Regulation of Enzyme Activity

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Overview

This is a unit which covers the effects of various factors on the activity of enzymes. It is also a means of reinforcing the process skills involved in the scientific method.

To introduce the topic and unit, two activities can be used: “Enzyme Specificity” or “Pineapple/Jell-O™ Lab”. There are three choices for the Exploration: “Beano™ and Lactaid™ Action”, “Teaching Enzyme Action Using CBL Technology” and “Proof of Enzyme Action”. It is recommended that students perform at least two of these activities, one of which should be the CBL laboratory to introduce students to the use of current technology to gather data. The complete activity is not included here, however the teacher can easily locate the source document (see the URL on pages 10 and 19). An Extension activity can also be obtained at the same site. Assessment items are included in the Evaluation section that mirror those that are found in the State High School Assessment.

The unit covers the following concepts and topics:

• The correlation between the structure and function of biologically important molecules and their relationship to cell processes, specifically, factors that affect enzyme activity:
  ➢ temperature,
  ➢ pH,
  ➢ concentration of enzyme
• Posing scientific questions and suggesting experimental procedures
• Carrying out investigations and employing instruments and materials
• Analyzing data
• Communicating information
• Using mathematical processes
• Connecting biology to mathematics and real-world applications
### Suggested Materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Quantity / Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>5% Sugar solutions</td>
<td></td>
</tr>
<tr>
<td>Amylase solution</td>
<td></td>
</tr>
<tr>
<td>Beakers</td>
<td></td>
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<tr>
<td>Benedict’s solution</td>
<td></td>
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<tr>
<td>Blender</td>
<td></td>
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<tr>
<td>Calf’s liver – fresh (OR substitute raw white potato)</td>
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<tr>
<td>Card stock</td>
<td></td>
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<tr>
<td>CBL/TI System</td>
<td></td>
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<tr>
<td>Cheesecloth</td>
<td></td>
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<tr>
<td>Distilled water</td>
<td></td>
</tr>
<tr>
<td>Envelopes</td>
<td></td>
</tr>
<tr>
<td>Erlenmeyer flasks - 125 mL (OR substitute 250 mL)</td>
<td></td>
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<tr>
<td>Eye droppers (pipettes)</td>
<td></td>
</tr>
<tr>
<td>Food cards</td>
<td></td>
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<tr>
<td>Gelatin cubes</td>
<td></td>
</tr>
<tr>
<td>Glucose test paper</td>
<td></td>
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<tr>
<td>Graduated cylinders</td>
<td></td>
</tr>
<tr>
<td>Hot plate</td>
<td></td>
</tr>
<tr>
<td>Hydrogen peroxide solution (3%)</td>
<td></td>
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<tr>
<td>Locks and keys (15 assorted)</td>
<td></td>
</tr>
<tr>
<td>pH buffers (pH 4, 7, and 10)</td>
<td></td>
</tr>
<tr>
<td>Pestle (or device for macerating liver)</td>
<td></td>
</tr>
<tr>
<td>Pineapple juice (canned)</td>
<td></td>
</tr>
<tr>
<td>Pineapple juice (fresh or frozen)</td>
<td></td>
</tr>
<tr>
<td>Potassium iodide solution (I₂KI)</td>
<td></td>
</tr>
<tr>
<td>Shallow dish or pan</td>
<td></td>
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<tr>
<td>Starch solution</td>
<td></td>
</tr>
<tr>
<td>Vernier Gas Pressure Sensor</td>
<td></td>
</tr>
<tr>
<td>Vernier Temperature Probe or Thermometer</td>
<td></td>
</tr>
<tr>
<td>Yarn</td>
<td></td>
</tr>
<tr>
<td>Yeast suspension</td>
<td></td>
</tr>
</tbody>
</table>

* Refer to “**Beano™ and Lactaid™**” Lab for complete list of required materials.

* Refer to “**Enzyme Action: Testing Catalase Activity**” Lab for complete list of required materials.

* Refer to “**Proof of Enzyme Action**” Lab for complete list of required materials.

* Refer to “**Teaching Enzyme Action Using CBL Technology**” Lab for complete list of required materials.

