readers L1

Previewing Visuals Have students look at the figures and read the captions before they read the section. This will give them an overview of what they are about to read and help them place it in context. This may improve their reading comprehension. **learning modality: visual**

Lab zone **Build Inquiry** L2

Classifying Chemical Reactions

Time 5 minutes

Focus Have students classify chemical reactions as endothermic or exothermic.

Teach Review the difference between endothermic and exothermic reactions. Then, name several chemical reactions, and have students decide whether they are endothermic or exothermic. Ask: **Is the baking of bread an endothermic or exothermic reaction?** *(Endothermic)* **The burning of wood?** *(Exothermic)* **The mixing of baking soda and vinegar?** *(Endothermic)* **The rusting of iron?** *(Exothermic)*

Apply Ask: **What endothermic and exothermic reactions have you used today?** *(For an endothermic reaction, students might say that they cooked food. For an exothermic reaction, they might say that they burned fuel while traveling to school by car or bus.)* **learning modality: verbal**

Use Visuals: Figure 13 L2

Energy Changes in Chemical Reactions

Focus Have students compare and contrast the graphs in Figure 13 for a better understanding of energy changes in exothermic and endothermic reactions.

Teach Tell students to read the caption and look at the graphs in Figure 13. Ask: **How are the two graphs the same?** *(Both graphs plot energy against time for chemical reactions. In both graphs, the reaction begins when energy rises to a peak, the activation energy, which is about the same for both reactions.)* **How are the two graphs different?** *(The graph on the left is for an exothermic reaction, and the graph on the right is for an endothermic reaction. In the exothermic reaction, heat is released, and the products have less energy than the reactants. In the endothermic reaction, heat is absorbed, and the products have more energy than the reactants.)*

Apply Ask: **If the energy level for the exothermic reaction had started out as low as the energy level for the endothermic reaction, would the activation energy also be lower? Why?** *(No, because the activation energy is the minimum amount of energy required to start the reaction)* **learning modality: visual**

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.

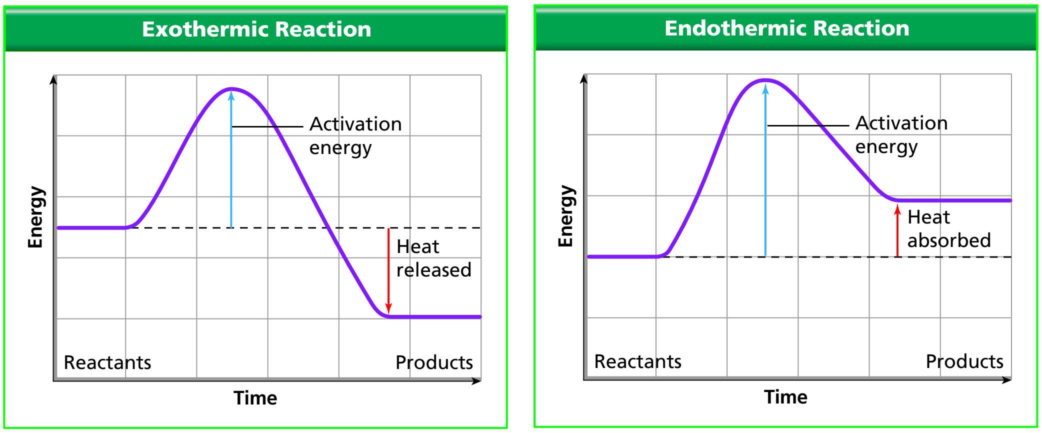
Exothermic reactions follow the pattern you can see in the first diagram in Figure 13. The dotted line marks the energy of the reactants before the reaction begins. The peak in the graph shows the activation energy. Notice that at the end of the reaction, the products have less energy than the reactants. 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?*



All in One Teaching Resources

- Transparency L24

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.

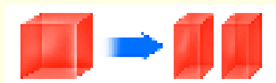
If you want to make a chemical reaction happen faster, you need to get more reactant particles together more often and with more energy. To slow down a reaction, you need to do the opposite. **Chemists can control rates of reactions by changing factors such as surface area, temperature, and concentration,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

Rates of Chemical Reactions

Teach Key Concepts L2

Factors Affecting Reaction Rates

Focus List and discuss four factors that affect rates of chemical reactions.

