Toothpick Biochemistry

Experiments with Enzyme Kinetics

Introduction

Without enzymes, the sun wouldn't shine, the earth wouldn't spin, and all biochemical processes would grind to a halt. Actually, the solar system would be fine—but life as we know it would not be. Here is a pair of activities designed to demonstrate some important relationships governing enzyme activity.

Concepts

- Enzyme and substrate
- Enzyme kinetics
- Reaction rate
- Saturation curve

Materials (for each group)

Blindfold (optional)
Graph paper
Paper clips (preferably "giant"-sized)
Shallow dish or bowl
Watch with a second hand
Wooden toothpicks (approximately 250)

Preparation

1. Part A, Rate of Product Formation, is most easily done in groups of three students. Each group will need 90 toothpicks, and the activity will take about five minutes to complete.
2. Part B, Reaction Rate versus Substrate Concentration, can be done in groups of two or three students. You may wish to assign each group a separate initial concentration (at least 10 groups will be needed) and then pool data. Alternatively, time permitting, each group can carry out the entire series of concentration tests. (Each group will need about 200 toothpicks to perform the entire series of tests.)

Procedure

Part A. Rate of Product Formation

1. Place 90 to 100 wooden toothpicks in a shallow bowl. The toothpicks represent the substrate (reactants) in this reaction.
2. In a group of three, one person will be the timer, one will record the data, and the third will be the "enzyme." The enzyme functions by randomly selecting toothpicks without looking at the bowl and snapping toothpicks in half using thumb, index finger, and middle finger. All "products" (broken toothpicks) are placed in the bowl.
3. The experiment is conducted in 20-second intervals. The timer (the instructor can play this role if students are working in pairs) calls out "start," and then audibly marks each 20-second interval. The recorder tallies the cumulative number of toothpicks broken as each interval is called out. A minimum of 14 data points should be tallied.
4. Graph the results by plotting product formed (the *total* number of toothpicks broken) versus time (20 seconds, 40 seconds, etc.)

Part B. Reaction Rate versus Substrate Concentration

1. Place 80 to 100 paper clips in the bowl. The paper clips represent a "solvent" in which the toothpicks are "dissolved." Different concentrations are simulated by mixing different numbers of toothpicks in with the paper clips.
2. For the first trial, place 10 toothpicks in the bowl with the paper clips. The enzyme has 20 seconds to "react" (break as many toothpicks as possible). Record the number broken at a concentration of 10.
3. Remove all broken toothpicks and repeat step 10 with concentrations of 20, 30, 40, etc., up to at least 100 toothpicks mixed with the paper clips. Generate at least 10 data points.

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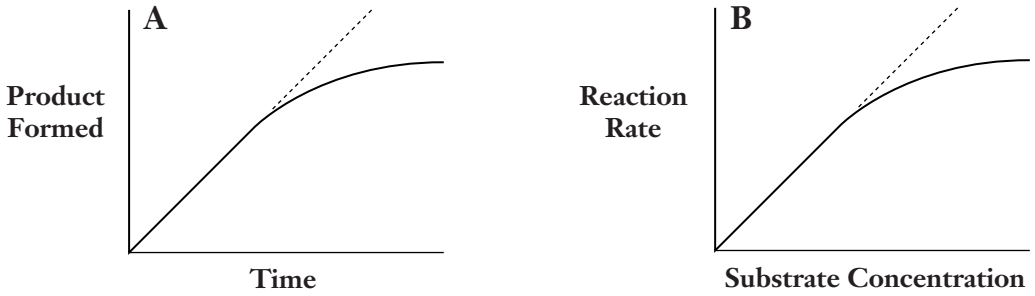
4. Graph the results by plotting reaction rate (toothpicks broken in 20 seconds) versus substrate concentration (10, 20, etc.).

Discussion



The resulting graphs should resemble those shown above for Parts A and B. In Part A, the initial rate of product formation will be fairly constant for the first two or three minutes—the initial rate (the dashed line) being approximately 25 toothpicks broken per minute. During this period, the ratio of unbroken to broken toothpicks is fairly high and the rate is determined by the efficiency (manual dexterity) of the enzyme. As this ratio decreases, the enzyme spends more and more time searching for unreacted substrate (unbroken toothpicks) and, as a result, the rate at which product is formed steadily decreases (the slope of the curved line decreases) until all toothpicks have reacted or the experiment is stopped.

Part B adds the variable of concentration—in this case, the concentration of toothpicks in a paper clip "solution." With the enzyme concentration constant, the rate will initially increase proportionally to the substrate concentration—which should be evident up to a concentration of 60 or 70 toothpicks. Beyond that, the rate increases more and more slowly until a rate maximum is reached — there is a physical limit to how fast the enzyme can react with the toothpicks. At high substrate concentrations, the enzyme becomes saturated with substrate. At this point, the limiting factors are the speed with which the enzyme and the substrate can combine and react (efficiency), and the concentration of the enzyme. To increase the reaction rate further would require either Superman (faster fingers), or a higher enzyme concentration (more fingers in the bowl). The shape of the curve in Part B is sometimes referred to as saturation kinetics.

Connecting to the National Standards

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

Unifying Concepts and Processes: Grades K–12
- Systems, order, and organization
- Evidence, models, and explanation
- Constancy, change, and measurement

Content Standards: Grades 5–8
- Content Standard A: Science as Inquiry
- Content Standard B: Physical Science, properties and changes of properties in matter
- Content Standard C: Life Science, structure and function in living systems

Content Standards: Grades 9–12
- Content Standard A: Science as Inquiry
- Content Standard B: Physical Science, chemical reactions
- Content Standard C: Life Science, matter, energy, and organization in living systems

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Reference

Green, N. P. O.; Stout, G. W.; Taylor, D. J. *Biological Science I: Organisms, Energy and Environment;* Cambridge University: Cambridge, England, 1990; pp 172–173.

Materials for *Toothpick Biochemistry* are available from Flinn Scientific, Inc.

Catalog No.	Description
AP2016	Toothpicks, Wooden, pkg. 250
AP1813	Graph Paper, 8½0 × 110, 5 squares per inch, Pad of 50

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