*NOTE: This list of materials is NOT complete. Teachers should refer to the actual lab references for a complete list of required materials.*
<table>
<thead>
<tr>
<th>LESSON COMPONENTS</th>
<th>SUGGESTED ACTIVITIES</th>
</tr>
</thead>
</table>
| **I. Engagement:** The activities in this section capture the students’ attention, stimulate their thinking, and help them access prior knowledge. | **I.** Enzyme Specificity Class Activity and/or Pineapple/Jell-O™ Lab  
CLG: 1.2.1, 1.2.2, 3.1.1, 3.1.2 |
| **II. Exploration:** In this section, students are given time to think, plan, investigate, and organize collected information. | **II.** Beano™ and Lactaid™ Action Lab, by Vernier or Teaching Enzyme Action Using CBL Technology, or Proof of Enzyme Action Lab  
CLG: 1.2.3, 1.2.5, 1.3.1, 1.3.2, 1.3.3, 1.4 (exc. ind. 5), 1.5.1–1.5.4, 1.6.1, 1.6.4, 1.7.1, 3.1.1, 3.1.2 |
| **III. Explanation:** Students are now involved in an analysis of their exploration. Their understanding is clarified and modified because of reflective activities. | **III.** Students will be guided through a discussion of enzyme action (enzymes, substrates, coenzymes) based upon Section II activities.  
CLG: 1.2.5, 3.1.1, 3.1.2 |
| **IV. Extension:** This section gives students the opportunity to expand and solidify their understanding of the concept and/or apply it to a real world situation. | **IV.** Enzyme Action: Testing Catalase Activity (Vernier), Observing the Effect of Concentration on Enzyme Activity, Observing the Effect of Temperature on Enzyme Activity  
CLG: 1.2.3, 1.2.5, 1.3.1, 1.3.2, 1.3.3, 1.4 (exc. ind. 5), 1.5.1–1.5.4, 1.6.1, 1.6.4, 1.7.1, 3.1.1, 3.1.2 |
| **V. Evaluation:** This performance-based helps the students to connect all of the pieces of information involved in these lessons. | **V.** Enzyme Graph Application: Provides students with a data set comparing time to enzyme concentration. Students will create and analyze their graph, and predict the effect of a change in enzyme concentration, pH or temperature on enzyme activity.  
CLG: 1.1.2, 1.4.2, 1.4.4, 1.5.1, 1.5.2, 3.1.2, 3.2.2 |

**Notes/Comments**  
- Addresses concept of Enzymes/Substrates/Regulation  
  - Possible assessment items can be found at the end of this packet.
I. ENGAGEMENT

“Enzyme Specificity: Introduction to Enzymes”

Rationale:
• To illustrate the specificity of enzyme action

Time:
• Approximately 30 minutes

Objectives:
• To introduce students to the concept of enzyme and substrate reactions

Materials: (for class of 30)
• Assorted locks/keys (15)
• Food Cards
• Card stock and envelopes
• Yarn

Overview:
• Students will use locks and matching keys to represent enzymes and substrates in human digestion.

Procedure:
1. Fifteen students (or half of the class) are chosen to represent food items.

2. Each student is given a sealed envelope with the name of the food item on it to wear.

3. Students then line up according to food item type (which is indicated on the outside of the envelope).

4. Each of these students is also given a specific lock.

5. Fifteen other students (or remaining class members) are given keys.

6. Students mingle attempting to match locks and keys.

7. When a key opens a lock, the pair of students returns to their original position in line.

8. After all locks and keys are matched, each person representing a food person opens his/her card and shares the enzyme/substrate information on the card with the class.
Food/Enzyme Chart

1. Coke- sucrose/sucrase
2. French fries- polysaccharide/amylase & lipid/lipase
3. Hamburger-
   bun- polysaccharide/amylase & nucleic acid/nuclease
   pickles- cellulose/cellulase
   cheese- lipid/lipase and protein/protease & lactose/lactase
   beef patty- protein/protease & lipid/lipase
   ketchup- sucrose/sucrase
   mustard- sucrose/sucrase
4. Ice cream- maltose/maltase, lipid/lipase, and lactose/lactase