Teach Read the boldface sentence identifying factors that speed up or slow down chemical reactions. Write each factor on the board. Explain how breaking a solid into smaller pieces increases its surface area. Say that more surface area means there are more exposed molecules of the substance to be involved in a reaction. Ask: **How do you think temperature affects a reaction?** *(Students might say that higher temperatures provide activation energy or the energy needed for an endothermic reaction.)* **What does concentration mean?** *(Sample answer: The amount of a substance in a given volume)* Explain how increasing concentration of a substance increases the number of molecules of a substance that are available to react. Define the term *catalyst* as a material that increases the rate of a reaction by lowering the activation energy.

Apply Ask: **How do you think an inhibitor affects the rate of a chemical reaction?** *(Decreases it)* **learning modality: verbal**

Lab zone Skills Activity

Skills Focus Interpreting data L3

Materials gelatin cube, plastic knife, ruler

Time 15 minutes

Tips Make the gelatin with half the water called for. Cut the cold gelatin into 5-cm cubes with a hot knife.

Expected Outcome The original total surface area was less than the total area after the cube was cut. Students may predict that cutting the cubes again will increase the total surface area.

Extend Students can graph surface area vs. the number of times the gelatin cube is cut. Have them use their graphs to determine the surface area if the original cube were cut into 16 equal-sized pieces. **learning modality: logical/mathematical**

Monitor Progress L2

Oral Presentation Call on students to name four factors that affect the rates of chemical reactions.

Answers

Figure 13 The peak in the curve in each graph represents activation energy.

Reading Checkpoint Reactants have less energy than products in endothermic reactions.

Lab zone **Build Inquiry** L2

Affect of Temperature on Chemical Reactions

Materials two antacid tablets, two plastic cups, cold tap water, hot tap water

Time 10 minutes

Focus Give students a chance to observe how increasing temperature speeds up a reaction.

Teach Divide the class into small groups. Give each group two antacid tablets and two plastic cups. Have groups fill one cup with cold tap water and the other cup with hot tap water. Ask: **Do you think the antacid will react faster in hot water or cold water?** *(Sample answer: Hot water)* Have students drop a tablet into each cup of water and observe what happens. Ask: **How did the two reactions differ?** *(The antacid reacted faster in the cup of hot water.)*

Apply Ask: **Why did the reaction occur faster in the hot water?** *(Sample answer: The greater temperature gave the particles more energy to move rapidly and come into contact with other particles, as well as more energy to get over the activation energy "hump.")* **learning modality: visual**

Integrating Life Science L2

Remind students that a catalyst is a material that increases the rate of a reaction by lowering the activation energy. Point out that the human body has thousands of different catalysts, called enzymes, and each one affects just one kind of chemical reaction. Tell students that human body temperature is normally around 37°C. Ask: **How might our normal body temperature be related to our dependence on catalysts?** *(Our body temperature is too low for many chemical reactions to take place without the help of catalysts.)* **learning modality: verbal**

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?**

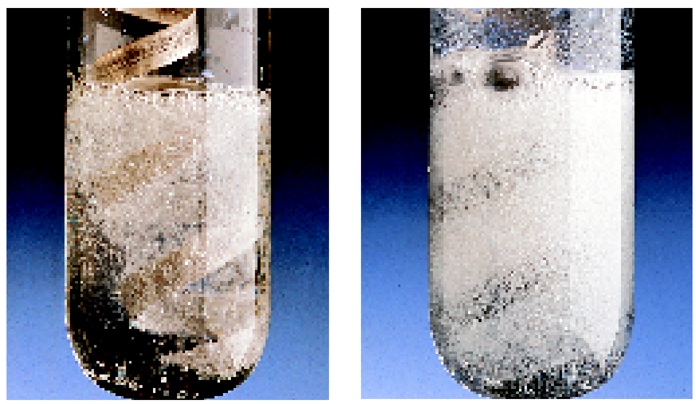


FIGURE 15
Concentration and Reaction Rate
Bubbles of hydrogren gas form when magnesium reacts with acid.
Relating Cause and Effect *What makes the reaction faster in the test tube on the right?*

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.

