The Floating Catalyst

An Enzyme Reaction

Introduction

Almost all chemical reactions that take place in living organisms are catalyzed by enzymes—nature's catalysts. A typical enzyme may make a chemical reaction occur about one million times faster than it would without a catalyst. This demonstration looks at the reaction of catalase, which catalyzes the decomposition of hydrogen peroxide in plant and animal tissues.

Concepts

- Catalyst
- Enzyme
- Reaction rate
- Concentration

Materials

Catalase solution, 0.01%, 50 mL*
Hydrogen peroxide solution, H_2O_2, 3%, 650 mL
Distilled or deionized water
Ice
Beakers, 600-mL, 4
Evaporating dish or Petri dish
Filter paper, 5.5-cm diameter, 4–8 pieces
Forceps or tongs
Graduated cylinders, 100- and 500-mL
Paper towels
Stirring rod
Stopwatch or timer

**Prepare the enzyme solution fresh before use and store over ice until needed. See the* Tips *section for instructions.*

Safety Precautions

Hydrogen peroxide is a strong oxidizing agent and may be irritating to eyes and skin. Avoid contact of all chemicals with eyes and skin. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Please review current Material Safety Data Sheets for additional safety, handling, and disposal information.

Procedure

1. Label four 600-mL beakers A–D.
2. Prepare a series of hydrogen peroxide solutions at different concentrations as described in Table 1. Measure and add the appropriate amounts of 3% hydrogen peroxide and distilled water into each beaker and stir to mix. Use a 100-mL or 500-mL graduated cylinder to measure the liquid volumes, as needed.

Table 1

Beaker	**A**	**B**	**C**	**D**
H_2O_2, mL	330 mL	170 mL	85 mL	40 mL
Distilled Water, mL	170 mL	330 mL	415 mL	460 mL
Concentration H_2O_2, %	2%	1%	0.5%	0.24%

3. Pour 20–30 mL of catalase solution into a wide shallow container such as an evaporating dish or a Petri dish.
4. Immerse four pieces of filter paper in the catalase solution and soak the filter paper for 2–3 minutes.
5. Using forceps or tongs, remove the filter paper from the catalase solution and gently blot dry on a paper towel.
6. Using forceps or tongs, submerge one piece of filter paper in the bottom of the hydrogen peroxide solution in Beaker A. Release the filter paper and immediately start timing. *(The solution will start bubbling at the surface of the filter paper and the filter paper will gradually float to the surface of the hydrogen peroxide solution.)*
7. Measure and record the time in seconds when the center of the filter paper touches the surface of the solution.

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8. Repeat steps 6 and 7 three more times in Beakers B, C, D. Use a fresh piece of catalase-soaked filter paper for each.
9. *(Optional)* Repeat the demonstration using fresh pieces of catalase-soaked filter paper and average the reaction times at each concentration. It is not necessary to prepare fresh hydrogen peroxide solutions—the solutions in the beakers may be reused several times.
10. Compare the reaction times for the four different concentrations of hydrogen peroxide. How does the concentration of hydrogen peroxide affect the rate of the catalase reaction?

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. Diluted hydrogen peroxide solutions may be disposed of down the drain with excess water according to Flinn Suggested Disposal Method #26b.

Tips

- The time required for the filter paper to float to the surface depends on the activity of the catalase solution, which is related to its concentration and to the purity or activity of the enzyme itself. The shelf life of many enzymes is poor. Store enzymes in a refrigerator and use them within one year of purchase.
- To prepare 0.01% catalase solution, first prepare 100 mL of a 0.1% solution by dissolving 0.10 g of catalase in 100 mL of distilled or deionized water. Dilute this solution tenfold by adding 90 mL of distilled water to 10 mL of the 0.1% solution. Test the activity of the enzyme solution with 2% hydrogen peroxide before performing the demonstration. Adjust the concentration as needed to obtain convenient "floating" times (neither too fast nor too slow).
- The enzyme catalase may be extracted from living tissue. Cut small sections (about 1 cm^3) of potato or beef liver, mash or grind them, and soak the pulp in 50 mL of ice-cold distilled water for 10 minutes. Strain the extract through cheesecloth and test its activity in 2% hydrogen peroxide. Dilute the extract, if necessary, to obtain convenient reaction times.

Discussion

A catalyst is a substance that increases the rate of a chemical reation without itself being consumed during the reaction. Decomposition of hydrogen peroxide to produce water and oxygen gas (Equation 1) is energetically favorable but kinetically very slow in the absence of a catalyst.

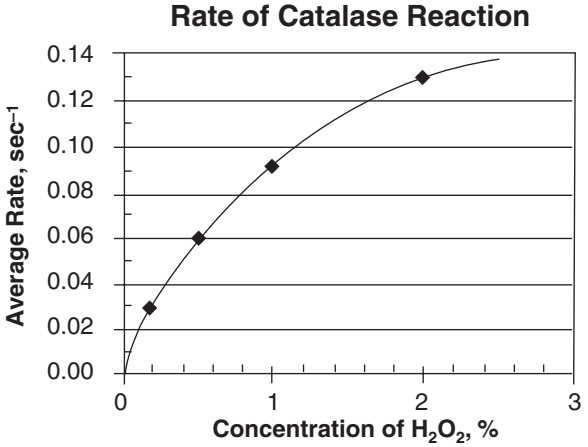
$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g) \qquad \textit{Equation 1}$$

In nature, this reaction is catalyzed by the enzyme catalase. This is an important reaction within cells. Hydrogen peroxide is generated as a byproduct of metabolic processes and the enzyme catalase prevents the accumulation of dangerous levels of this toxic chemical. The rate of the catalase reaction can be determined by measuring the time required for the enzyme-soaked filter paper disk to rise to the surface in a solution of hydrogen peroxide. Oxygen bubbles form on the filter paper and cause it to float. The rate of the reaction is inversely related to the reaction time. See Table 2 for sample data and results.

Table 2

Beaker	**A**	**B**	**C**	**D**
Concentration of H_2O_2	2%	1%	0.5%	0.24%
Average Reaction Time	8 sec	11 sec	18 sec	31 sec
Average Rate (1/Time)	0.13 sec^{-1}	0.09 sec^{-1}	0.06 sec^{-1}	0.03 sec^{-1}

At low concentrations of hydrogen peroxide, the rate of the reaction increases almost linearly as the concentration increases. At higher concentrations of hydrogen peroxide, the enzyme-catalyzed reaction behaves differently than a typical chemical reaction—the rate increase becomes more gradual. Eventually, the rate of the enzyme-catalyzed reaction would be expected to level off or reach a maximum value. A plot of the rate of the catalase reaction versus hydrogen peroxide concentration is shown below. The shape of the curve is characteristic of an enzyme-catalyzed reaction.



Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
Evidence, models, and explanation
Constancy, change, and measurement
Content Standards: Grades 9–12
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, chemical reactions
Content Standard C: Life Science, the cell, matter, energy, and organization in living systems

Reference

This activity was adapted from *Biochemistry—The Molecules of Life*, Volume 20 in the *Flinn ChemTopic™ Labs* series; Cesa, I., Editor; Flinn Scientific, Inc.: Batavia, IL (20o2).

The Floating Catalyst is available as a Chemical Demonstration Kit from Flinn Scientific, Inc.

Catalog No.	Description
AP6691	The Floating Catalyst—Chemical Demonstration Kit
H0009	Hydrogen Peroxide, 3%, 473 mL
C0359	Catalase, 1 g

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.