Enzyme/Food Matches

1. Carbohydrates:
   Sucrose - sucrase
   Maltose - maltase
   Lactose - lactase
   Polysaccharides - amylase
   Cellulose – cellulase
2. Proteins – protease
3. Lipids – lipase
4. Nucleic Acids – nuclease
<table>
<thead>
<tr>
<th>Category of Food</th>
<th>Matching Food</th>
<th>No. of Locks</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Carbohydrates</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Sucrose</td>
<td>Coke</td>
<td>2 identical</td>
</tr>
<tr>
<td></td>
<td>Ketchup/Mustard</td>
<td></td>
</tr>
<tr>
<td>2. Maltose</td>
<td>Ice Cream</td>
<td>1</td>
</tr>
<tr>
<td>3. Lactose</td>
<td>Ice Cream</td>
<td>2 identical</td>
</tr>
<tr>
<td></td>
<td>Cheese</td>
<td></td>
</tr>
<tr>
<td>4. Polysaccharides</td>
<td>Fries</td>
<td>2 identical</td>
</tr>
<tr>
<td></td>
<td>Bun</td>
<td></td>
</tr>
<tr>
<td>5. Cellulose</td>
<td>Pickle</td>
<td>1</td>
</tr>
<tr>
<td>B. Proteins</td>
<td>Beef Patty</td>
<td>2 identical</td>
</tr>
<tr>
<td></td>
<td>Cheese</td>
<td></td>
</tr>
<tr>
<td>C. Lipids</td>
<td>Beef Patty</td>
<td>4 identical</td>
</tr>
<tr>
<td></td>
<td>Cheese</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ice Cream</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fries</td>
<td></td>
</tr>
<tr>
<td>D. Nucleic Acids</td>
<td>Bun</td>
<td>1 lock</td>
</tr>
</tbody>
</table>
INFORMATION FOR FOOD CARDS

SODA (on exterior of envelope)

(Inside envelope) Disaccharides are carbohydrates essential in supplying the body with energy. The energy contained in a disaccharide is released only when it is broken down by an enzyme. This enzymatic reaction takes place in the stomach and small intestine.

A glass of soda can contain up to 50 grams of sucrose. Sucrose is a type of disaccharide that is composed of glucose molecules that are chemically bonded to fructose molecules. The only key that unlocks sucrose is sucrase.

KETCHUP/MUSTARD

Although, ketchup and mustard contain tomatoes and mustard seeds, respectively, their primary ingredients are sugar and water! The sugar that is most commonly found in both ketchup and mustard is sucrose. The only key that unlocks sucrose is sucrase.

ICE CREAM (1)

Ice cream is a colloid, a suspension of sugar molecules in frozen fat. Maltose is one type of sugar that may be found in ice cream. Maltose is a second type of disaccharide. Maltose molecules are formed from two glucose molecules that are chemically bonded. The only key that unlocks maltose is maltase.

CHEESE (1)

A type of sugar that is always found in cheese and other dairy products is lactose. Lactose is a third type of disaccharide. Lactose, is composed of glucose molecules that are chemically bonded to galactose molecules. Some people lack the enzyme required to break down lactose. We say that those people are “lactose intolerant.” The only key that unlocks lactose is lactase.

ICE CREAM (2)

Since ice cream is a dairy product, it also contains lactose. Lactose that is not broken down by the body’s natural lactose is fermented by bacteria in the intestine. This process can produce large quantities of gas. The only key that unlocks lactose is lactase.

FRENCH FRIES (1)

French fries are made from potatoes. Potatoes are filled with starch. Plants produce starch as a way to store extra energy. Starch is a polysaccharide containing long chains of repeating units of glucose. One enzyme that unlocks starch is amylase.
BUN (1)

Buns contain starch and other complex carbohydrates. Starches are broken down by amylase. Amylase is found in saliva, so digestion starts the moment you begin to chew. Amylase is also produced by the pancreas. One enzyme that unlocks starch is amylase.

