Experiment
31C
Photosynthesis and Respiration

Plants make sugar, storing the energy of the sun into chemical energy, by the process of photosynthesis. When they require energy, they can tap the stored energy in sugar by a process called cellular respiration.

The process of photosynthesis involves the use of light energy to convert carbon dioxide and water into sugar, oxygen, and other organic compounds. This process is often summarized by the following reaction:

$$6\ H_2O + 6\ CO_2 + \text{light energy} \rightarrow C_6H_{12}O_6 + 6\ O_2$$

Cellular respiration refers to the process of converting the chemical energy of organic molecules into a form immediately usable by organisms. Glucose may be oxidized completely if sufficient oxygen is available by the following equation:

$$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ H_2O + 6\ CO_2 + \text{energy}$$

All organisms, including plants and animals, oxidize glucose for energy. Often, this energy is used to convert ADP and phosphate into ATP.

OBJECTIVES

In this experiment, you will

- Use an O_2 Gas Sensor to measure the amount of oxygen gas consumed or produced by a plant during respiration and photosynthesis.
- Use a CO_2 Gas Sensor to measure the amount of carbon dioxide consumed or produced by a plant during respiration and photosynthesis.
- Determine the rate of respiration and photosynthesis of a plant.

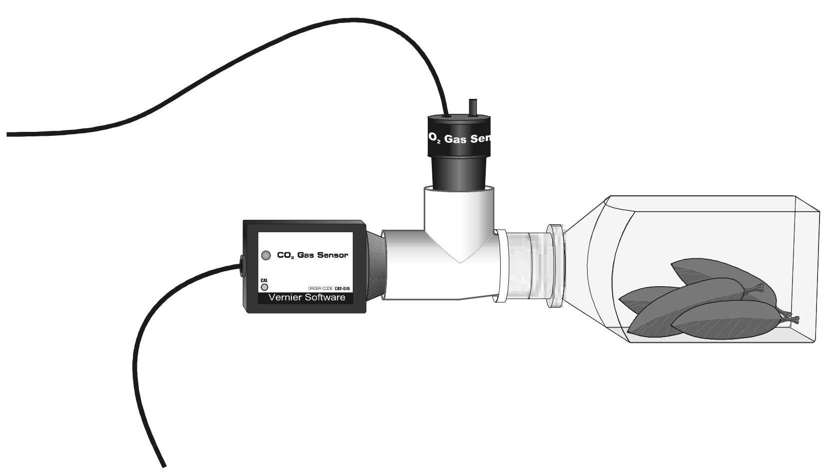


Figure 1

MATERIALS

TI-83 Plus or TI-84 Plus graphing calculator
EasyData application
data-collection interface
Vernier O_2 Gas Sensor
Vernier CO_2 Gas Sensor
CO2–O2 Tee
250 mL respiration chamber
plant leaves
500 mL tissue culture flask
lamp
aluminum foil
forceps

PROCEDURE

1. Turn on the calculator and connect it to the data-collection interface. Connect the O_2 Gas Sensor to Channel 1 of the interface and the CO_2 Gas Sensor to Channel 2.

2. Set up EasyData for data collection.
   a. Start the EasyData application if it is not already running.
   b. Select (File) from the Main screen, and then select **New** to reset the application.
   c. Select (Setup) from the Main screen, then select **Time Graph…**
   d. Select (Edit) on the Time Graph Settings screen.
   e. Enter **15** as the time between samples in seconds and select (Next).
   f. Enter **40** as the number of samples and select (Next) (data will be collected for 10 minutes).
   g. Select (OK) to return to the Main screen.

3. Obtain several leaves from the resource table and blot them dry, if damp, between two pieces of paper towel.

4. Place the leaves into the respiration chamber, using forceps if necessary. Wrap the respiration chamber in aluminum foil so that no light reaches the leaves.