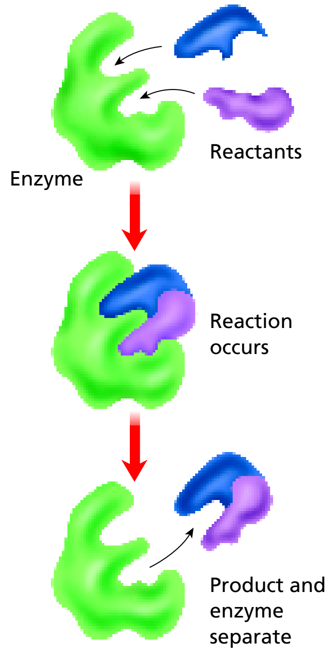


FIGURE 16
Enzyme Action
After a reaction, an enzyme molecule is unchanged.

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.

All in One Teaching Resources
- Transparency L25

Monitor Progress L2

Answers

Figure 15 A greater concentration of acid makes the reaction faster in the test tube on the right.

Reading Checkpoint An increase in temperature may allow particles to have more energy so they are more likely to come into contact with each other and to reach the activation energy level.

Assess

Reviewing Key Concepts

1. a. The minimum amount of energy needed to start a chemical reaction **b.** All chemical reactions need a certain amount of activation energy to get started. **c.** Students might say that both endothermic and exothermic reactions need a similar level of activation energy in order to begin.
2. a. Chemists can control the rates of chemical reactions by changing factors such as surface area, temperature, and concentration, and by using substances called catalysts and inhibitors. **b.** Sugar crystals, because more particles of sugar are exposed than in a sugar cube

Reteach L1

Call on students to define each of the key terms in the section.

Performance Assessment L2

Skills Check Have students draw a graph showing the general relationship between the concentration of reactants and the speed of a chemical reaction.

Students can keep their graphs in their portfolios. Portfolio

All in One Teaching Resources
- Section Summary: *Controlling Chemical Reactions*
- Review and Reinforce: *Controlling Chemical Reactions*
- Enrich: *Controlling Chemical Reactions*

Lab zone At-Home Activity

Comparing Reaction Rates L2
Students should use a non-galvanized nail. Point out that steel wool is made of iron mixed with carbon. Family members might predict correctly that the steel wool will rust more than the nail. Students are expected to explain that the steel wool has more rust because it has a greater surface area.

Lab zone Chapter Project

Keep Students on Track Remind students to interpret their results from the sugar-burning reaction to determine whether the results support the principle of conservation of mass. Tell students to start summarizing their findings and thinking of ways to present their results to the class.

Skills Lab

Temperature and Enzyme Activity

L3

Prepare for Inquiry

Key Concept

Temperature affects the rate at which chemical reactions occur. Students will determine the effect of temperature on catalyzed reactions.

Skills Objective

After this lab, students will be able to

- calculate the time it takes for a reaction to occur
- interpret data to determine how temperature affects the rate of a reaction
- draw conclusions about how the activity of a catalyst is affected by temperature

Prep Time 60 minutes
Class Time 40 minutes

Advance Planning

- Prepare the catalase solution by placing fresh liver in a blender and blending until soupy. Add twice the volume of distilled water and mix.
- Make about a dozen disks for each group by using a paper punch to make disks of filter paper. Place the disks in the liver solution and stir gently.
- Divide the disks and solution into fourths and place in beakers. Keep one beaker at room temperature. Place one beaker in an ice water (0°C) bath, one in a bath of 37°C water, and one in a boiling water (100°C) bath.
- Prepare the 0.1% hydrogen peroxide solution by adding 500 mL of distilled water to 25 mL of 3% hydrogen peroxide.

Safety

Caution students to be careful around the boiling water bath. You may want to distribute the disks from the boiling water so students do not have to handle hot equipment. Make sure students wash their hands after performing the experiment. Review the safety guidelines in Appendix A.