PICKLE

Pickles and all other vegetables contain the polysaccharide, cellulose. Cellulose is important in the structure of the cell wall of plants. Although cattle and other herbivores have the ability to digest cellulose, human beings lack the enzyme needed to break down cellulose. Therefore, cellulose passes undigested from the body human body. Cellulose provides the fiber or roughage that is an important component of the human diet. The only key that unlocks cellulose is cellulase.

BEEF PATTY (1)

Meat is the muscle tissue of an animal. Meat is composed primarily of proteins, which are, in turn, composed of amino acids. Like the letters of the alphabet, which are combined in nearly infinite ways to form words, amino acids are combined to form proteins. There are thousands of different proteins yet only 20 different amino acids. The enzymes that unlock proteins are collectively called proteases. The only key that unlocks a protein is a protease.

CHEESE (2)

The protein that is found in cheese was assembled by a cow from the amino acids she consumed in her diet. After digesting protein, humans also reassemble the component amino acids into human proteins; thus, the expression, “You are what you eat.” The only key that unlocks a protein is a protease.

BEEF PATTY (2)

As much as 30% of a beef patty is fat. This fat was stored by a cow for its future energy needs. The excess fat that we eat goes directly to OUR storage areas. The group of enzymes that break down lipids are called lipases. The only key that unlocks a lipid (fat) is a lipase.

CHEESE (3)

Cheese is made from the fat that is skimmed from the surface of raw milk (milk that has not been homogenized). In fact, the main ingredient in cheese is milk fat. Fat is a lipid. The only key that unlocks a lipid is a lipase.
ICE CREAM (3)

When raw milk settles, cream floats to the top. This cream is used to make ice cream. When milk is used instead, the product is called “ice milk.” Ice milk contains less fat than ice cream. Cream is a lipid. The only key that unlocks a lipid is a lipase.

FRENCH FRIES (2)

Although potatoes contain no fat, french fries are among the fattiest of foods that you can eat. The fat is added when the potato strips are deep-fried. The only key that unlocks a lipid is a lipase.

BUN (2)

Nucleic acids include DNA and RNA, the molecules that provide the “blueprints” for all organisms. Because they are found in all living things, nucleic acids are present in all foods. The enzymes that break down nucleic acids are called nucleases. The only key that unlocks a nucleic acid is a nuclease.
I. ENGAGEMENT
“Pineapple/Jell-O™ Lab”

Rationale:
• To show that food items contain enzymes.

Time:
• Approximately 30 minutes

Objectives:
• To introduce students to the concept of enzyme and substrate reactions

Materials: (for class of 30)
• Prepared 2-3 cm Jell-O™ Brand gelatin cubes (4-5 cubes per group)
• Shallow dish or pan
• Fresh and canned pineapple juice
• Blender
• Cheesecloth

Overview:
• Students will use pineapple juice as an enzyme and Jell-O™ as a substrate to illustrate an enzyme/substrate complex.
• Students will discover that the processing of food will denature enzymes.

Procedure:
1. Teacher or students prepare Jell-O™ the day before this activity.
2. Teacher or students prepare fresh pineapple juice by pureeing fresh pineapple in a blender. The puree should be strained through cheesecloth to separate the pulp from the juice. Repeat this procedure for the canned pineapple.
3. Student groups receive a sample of either fresh or canned pineapple juice and cubes of Jell-O™.
4. Place Jell-O™ cubes in a shallow dish or pan.
5. Pour juice sample over the Jell-O™ cubes until the bottom of the dish or pan is covered.
6. Students should observe the experimental set-up for 30 minutes and record observations at 5 minute intervals.
For additional information and optional activities see the following resources:
Access Excellence –
http://www.gene.com/ae
“Catalysis Using Enzymes in Pineapple” –

Background information:
1. Gelatin is made from a protein called collagen which comes from the joints of animals. Gelatin may be dissolved in hot water. As the dissolved gelatin mixture cools, the collagen forms into a matrix that traps the water; as a result, the mixture turns into the jiggling semi-solid mass that is so recognizable as Jell-O™.