5. Insert the CO_2–O_2 Tee into the neck of the respiration chamber. Place the O_2 Gas Sensor into the CO_2–O_2 Tee as shown in Figure 1. Insert the sensor snugly into the Tee. The O_2 Gas Sensor should remain vertical throughout the experiment. Place the CO_2 Gas Sensor into the Tee directly across from the respiration chamber as shown in Figure 1. Gently twist the stopper on the shaft of the CO_2 Gas Sensor into the chamber opening. Do not twist the shaft of the CO_2 Gas Sensor or you may damage it.

6. Wait two minutes, then select (Start) to begin data collection. Data will be collected for 10 minutes. Note: The graph may not show the slight change in O_2 level that occurs during the experiment.

7. When data collection has finished, remove the aluminum foil from around the respiration chamber.

8. Fill the tissue culture flask with water and place it between the lamp and the respiration chamber. The flask will act as a heat shield to protect the plant leaves.

9. Turn the lamp on. Place the lamp as close to the leaves as reasonable. Do not let the lamp touch the tissue culture flask.

10. When data collection is complete, a graph of O_2 *vs*. time will be displayed. Sketch a copy of your graph in the Graph section below. When finished, select (Plots), then select **CH2:CO2 Gas(ppm) vs time** to view the graph of CO_2 *vs*. time. Sketch a copy of your graph in the Graph section below.

11. Perform a linear regression to calculate the rate of respiration/photosynthesis.
    a. View the O_2 *vs*. time again by selecting (Plots), then **CH1:O2 Gas(ppm) vs time**.
    b. Select (Anlyz), and then select **Linear Fit**.
    c. The linear-regression statistics for these two lists are displayed for the equation in the form:

$$y=ax+b$$

    d. Enter the value of the slope, *a*, as the rate of respiration/photosynthesis in Table 1.
    e. Select (OK) to view a graph of the data and the regression line.
    f. Select (Plots), select **CH2:CO2 Gas(ppm) vs time**, then repeat Steps 11b–11e to calculate the respiration/photosynthesis rate using the data from the CO_2 Gas Sensor.

12. Select (Main) to return to the Main screen, then repeat Steps 6–11 to collect data with the plant exposed to light. **Note**: After selecting (Start), select (OK) to start collecting data. Your stored data will not be overwritten.

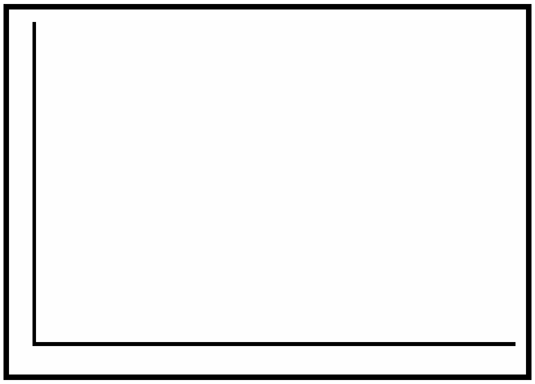
13. Remove the plant leaves from the respiration chamber, using forceps if necessary. Clean and dry the respiration chamber.

DATA

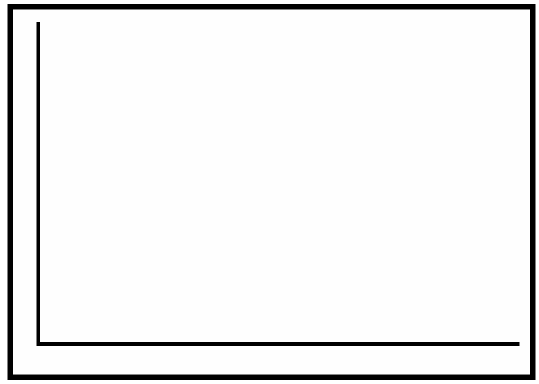
Table 1		
Leaves	O_2 rate of production/consumption (ppt/s)	CO_2 rate of production/consumption (ppt/s)
In the dark		
In the light		

