

# Investigating Enzyme Reaction Rates Using *Toothpickase*

## A Dry-Lab Student Activity to Accompany AP® Biology Lab 2

Peggy O'Neill Skinner

Science Department Chair, AP® Biology and Biology Teacher, The Bush School, Seattle, WA

### Objectives

At the end of this activity, students should be able to demonstrate their understanding of the vocabulary describing an enzyme reaction, including the following terms: enzyme, quaternary structure, active site, substrate, products, V-max, substrate concentration, competitive inhibitors, and enzyme concentration.

### Background

The vocabulary needed to describe an enzyme reaction can be demonstrated using hands and toothpicks as the model. The **enzyme**, called *toothpickase* in this activity, is the student's 2 hands holding the toothpick (this demonstrates the **quaternary structure** of the toothpickase enzyme's 2 subunits coming together). The **active site** of toothpickase is the portion of the thumb and index finger forming the space within which the toothpick fits. The **substrate** is the toothpick. A toothpick can be broken into 2 **products**. The rate of the reaction can be measured by counting the amount of product produced or by counting the amount of substrate remaining. There are many factors that affect the rate of an enzyme reaction.

### Materials and preparation

The activity takes from 30 to 40 minutes to complete.

Each student group needs 250 flat toothpicks and a copy of the **Student Activity Sheet (pg. 3)**. Two boxes of toothpicks are enough for either 6 students working individually or 6 student groups.

At the beginning of the activity, have students divide their 250 toothpicks into 6 piles of 40 toothpicks with a few left over.

### Activity

1. To begin, have students break a toothpick. Ask them "Can it be broken faster? Can it be broken infinitely faster?" Students will intuitively understand that even under ideal conditions it will still take some time for them, in their role as toothpickase, to act on the toothpicks (their substrate). The maximum rate at which students can break the toothpicks is the **V-max** of toothpickase. Even if the room were filled with toothpicks, the rate would not increase, at least initially.
2. Ask students, "Would it take longer to break the toothpick if it were across the room on the floor?" This is an example of lower **substrate concentration**.
3. Ask students, "What would happen if the toothpicks were surrounded by a look-alike, such as round

toothpicks?” This is an example of **competitive inhibitors**.

4. Finally, ask students, “What would happen to the amount of time required to break the toothpicks if 2 people were breaking them at the same time?” This is an example of **enzyme concentration**.

### Tip

When students are breaking toothpicks, some will invariably (and anxiously) say after the 60-second interval that they are out of toothpicks. Of course, that is the point, because their rate will decrease as it becomes harder to find toothpicks to break. They now have a sense of how substrate availability affects the rate of an enzymatic reaction.

### Questions

The questions at the end of the Student Activity Worksheet can be used as an additional means of assessment to tie back into the laboratory work.

### Extensions

There are numerous extension activities for toothpickase. Here are a few suggestions:

- Students can search for toothpicks scattered around the room to demonstrate the effect of substrate concentration.
- Students can put their hands in ice water for a minute before breaking toothpicks to simulate the effect of lowering the temperature of an enzymatic reaction.
- Students can break toothpicks in groups to demonstrate the effect of enzyme concentration.
- Students can model denatured toothpickase enzyme by breaking toothpicks with their fingers crossed.
- You can also put round toothpicks in the students’ piles of flat toothpicks to simulate the effect of competitive inhibitors.

### Additional resources

- [Enzyme Catalysis, 8-Station Kit](#)
- [Enzyme Catalysis, 8-Station Kit with 8 Burets](#)
- [Enzyme Catalysis, 1-Station Kit](#)
- [Fruit Juice Release BioKit®](#)
- [Carolina™ Cheese Production BioKit®](#)
- [Starch Breakdown BioKit®](#)
- [Digestion BioKit®](#)

# Enzyme Reaction Rates Using *Toothpickase*

## Student Activity Sheet

Enzymes are agents that change the rate of a reaction without being changed themselves. You might already have learned the terms that describe an enzymatic reaction: enzyme, quaternary structure, active site, substrate, products, V-max, substrate concentration, competitive inhibitors, and enzyme concentration. This exercise is designed to give you hands-on experience with these factors.

In this activity, your hands are the enzyme *toothpickase*. Your substrate is the toothpick. When you find a toothpick, you react with it and break it into 2 pieces. Your goal is to break toothpicks quickly and efficiently (without damaging yourself in the process!).

### Pre-lab questions

1. How many subunits does the toothpickase enzyme have?
2. What is the quaternary structure of your enzyme?
3. What is the enzyme's active site?
4. What are the products of the reaction of toothpickase with its substrate?

### Exercises and questions

Divide your initial pile of approximately 250 toothpicks into 6 piles of 40 toothpicks. Position these piles conveniently around yourself, so you can break them quickly and efficiently.

1. Your instructor will tell you when to activate your toothpickase to begin reacting with its substrate. This reaction will be timed to determine the V-max of the toothpickase. At each specified interval, the toothpickase will move to a new pile of toothpicks. This will make it easy to keep track of how many toothpicks are broken in each interval. Record this information in the following chart.

Time in Seconds (s)	Toothpicks Metabolized
0	
10	
30	
60	
120	
180	

1. Make a line graph of the number of toothpicks metabolized over time in seconds (s). Is the rate of

reaction the same over the entire reaction? Remember to label each axis.



- a. What does the line on your graph represent?
- b. What does your graph tell you about the rate of reaction over time?

2. For each interval of time, calculate the rate of reaction of the toothpickase enzyme using the formula for the slope of the line graphed above.

$$\text{Reaction rate (toothpicks/s)} = \frac{M_2 - M_1}{T_2 - T_1} = \frac{\Delta M}{\Delta T}$$

Where  $M_1 = 0$  toothpicks

$M_2 = 5$  toothpicks

$T_1 = 0$  s

$T_2 = 10$  s

Then

$$\text{Reaction rate} = \frac{5 \text{ toothpicks}}{10 \text{ s}} = 0.5 \text{ toothpicks/s}$$

Record your data in the table below.

<b>Time Interval (in s)</b>	<b>Rate of Reaction of Toothpickase (in toothpicks metabolized/s)</b>
0 to 10	
10 to 30	
30 to 60	
60 to 120	
120 to 180	

### Questions

1. What functions do enzymes serve in living systems?
2. What are the reactants that bind to an enzyme called?
3. What is the name of the specific location where the reaction occurs?
4. During the reaction, what happens to the enzyme? What happens to the reactants?
5. Can the enzyme be used again after the reaction is complete and the product released?
6. Name 3 factors that affect how enzymes function.
7. Name an enzyme found in liver or a yeast suspension.
8. Research how enzymes are used in manufacturing processes and give 2 examples below.
9. Create your own enzyme in the space below. Give it a name and function and draw its structure.
10. Find 2 examples of enzymes at your local grocery store or hardware store and write them below. Include what function each is intended to perform.



© 2009 Carolina Biological Supply Company