All in One Teaching Resources

- Lab Worksheet: *Temperature and Enzyme Activity*

Skills Lab

Temperature and Enzyme Activity

Problem

Catalase is an enzyme that speeds up the breakdown of hydrogen peroxide into water and oxygen gas. Hydrogen peroxide is a poisonous waste product of reactions in living things. How does temperature affect the action of the enzyme catalase?

Skills Focus

calculating, interpreting data, drawing conclusions

Materials

- forceps
- stopwatch
- test tube with a one-hole stopper
- 0.1% hydrogen peroxide solution
- filter paper disks soaked in liver preparation (catalase enzyme) and kept at four different temperatures (room temperature, 0–4°C, 37°C, and 100°C)
- container to hold water (beaker or bowl)

Procedure

1. Form a hypothesis that predicts how the action of the catalase enzyme will differ at the different temperatures to be tested.
2. Fill a container with water. Then fill a test tube with 0.1% hydrogen peroxide solution until the test tube is overflowing. Do this over a sink or the container of water.
3. Make a data table similar to the one shown.
4. Moisten the small end of a one-hole stopper with water.
5. Using forceps, remove a filter paper disk soaked in liver preparation (catalase enzyme) that has been kept at room temperature. Stick it to the moistened end of the one-hole stopper.
6. Your partner should be ready with the stopwatch for the next step.
7. Place the stopper firmly into the test tube, hold your thumb over the hole, and quickly invert the test tube. Start the stopwatch. Put the inverted end of the test tube into the container of water, as shown in the photograph, and remove your thumb.

Data Table

Temperature (°C)	Time (sec)	Average Time for Class (sec)

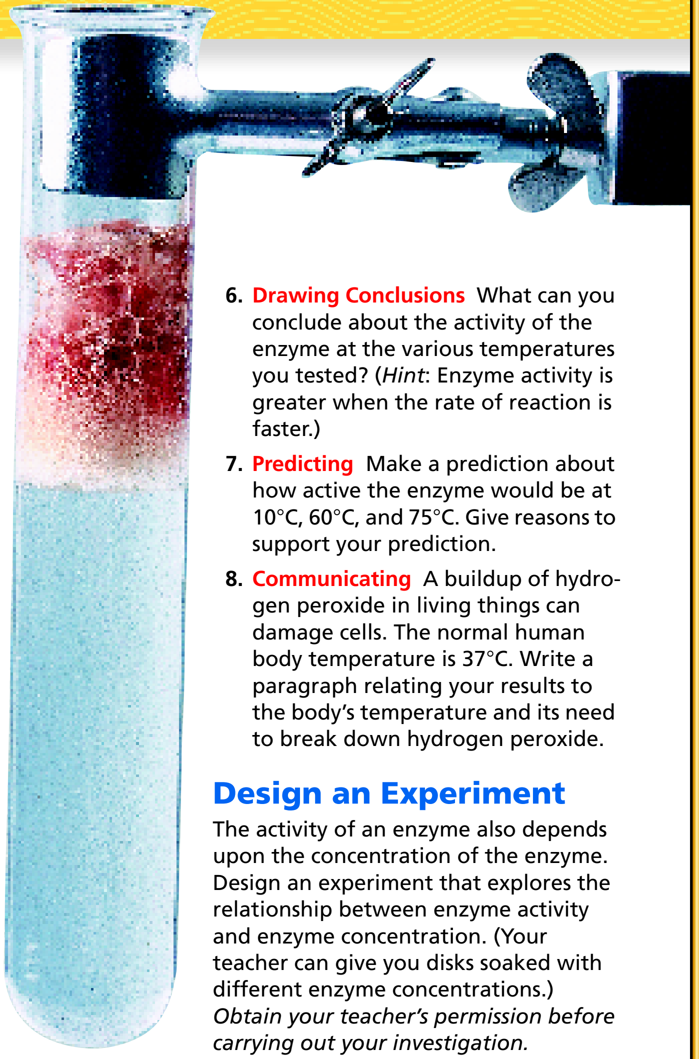
Guide Inquiry

Invitation

Ask: **What happens when you use hydrogen peroxide to clean a cut or scrape?** *(The hydrogen peroxide bubbles.)* Explain that the bubbling is caused by the release of oxygen in a reaction between hydrogen peroxide and catalase. Add that catalase is an enzyme found in many organisms. In humans, it is found in blood.