GRAPHS

Darkness

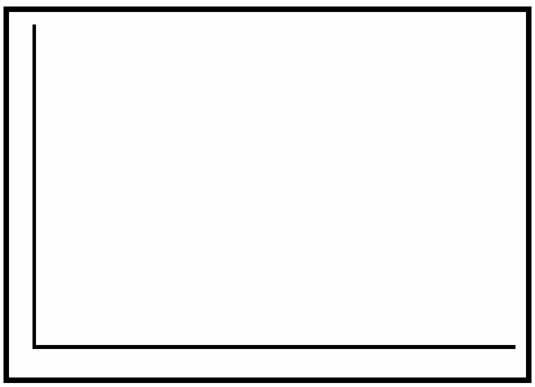


O_2 Gas *vs*. Time

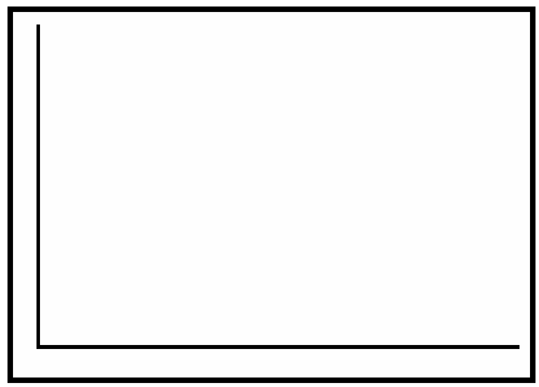


CO_2 Gas *vs*. Time

Light



O_2 Gas *vs*. Time



CO_2 Gas *vs*. Time

QUESTIONS

1. Were either of the rate values for CO_2 a positive number? If so, what is the biological significance of this?
2. Were either of the rate values for O_2 a negative number? If so, what is the biological significance of this?
3. Do you have evidence that cellular respiration occurred in leaves? Explain.
4. Do you have evidence that photosynthesis occurred in leaves? Explain.
5. List five factors that might influence the rate of oxygen production or consumption in leaves. Explain how you think each will affect the rate?

EXTENSIONS

1. Design and perform an experiment to test one of the factors that might influence the rate of oxygen production or consumption in Question 5.
2. Compare the rates of photosynthesis and respiration among various types of plants.

TEACHER INFORMATION

Experiment
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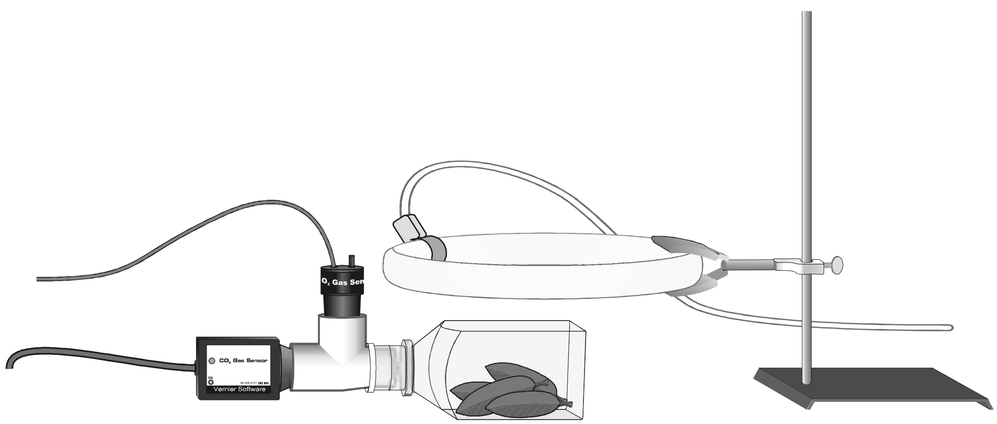
Photosynthesis and Respiration

1. This activity can be performed with calculators from the TI-83 Plus or TI-84 Plus families and a LabPro or CBL 2. It can not be performed with Easy products because the CO_2 Gas Sensor is not supported by EasyLink.
2. Spinach leaves purchased from a grocery store work very well and are readily available any time of the year. For best results, keep the leaves cool until they are to be used. Just before use, expose the leaves to bright light for 5 minutes.
3. A fluorescent ring lamp works very well since it bathes the plant in light from all sides and it gives off very little heat. When using a ring lamp as shown below, it is not necessary to use a heat shield.