2. Pineapple belongs to a group of plants called Bromeliads. Kiwi, papaya, and figs are other types of Bromeliads. The enzyme in pineapple juice that is responsible for the breakdown of collagen is bromelin. The process of canning pineapple denatures the bromelin, rendering it incapable of catalyzing the break down of gelatin.
II. EXPLORATION
“Beano™ and Lactaid™ Action”

Rationale:

• To show the action of two different commercially prepared enzymes, Beano™ and Lactaid™.

Time:

• Approximately 30-40 minutes for 1 trial

Objectives:

• To test the action of two commercial products, Beano™ and Lactaid™
• To use glucose test paper to monitor the presence of glucose
• To determine if yeast can metabolize glucose, lactose, or galactose
• To determine if yeast can metabolize glucose, lactose, or galactose in the presence of Beano™ or Lactaid™

Materials:

• CBL/TI system
• Vernier Gas Pressure Sensor
• glucose test paper
• 5% sugar solutions
• yeast suspension
• see lab for other materials

Overview:

• Students will monitor CO₂ production for evidence of fermentation in yeast with and without the help of commercial enzymes.

Procedure:

EXPLORATION (Alternative)
“Teaching Enzyme Action Using CBL Technology”

Rationale:
- To explore the reaction rate of the enzyme, catalase, on the breakdown of hydrogen peroxide

Time:
- Approximately 30-40 minutes

Objectives:
- To measure the action of an enzyme (catalase) on its substrate (hydrogen peroxide)
- To prepare a catalase solution from fresh liver
- To collect data using a CBL.

Materials:
- CBL/TI system
- Vernier Gas Pressure Sensor
- fresh liver
- hydrogen peroxide
- see lab for additional materials

Overview:
1. Students will monitor the reaction by recording pressure changes as oxygen gas is given off during the reaction.

Procedure:
BIOLOGY CBL LAB  
ENZYME CATALYSIS: CATALASE

PURPOSE:
To demonstrate the action of the enzyme catalase. Harmful hydrogen peroxide forms within many cells. The enzyme catalase catalyzes the breakdown of hydrogen peroxide according to the reaction shown below:

\[ 2H_2O_2 \rightarrow 2H_2O + O_2 \]

We will monitor the reaction by recording pressure changes as oxygen gas is given off during the reaction.

MATERIALS:
- CBL
- TI-82/83 Calculator
- Erlenmeyer Flask
- Pressure Sensor (PS-DIN)
- Pipettes
- 1.5% solution of \( H_2O_2 \)
- 1-holed rubber stopper to fit flask, fitted with glass tube
- Catalase solution prepared from fresh calf’s liver or potato (must be kept on ice)

TEACHER PREPARATION

1. Preparation of Hydrogen Peroxide Solution (\( H_2O_2 \))
   - Hydrogen Peroxide can be purchased from the grocery store or pharmacy in a 3.0% concentration.
   - Dilute it to 1.5% by adding an equal volume of distilled water. You will need 10 mL of \( H_2O_2 \) per laboratory set-up.

2. Preparation of Enzyme Solution (Catalase)
   A solution of catalase can be made from fresh calf’s liver. Use the following procedure:
   - Macerate a small 2 – 3 cm\(^2\) piece of fresh calf’s liver in a beaker.
   - Add 100 mL of ice cold distilled water and stir.
   - Filter the mixture through cheesecloth. The color of the resulting filtrate should be light pink.
   - An alternative source of catalase is raw white potato. Repeat the procedure above using similar size pieces of raw white potato.

3. Set-Up of Erlenmeyer Flask
   - Select an Erlenmeyer flask that can be stoppered snugly with a 1-holed rubber stopper. (A 125 mL flask is recommended, however, a 250 mL flask can be used. If the larger flask is used, the quantities of solutions will have to be doubled.)
   - Insert the glass portion of an eyedropper (pipette) through the hole in the stopper so that the point of the dropper faces up. This set-up will permit the Tygon™ tubing of the CBL probe to fit onto the top of the eyedropper.
STUDENT LAB

A. SETTING UP THE TI-82, CBL, AND PRESSURE SENSOR
   • Connect the CBL unit to the TI-82/83 graphing calculator using the unit-to-unit link cable and the I/O ports located at the bottom edge of each unit.
   • Connect the Vernier Pressure Sensors to the Channel 1 port located at the top edge of the CBL unit.