Introduce the Procedure

Tell students they will measure the rate at which small paper disks soaked with catalase collect oxygen bubbles and float to the top of an inverted test tube of hydrogen peroxide. Have students look at the picture to see how they will hold the inverted test tube.



Catalase from blood reacts with hydrogen peroxide.

8. Observe what happens to the filter paper inside the test tube. Record the time it takes for the disk to rise to the top. If the disk does not rise within 2 minutes, record "no reaction" and go on to Step 9.
9. Rinse the test tube and repeat the procedure with catalase enzyme disks kept at 0°C, 37°C, and 100°C. **CAUTION:** *When you remove the disk kept in the hot water bath, do not use your bare hands. Avoid spilling the hot water.*

Analyze and Conclude

1. **Observing** What makes the disk float to the top of the inverted test tube?
2. **Calculating** Calculate the average time for each temperature based on the results of the entire class. Enter the results in your data table.
3. **Graphing** Make a line graph of the data you collected. Label the horizontal axis (*x*-axis) "Temperature" with a scale from 0°C to 100°C. Label the vertical axis (*y*-axis) "Time" with a scale from 0 to 30 seconds. Plot the class average time for each temperature.
4. **Interpreting Data** What evidence do you have that your hypothesis from Step 1 is either supported or not supported?
5. **Interpreting Data** How is the time it takes the disk to rise to the top of the inverted tube related to the rate of the reaction?
6. **Drawing Conclusions** What can you conclude about the activity of the enzyme at the various temperatures you tested? (*Hint*: Enzyme activity is greater when the rate of reaction is faster.)
7. **Predicting** Make a prediction about how active the enzyme would be at 10°C, 60°C, and 75°C. Give reasons to support your prediction.
8. **Communicating** A buildup of hydrogen peroxide in living things can damage cells. The normal human body temperature is 37°C. Write a paragraph relating your results to the body's temperature and its need to break down hydrogen peroxide.

Design an Experiment

The activity of an enzyme also depends upon the concentration of the enzyme. Design an experiment that explores the relationship between enzyme activity and enzyme concentration. (Your teacher can give you disks soaked with different enzyme concentrations.) *Obtain your teacher's permission before carrying out your investigation.*

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Troubleshooting the Experiment

- Monitor the temperature of the baths. It is important to keep the disks in the warm water close to 37°C to duplicate normal body temperature.
- Remind students that they must invert the test tube quickly and begin timing the rise of the disk immediately after inverting the test tube.

Expected Outcome

The catalase at 37°C is the fastest, followed by room-temperature catalase, and then by catalase at 0°C. At 100°C, there is no reaction.

Analyze and Conclude

1. Oxygen bubbles cling to the disk and cause it to float.

2. Average times should decrease from 0°C through room temperature to 37°C, with no reaction at 100°C.

3. Check that students have correctly labeled both axes and used appropriate scales. Data from the third column of their data table should be plotted in the graph.

4. Answers will vary depending on students' hypotheses. The data will show that the reaction is fastest at 37°C. Students may have predicted that the reaction would occur fastest at the highest temperature, 100°C.

5. A slower reaction rate will result in a longer time for the disk to rise to the top of the inverted tube.

6. Students might conclude that the enzyme shows a little activity at 0°C, more activity at room temperature, the greatest activity at normal body temperature of 37°C, and no activity at 100°C.

7. Students are likely to predict that at 10°C, the enzyme would show more activity than at 0°C but less activity than at room temperature. They might predict that at 60°C the enzyme would show less activity than at body temperature and at 70°C it would show less activity than at 60°C.

8. Catalase is most effective at breaking down hydrogen peroxide at 37°C, which is normal body temperature. As a result, hydrogen peroxide does not build up and damage cells.

Extend Inquiry

Design an Experiment Students can design a procedure, similar to the one in this lab, to test disks treated with varying concentrations of enzyme. The expected outcome is that the activity will be greater for the higher enzyme concentration.

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Students can go online to pool and analyze their data with students nationwide.