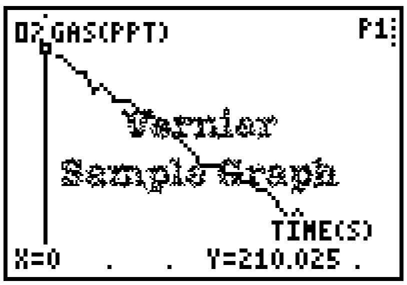
4. If tissue culture flasks are not available, a beaker or flask of water will also work. The tissue culture flask is very thin, however, and will allow leaves to receive much more light from the same lamp.
5. To extend the life of the O_2 Gas Sensor, always store the sensor upright in the box in which it was shipped.
6. The waiting time before taking data may need to be adjusted depending on the rate of diffusion of the oxygen gas and the carbon dioxide gas. Monitor the gas concentrations and start collecting data when the levels of gas begin to move in the correct direction.
7. The stopper included with the CO_2 Gas Sensor is slit to allow easy application and removal from the probe. When students are placing the probe in the CO_2–O_2 Tee, they should gently twist the stopper into the adapter opening. Warn the students not to twist the probe shaft or they may damage the sensing unit.
8. To conserve battery power, we suggest that AC Adapters be used to power the interfaces rather than batteries when working with the CO_2 Gas Sensor. An AC Adapter is shipped with each LabPro interface at the time of purchase. If you are using the CBL 2, you can purchase a Vernier AC Adapter (order code: IPS).

SAMPLE RESULTS

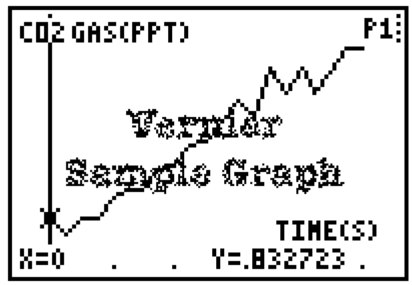
Table 1		
Leaves	O_2 rate of production/consumption (ppt/s)	CO_2 rate of production/consumption (ppt/s)
In the dark	xxxx	xxxx
In the light	xxxx	xxxx

GRAPHS

Darkness

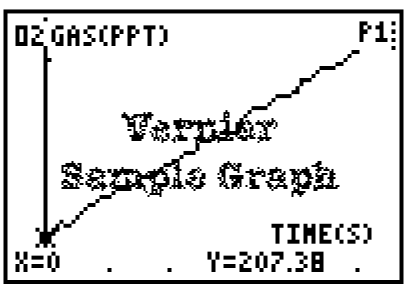


O_2 Gas vs. *Time*

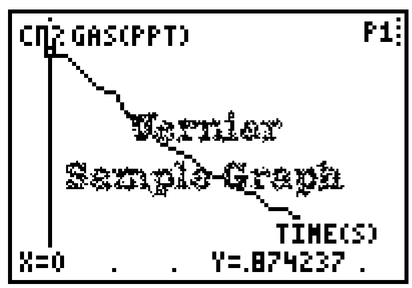


CO_2 Gas vs. *Time*

Light



O_2 Gas vs. *Time*



CO_2 Gas vs. *Time*

ANSWERS TO QUESTIONS

Answers have been removed from the online versions of Vernier curriculum material in order to prevent inappropriate student use. Graphs and data tables have also been obscured. Full answers and sample data are available in the print versions of these labs.