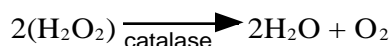


## Enzyme Model—Catalase Student Guide

Catalysts accelerate chemical reactions that otherwise proceed slowly. The enzyme called catalase is a catalyst. It exists in plant and animal cells and breaks down hydrogen peroxide, H<sub>2</sub>O<sub>2</sub>, which is a byproduct of metabolism. Hydrogen peroxide is toxic if it accumulates in a cell.

The chemical reaction accelerated by catalase is written



Under favorable conditions, the reaction occurs very fast. The maximum catalytic rate for one catalase molecule is 6 million molecules of hydrogen peroxide converted to water and oxygen per minute. The reaction product is 6 million molecules of water and 3 million molecules of oxygen. (Because the oxygen molecule consists of two oxygen atoms, the number of oxygen molecules made in the reaction is half the number of water molecules.)

### Part A. Graphing the reaction

Catalase, like most enzymes, is sensitive to the conditions in which it operates. The main factors that influence enzyme-catalyzed reactions are temperature, pH, enzyme concentration, and substrate concentration. In this activity, you will simulate how the enzyme catalysis rate (the rate of hydrogen peroxide conversion) changes as these factors change. The changes are shown in graphs generated by a predesigned model made with the STELLA® application and adapted from a model on the Creative Learning Exchange web site.

- Open the file called Enzyme.stm to launch the STELLA® application. You will see four blank graphs and four sliders.

When you run the model, each graph will show a dependent variable plotted as a function of time. Time is the independent variable in this activity and is set in minutes. The model has been arranged so that the graphs will show:

Hydrogen peroxide (expressed as number of molecules) versus time

Water (number of molecules) vs. time

Oxygen (number of molecules) vs. time

H<sub>2</sub>O<sub>2</sub> to water rate (number of hydrogen peroxide molecules converted per minute, which is equal to the number of water molecules produced per minute) vs. time

1. Record the initial amount of each dependent variable, shown above each graph. Be sure to record the units of measure.

Amount of hydrogen peroxide

Amount of oxygen

Amount of water

H<sub>2</sub>O<sub>2</sub> to water rate

The sliders represent factors that can influence the enzyme catalysis rate.

2. Record the initial value on each factor's slider and indicate what it measures.

Hydrogen peroxide exponent (amount of substrate)

pH

Temperature

Available enzyme

In laboratory work, you have measured enzyme catalysis rates in different ways. In this computer activity, you will use the STELLA® model to change factors individually, simulating their effect on the enzyme catalysis rate.

- Run the model at its initial settings.
- On the four temperature-effect graphs, sketch the curves that STELLA® generates. Label each curve with the initial temperature setting.

3. What does the shape of each curve indicate about the change in that variable over the simulated 10 minutes of enzyme activity?

3a. Hydrogen Peroxide

3b. Water

3c. Oxygen

3d. H<sub>2</sub>O<sub>2</sub> to Water Rate

4. Why do you think the curves show no change after about 5 minutes?

### **Part B. Changing the temperature**

Temperature affects nearly all chemical reaction rates. Rising temperature increases enzyme reactions rates until, at high temperatures, enzymes fail to work. Some of the chemical bonds of the enzyme give way and the enzyme's three-dimensional structure begins to come apart, that is, the enzyme denatures.

In this part of the activity, you will choose different temperatures for the reaction so you can simulate how the enzyme catalysis rate, amount of substrate, and amounts of reaction products change. You will also find the optimum temperature range for catalase to operate.

- Use the Temperature slider to select temperature, or click the number box and type your values.
- Run the model after each change.
- As STELLA® generates each set of curves for each temperature, sketch the curves on the temperature-effect graphs at the end of the activity. Note that STELLA® uses a different color for each model run.
- Label each curve with the temperature you selected for that model run.

5. According to the graphs of temperature effect, how do the variables change as temperature changes?

6. What is the optimum temperature range for catalase to break down hydrogen peroxide?

7. What relationship between temperature and enzyme catalysis rate does the H<sub>2</sub>O<sub>2</sub> to Water graph show?

### **Part C. Changing the pH**

Acidity and alkalinity are measured as pH. The pH of the cellular environment greatly affects the ability of catalase to break down hydrogen peroxide. In this part of the activity, you will run the model through a range of pH settings to simulate how changes in pH affect the enzyme catalysis rate, amount of substrate, and amounts of reaction products. You will also find the optimum pH range for catalase to operate.