B. ENTERING THE PROGRAM
   • Press “ON” to turn on your CBL.
   • Press “ON” to turn on your TI-82/83 calculator.
   • Press the PRGM button.
   • Choose “CHEMBIO” from the menu.
   • Press ENTER three times.

C. SETTING UP PROBES
   • Choose “SET UP PROBES.”
   • “ENTER NUMBER OF PROBES” will appear. Press “1” and then ENTER.
   • Choose “PRESSURE” for type of probe.
   • “USE LOWEST AVAILABLE CHANNELS. ENTER CHANNEL NUMBER” will appear. Press “1” and then ENTER.
   • Choose “USE STORED” to set calibration. Press ENTER.
   • Choose “mmHg” for units.

*** BEFORE PROCEEDING, PLEASE READ THE INFORMATION BELOW ***

RUNNING THE EXPERIMENT
D. Time Set up
   • Choose “COLLECT DATA.” Press ENTER.
   • Choose “TIME GRAPH.” Press ENTER.
   • “TIME BETWEEN SAMPLES IN SECONDS” will appear. Press “2” and then press ENTER.
   • “NUMBER OF SAMPLES” will appear. Press “90” and then press ENTER.
   • “SAMPLE, TIME 2.00 S: SAMPLES 90; EXPERIMENT LENGTH 180.00 S” will appear. Press ENTER.
   • Choose “USE TIME SETUP.” Press ENTER.
   • “SET Y-AXIS Ymin=” will appear. Press “700” and then press ENTER.
   • “Y max=” will appear. Press “1100” and then press ENTER.
   • “Y scl=” will appear. Press “50” and then press ENTER.
   • “PRESS ENTER TO BEGIN COLLECTING DATA” will appear . . . BUT . . .

Don’t press ENTER ... not yet!!!
D. Using a 10 mL pipette and pump, place 10 mL of 1.5% hydrogen peroxide solution into the 125 mL flask (or use 20 mL H₂O₂ in a 250 mL flask). Attach the Tygon™ tubing of the PRESSURE probe to the glass tube in the rubber stopper. Open the valve so that the vial and outside air are continuous (the stopcock should be parallel to the Tygon™ tubing and facing the pressure sensor box). (The blue nozzle will be parallel to the tubing rubber.)

E. Using a 1 mL pipette and pump, add 1 mL (or 2 mL if using 20 ml H₂O₂) of catalase solution to the flask. Cover the flask with the stopper/glass tube/Tygon™ tubing apparatus.

G. Close the valve (turn the blue stopcock so that it is perpendicular to the Tygon™ tubing) and press **ENTER** to start the experiment. The CBL/Calculator/TI-82 will take and display the pressure readings every 2 seconds. Do not move the apparatus since movement may cause small pressure fluctuations.

H. When the CBL reads DONE, the experiment is over. The calculator screen will show “TIME IN L₁ ; Pressure in L₂.”

I. Press **ENTER** to see a rough copy of the graph. Please show this graph to your teacher to determine if the procedure needs to be repeated.

J. To see data from the 90 points that were collected, press **ENTER**. When the screen asks if you want to repeat, press NO. At the next menu press “QUIT.” You should now have a blank screen.

K. On the calculator, press “STAT”; under the new menu, choose “EDIT”. Your data should appear under L₁ and L₂. Take the calculator to the computer to create a graph that can be printed out.

**TRANSFERRING DATA FROM TI-82/83 CALCULATORS TO GRAPHICAL ANALYSIS**

1. Connect the GraphLink™ cable to the modem (phone) serial port on the back of the computer.

2. Start up the Graphical Analysis™ program (Mac version 2.0.3 or higher) on the computer.

3. Firmly insert the GraphLink™ cable into the data port on the calculator.

4. On the computer, pull down the menu under “File to Import” from TI-82/83/85.

5. On the calculator, press the **2nd** key, then the “LINK” key.
If you are using a TI-82:

1. Choose “2: SelectAll-“
2. Mark the Lists you want to send by moving the them with the arrows, and pressing the ENTER key. A mark will appear next to the marked lists.
3. Use the ► key to move over to “TRANSMIT.”
4. Press the ENTER key to send the data to the computer.

