Ticketase

Focus questions	What roles do different enzymes play in the fermentation of starch? How do enzymes act upon complex sugars like starch? What is the rate of enzyme activity for Ticketase and Glucoticketase? Does enzyme or substrate concentration affect the rate of enzymatic activity?
Learning target	Students will explain how enzymes perform in the process of fermentation.
Vocabulary	activation energy, reaction rate, active site, enzyme concentration, substrate concentration, products, reactants

HS-LS1-6 Matter and Energy in Organisms and Ecosystems

Performance expectation HS-LS1-6	**Classroom connection:** Students use tickets to represent starch molecules and interact as if they are enzymes to break the molecules down.

Science and engineering practices

Constructing Explanations and Designing Solutions	**Classroom connection:** Students deconstruct a model of starch in order to provide reliable evidence for their explanation on how enzymes work together to produce glucose for ethanol production.

Disciplinary core ideas

LS1.C: Organization for Matter and Energy Flow in Organisms	**Classroom connection:** Students construct explanations for enzymatic action on complex sugar molecules to create simple sugars for fermentation.

Cross-cutting concepts

Energy & Matter	**Classroom connection:** Students design new solutions for enzyme action on starch to make the fermentation process more efficient.

This lesson is designed to follow Lesson 1, Fermentation Factories, where students utilized different components (enzymes, yeast, feedstocks, and water) to produce ethanol and carbon dioxide through the process of fermentation. This lesson focuses on Constructing Explanations and Designing Solutions as a way to make a qualitative or quantitative explanation regarding the relationship between feedstock and glucose availability for ethanol production. Students will deconstruct a model of starch to examine enzyme and starch reactions and to determine how starch is changed into smaller molecules (glucose) for yeast consumption. Students will construct an explanation for enzyme action and design solutions for future enzyme use in ethanol production.

Background

Enzymes work to speed up biological reactions by lowering their **activation energy.** There are certain conditions that must be met for enzymes to work efficiently. One of these conditions is **substrate concentration.** Students use tickets to model how various enzymes interact with starch to produce smaller sugar molecules. The tickets represent the **substrate.** The ends of the ticket strings represent the **active sites** of the enzymes "Ticketase" and "Glucoticketase." To **catalyze** the reaction (tearing groups or single tickets off of the string of tickets), students may only tear a single ticket off at a time if they are Glucoticketase or a group of 2 or 3 tickets off at a time if they are Ticketase. Products and reactants must be dropped back into the pile after every tear off to mix and the process is repeated. A single ticket is the desired product for fermentation and must be torn cleanly off on both sides to count as **product.**

- **Ticketase** represents the enzyme Amylase that acts on starch (polysaccharide) to break off a disaccharide (2-sugar molecule) or a trisaccharide (3-sugar molecule).
- **Glucoticketase** represents the enzyme Glucoamylase that acts on polysaccharides to break off a single sugar molecule.

Prior knowledge

Students should be familiar with enzymes and the naming of enzymes. A brief review of enzyme action may be necessary before beginning this activity.

Materials

- 4 sets of 50 single entrance tickets (all connected) per student group
- Timer (optional)
- Blindfold (optional)

Teacher preparation

1. Remind the students of the 4 fermentation bags used as the phenomena in lesson 1. What was occurring in each of the four bags? You can help guide the students' discussion by asking questions as you record their observations/questions.
    - How did the amylase and/or glucoamylase impact the fermentation reaction?
    - What are the roles of amylase and glucoamylase?
    - Did amylase/glucoamylase help the fermentation process occur more slowly, rapidly, or have no net effect?
2. Have students work together in groups of 5. Provide each group with 4 strings of 50 connected tickets. Instructions for the activity are included on the student page.

Student handout

Reflection

Create an explanation for the current use of enzymes in commercial ethanol production in the United States. Reflect on the following questions while creating your explanation.

1. What happened to the first polysaccharide as Ticketase was introduced? What happened to the second polysaccharide when Glucoticketase was introduced? How are they similar and different?

Possible answer: The first polysaccharide was broken into small ticket groups of 2-3 tickets per group. Yeast feed on glucose molecules, so it could not ferment the small ticket groups. The second polysaccharide was broken into single tickets. They are similar in that they break the polysaccharide into smaller pieces. They are different in the size of the polysaccharide that they break off.

2. What happened to the reaction rate when the enzyme concentration and substrate concentration increased? Why did this happen?

Possible answer: The reaction rate increased due to the additional substrate and activation sites that were available to both of the enzymes.

3. Why does industry use a combination of enzymes such as Ticketase and Glucoticketase for the fermentation process?

Possible answer: The synergy of the enzymes working together help to produce more products that are available to yeast for fermentation.

4. Construct an explanation and design future solutions for the current use of enzymes in commercial ethanol production in the United States. How can enzyme use make ethanol production more efficient in the future?

Possible answers: Students' answers will vary.

Differentiation

Other ways to connect with students with various needs:

- **Local community:** Students may investigate the use of enzymes in digestion. How can the amylase found in human saliva help to break apart food molecules in preparation for digestion? How is this similar to the action of Ticketase? Students can communicate with their findings with their local community.
- **Students with special needs (auditory/visual/language/reading):** See the extra support below.
- **Extra Support:** Video: How ethanol is made (youtu.be/59R-NqykoXs). This video helps demonstrate relationships between the components of the ethanol fermentation ecosystem.
  Infographic: vitalbypoet.com/infographics/ethanol-process-2
  This infographic represents the process of corn flour breakdown into glucose for fermentation.
- **Extensions:** Students can research the current use of enzymes in corn ethanol production. Students can also research additional feedstocks for ethanol such as cellulosic switchgrass, sugarcane, woody biomass and the enzymes that would be necessary for breakdown of lignin or complex starches.

Assessments

Rubric for assessment

Skill	Developing	Satisfactory	Exemplary
Constructing explanations	The student is able to use the data generated to construct an explanation for the use of enzymes in commercial ethanol production.	The student is able to use the data generated to construct an explanation for the use of enzymes in commercial ethanol production and make the connection that starch molecules are broken down into simple sugars so that yeast can ferment corn mash into ethanol.	The student is able to use the data generated to construct an explanation for the use of enzymes in commercial ethanol production; make the connection that starch molecules are broken down into simple sugars so that yeast can ferment corn mash into ethanol; and design future solutions to create a more efficient use of enzymes in commercial ethanol production.

Rubric for self-assessment

Skill	Yes	No	Unsure
I can explain the function of Ticketase.			
I can explain the function of Glucoticketase			
I used reasoning to connect the evidence of enzyme function on starch to construct an explanation for the use of enzymes in commercial ethanol production.			