- Pull down the Map menu and choose Restore, then choose All Devices. The graphs will become blank and the sliders will return to their initial value.
- Run the model with the initial settings to generate curves for comparison.
- Use the pH slider to change the pH value, or click the number box and type your values.
- Choose several new values.
- Run the model after each change.
- As STELLA® generates each set of curves for each pH, sketch the curves on the pH-effect graphs at the end of the activity. Label each curve with the pH you selected for that model run.

8. What is the optimum pH range for catalase to break down hydrogen peroxide?

9. What relationship between pH and enzyme catalysis rate does the H<sub>2</sub>O<sub>2</sub> to Water graph show?

### **Part D. Changing the enzyme concentration**

The amount of enzyme available to process the substrate can control an enzyme catalytic reaction. In this part of the activity, you will use the Available Enzyme slider to simulate how doubling the amount of enzyme affects the enzyme catalysis rate, amount of substrate, and amounts of reaction products.

- Use Restore All Devices.
- Run the model with the initial settings.

10. What effect do you think doubling the amount of catalase will have on the enzyme catalysis rate?

- Use the slider to double the available enzyme value, or click the number box and type your values. Double the value once, then increase the value by a small number, like 4 or 5, so you can see changes in the graphs.
- Run the model after each change.
- As STELLA® generates curves for each value increase, sketch the curves on the available-enzyme graphs at the end of the activity. Label each curve with the available enzyme value you selected for that model run.

11. What relationship between the amount of catalase and the enzyme catalysis rate does the H<sub>2</sub>O<sub>2</sub> to Water graph show?

12. Why do you think the enzyme catalysis rate declines rapidly?

### **Part E. Changing the substrate concentration**

The amount of substrate can control an enzyme catalytic reaction. In the model the amount of substrate is set by the hydrogen peroxide exponent. A change of 1 in the hydrogen peroxide exponent value changes the amount of substrate by a factor of 10.

In this part of the activity, you will change the value of the hydrogen peroxide exponent to simulate how changing the amount of substrate affects the enzyme catalysis rate, amount of enzyme, and amounts of reaction products.

- Use Restore All Devices.
- Run the model with the initial settings.

13. What effect do you think changing the amount of hydrogen peroxide by a factor of 10 will have on the enzyme catalysis rate?

- Use the slider to decrease the hydrogen peroxide exponent value to 7, or click the number box and type your value.
- Run the model.
- As STELLA® generates curves for the new exponent value, sketch them on the substrate-amount graphs at the end of the activity. Label each curve Hydrogen Peroxide Exponent 7.
- Change the exponent value to 9, run the model, and sketch and label the curves that STELLA® generates.

14. What relationship between the amount of hydrogen peroxide and the enzyme catalysis rate does the H<sub>2</sub>O<sub>2</sub> to Water graph show?

15. Why do you think the enzyme catalysis rate curves have the shape you see in the H<sub>2</sub>O<sub>2</sub> to Water graph?

### **Part F. Interpreting the graphs**

Simulating an enzyme catalytic reaction with a computer model allows you to change one variable while holding the others constant.

Look at the sets of graphs you have sketched for all the changes of the four variables. Questions 16 through 20 ask you to interpret the graphs.

16. How can you tell from the graphs what the optimum conditions are for each variable in this simulation?

17. What are the most favorable conditions for catalase to break down hydrogen peroxide?

18. How do the curves for hydrogen peroxide and water compare?

19. How do the graphs for water and oxygen compare?

20. How do you think the catalase reaction simulated by the STELLA® model compares with the reaction in living organisms?

Name \_\_\_\_\_

**Part B. Effect of temperature on enzyme reactions rates**

Hydrogen Peroxide


Oxygen


Water


H<sub>2</sub>O<sub>2</sub> to Water


**Part C. Effect of pH on enzyme reactions rates**

Hydrogen Peroxide


Oxygen


Water


H<sub>2</sub>O<sub>2</sub> to Water




Name \_\_\_\_\_

**Part D. Effect of available enzyme on enzyme reactions rates**

Hydrogen Peroxide


Oxygen


Water


H<sub>2</sub>O<sub>2</sub> to Water


**Part E. Effect of substrate amount on enzyme reactions rates**

Hydrogen Peroxide


Oxygen


Water


H<sub>2</sub>O<sub>2</sub> to Water