If you are using a TI-83:

1. Choose Lists
2. Mark the Lists you want to send by moving the cursor you them with the arrows, and pressing the ENTER key. A mark will appear next to the marked lists.
3. Use the ►key to move over to “TRANSMIT.”
4. Press the ENTER key to send the data to the computer.

GRAPHICAL ANALYSIS

1. You will need to rename the axis and add labels.
2. Click on “L1”, in the Data window. Type the label for the X axis.
3. In the box below, add the units for the X axis.
4. Repeat for the data in the next column (possibly L2) for the Y axis.
5. Rename your graph using “Rename Graph” under the “GRAPH” menu. If you are printing on a network or shared printer, add your initials to the graph title.
6. To fit a regression line to linear data select “Regression Line” and/or “Regression Statistics” from under the “GRAPH” menu.
7. You can have the “Graphical Analysis” feature automatically fit a curve to the data. Select “Automatic Curve Fit” under the “ANALYZE” menu.
RESCALING AXES

1. Click once on the number at the end of each axis.
2. Enter a new value. Graphical Analysis will automatically rescale the axis.

PRINTING

1. Graphical Analysis will print the active window. To make a window active, just click on it.
2. Select “Print Graph” from the “FILE” menu.

CREATING MULTIPLE GRAPHS ON GRAPHICAL ANALYSIS

1. To create another line on your graph, you need to download data to a “New Data Set”. Create this set by using the command under the “DATA” menu.
2. Graphical Analysis will create a new line with new point protectors. To enhance your graph, add a legend to your graph. The command is under the “GRAPH” menu.
3. Rename your data sets to improve your graph (check under the “DATA” menu).
QUESTIONS

1. How is pressure used in this experiment? What is the pressure really measuring?

2. Relate the shape of the graph to the amount of O₂ released and the amount of H₂O₂ broken down.

3. If you continued the lab without disturbing the set up for 2 minutes longer, what prediction could you make about the shape of the graph?

4. The shape of the graph will change if changes are made in the H₂O₂ or catalase solutions.
   • Identify the changes that could be made in each solution.
   • Explain how each change will affect the shape of the graph.
EXPLORATION (Alternative)
“Proof of Enzyme Action”

Rationale:
- To explore the effect of an enzyme on its substrate.

Time:
- Approximately 45 minutes

Objectives:
- To use models to demonstrate the effect of an enzyme on its substrate (starch molecules will be broken down into their component monosaccharide units).
- To use Benedict’s solution to test for the presence of starch and glucose
- To look for evidence of enzyme action by testing an starch/amylase solution

Materials:
- starch solution
- Benedict’s solution
- iodine solution
- amylase
- hot plate
- see lab for additional materials

Overview:
- Students will use models to illustrate enzyme action.
- Students will test a starch solution with iodine and Benedict’s solution
- Students will test a starch/amylase solution with iodine and Benedict’s solution


IV. EXTENSION
“Enzyme Action: Testing Catalase Activity”

**Rationale:**
- To explore the effect of changes in enzyme concentration, temperature, and pH on enzyme activity

**Time:**
- Approximately 45 minutes

**Objectives:**
- To test the effect of the concentration of catalase on the enzymatic breakdown of hydrogen peroxide
- To test the effect of pH on the enzymatic breakdown of hydrogen peroxide
- To test the effect of temperature on the enzymatic breakdown of hydrogen peroxide

**Materials:**
- CBL/TI system
- Vernier Biology Gas Pressure Sensor
- temperature probe or thermometer
- hydrogen peroxide
- fresh calf’s liver
- water bath
- pH buffers (4, 7, and 10)
- see lab for additional materials

**Overview:**
- Student groups will measure the effect of enzyme concentration, pH, or temperature on the breakdown of hydrogen peroxide by catalase.
- Data will be shared among groups.
- Students will compare experimental results to conditions normally found in the human body.

**Procedure:**

V. Evaluation
“Factors That Affect the Activity of Enzymes”

A student conducted an experiment to measure the reaction rate of the enzyme catalase on a solution of hydrogen peroxide. In this reaction, the enzyme facilitates the breakdown of hydrogen peroxide into water and oxygen. The reaction is illustrated by the following chemical equation:

\[ 2\text{H}_2\text{O}_2 \rightarrow 2\text{H}_2\text{O} + \text{O}_2 \]

The release of oxygen causes a change in pressure which can be measured by a CBL apparatus. Data from this reaction are shown in the table below.

**THE CHANGE IN PRESSURE CAUSED BY THE REACTION OF CATALASE AND HYDROGEN PEROXIDE**

<table>
<thead>
<tr>
<th>Time (seconds)</th>
<th>Pressure (mm Hg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>4</td>
<td>16</td>
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<tr>
<td>6</td>
<td>24</td>
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</tr>
<tr>
<td>16</td>
<td>48</td>
</tr>
<tr>
<td>18</td>
<td>48</td>
</tr>
</tbody>
</table>

- Use the data provided to construct a line graph of this reaction. Be sure to include all of the elements specified on the “Scoring Criteria for Graphs” sheet.

- Next, select one of the following variables and describe how it would affect the rate of the reaction.

**Variables:**

A. The temperature drops
B. The pH drops
C. The substrate concentration increases

- Finally, draw a dashed line on the graph to illustrate the change that would occur.
ASSESSMENT ITEMS

Selected Response Items (SRs)

1. **Measures CLGs 3.1.2, 3.2.2**
   Which of these factors would cause a decrease in the enzyme activity of bacteria that live in hot springs where the temperature is 95°C and the normal pH is between 2 and 4?
   A introducing the enzyme sucrase into the hot springs
   B placing the bacteria into an environment of pH 3
   C moving the bacteria to a temperature of 37°C
   D agitating the water in the hot springs

   Correct Response: C

2. **Measures CLGs 1.7.1, 3.1.1**
   Many people lack the enzyme that allows them to digest lactose, a sugar that is found in dairy products. These people are referred to as “lactose-intolerant.” The enzyme that will allow them to digest lactose is
   A amylase
   B galactase
   C lactase
   D protease

   Correct Response: C

Brief Constructed Response Items (BCRs)

1. **Measures CLGs 1.2.5, 1.5.1, 3.1.2, 3.2.2**
   A change in temperature from 37°C to 45°C would affect the activity of catalase, a common enzyme found in liver.
   • Describe how the structure of the enzyme would be affected
   • Describe how the function of the enzyme would be affected

   **Answer Cues:** Students should discuss the idea that if this increase in temperature were to occur, the enzyme would be denatured thus rendering it inactive. The 3-D structure of the enzyme would be changed. Students may also say that the shape of the active site would be changed. They may also relate this to the lock and key activity completed in the Engagement section where the shape of the key determines its fit into the lock.
2. **Measures CLGs 1.4.8, 1.5.1, 3.1.1**

Construct a possible model for the enzyme that could break down Molecule A drawn below. Describe why this same enzyme cannot break down Molecule B.

![Molecule A](image1)

![Molecule B](image2)

**Answer Cues:** Students should sketch an enzyme that “fits” the given model of Molecule A. Students should also discuss why this enzyme cannot break down Molecule B. This explanation should discuss the specificity of enzymes, a certain enzyme can only bind to a specific substrate.

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**Extended Constructed Response Item (ECR)**

1. **Measures CLGs 1.4.1, 1.4.2, 1.5.2, 3.1.1, 3.1.2**

Enzymes function in a narrow range of pH.

- Describe the effect of a change in pH on the activity of a particular enzyme.
- Construct a graph which shows the expected change in activity. Be sure to include all of the elements specified on the “Scoring Criteria for Graphs” sheet.

**Answer Cues:** The graph should be appropriately labeled and the line should show a drop in enzyme activity as the pH changes. The description should explain the idea that a change in pH will denature the enzyme resulting in decreased enzymatic activity. The enzyme activity curve should be placed over the appropriate pH values on the X-axis.