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.

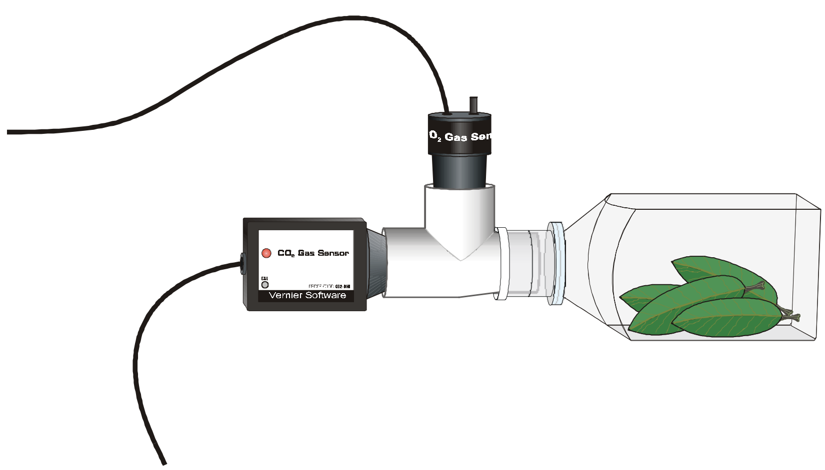


Figure 1

MATERIALS

LabPro or CBL 2 interface
TI Graphing Calculator
DataMate program
Vernier O_2 Gas Sensor
Vernier CO_2 Gas Sensor
CO_2–O_2 Tee
250-mL respiration chamber
plant leaves
500-mL tissue culture flask
lamp
aluminum foil
forceps

PROCEDURE

1. Plug the O_2 Gas Sensor into Channel 1 and the CO_2 Gas Sensor into Channel 2 of the LabPro or CBL 2 interface. Use the link cable to connect the TI Graphing Calculator to the interface. Firmly press in the cable ends.

2. Turn on the calculator and start the DATAMATE program. Press CLEAR to reset the program.

3. Set up the calculator and interface for an O_2 Gas Sensor and CO_2 Gas Sensor.
   a. Select SETUP from the main screen.
   b. If the calculator displays an O_2 Gas Sensor in CH 1 and a CO_2 Gas Sensor in CH2, proceed directly to Step 4. If it does not, continue with this step to set up your sensors manually.
   c. Press ENTER to select CH 1.
   d. Select OXYGEN GAS from the SELECT SENSOR menu.
   e. Select parts per thousand (PPT) as the unit.
   f. Press ▼ once, then press ENTER to select CH2.
   g. Select CO2 GAS from the SELECT SENSOR menu.
   h. Select parts per thousand (PPT) as the unit.

4. Set up the data-collection mode.
   a. To select MODE, press ▲ (the up arrow key) twice and press ENTER.
   b. Select TIME GRAPH from the SELECT MODE menu.
   c. Select CHANGE TIME SETTINGS from the TIME GRAPH SETTINGS menu.
   d. Enter “15” as the time between samples in seconds.
   e. Enter “40” as the number of samples (data will be collected for 10 minutes).
   f. Select OK twice to return to the main screen.

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

6. 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.

7. 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.

8. Wait two minutes, then select START to begin data collection. Data will be collected for 10 minutes.

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

10. 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.

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

12. Press ENTER to view the graph of O2 GAS VS. TIME. Sketch a copy of your graph in the Graph section below. When finished, press ENTER to return to the graph menu.

    Press ▼ once, then press ENTER to view the graph of CO2 GAS VS. TIME. Sketch a copy of your graph in the Graph section below. When finished, press ENTER to return to the graph menu. Select MAIN SCREEN from the graph menu.

13. Perform a linear regression to calculate the rate of respiration/photosynthesis.

    a. Select ANALYZE from the main screen.
    b. Select CURVE FIT from the ANALYZE OPTIONS menu.
    c. Select LINEAR (CH 1 VS TIME) from the CURVE FIT menu.
    d. The linear-regression statistics for these two lists are displayed for the equation in the form:

    $$Y=A*X+B$$

    e. Enter the value of the slope, *A*, as the rate of respiration/photosynthesis in Table 1.
    f. Press ENTER to view a graph of the data and the regression line.
    g. Press ENTER to return to the ANALYZE menu.
    h. Repeat Steps 13b – 13g to calculate the respiration/photosynthesis rate using the data from the CO_2 Gas Sensor (CH 2 VS TIME).
    i. Select RETURN TO MAIN SCREEN from the ANALYZE menu.

14. Repeat Steps 8 – 13 to collect data with the plant exposed to light.

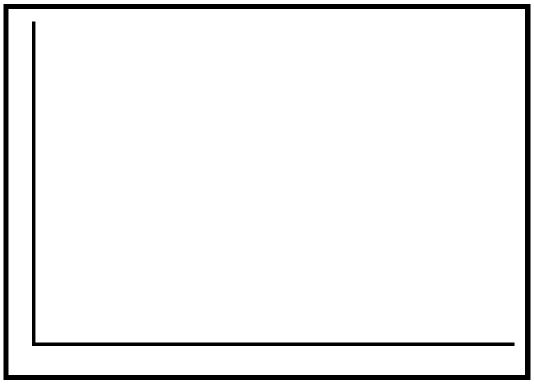
15. Remove the plant leaves from the respiration chamber, using forceps if necessary. Clean and dry the respiration chamber.

DATA

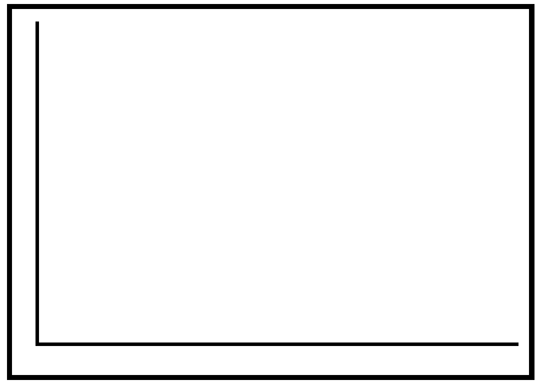
Table 1		
Leaves	O_2 rate of production/consumption (ppt/s)	CO_2 rate of production/consumption (ppt/s)
In the dark		
In the light		

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.

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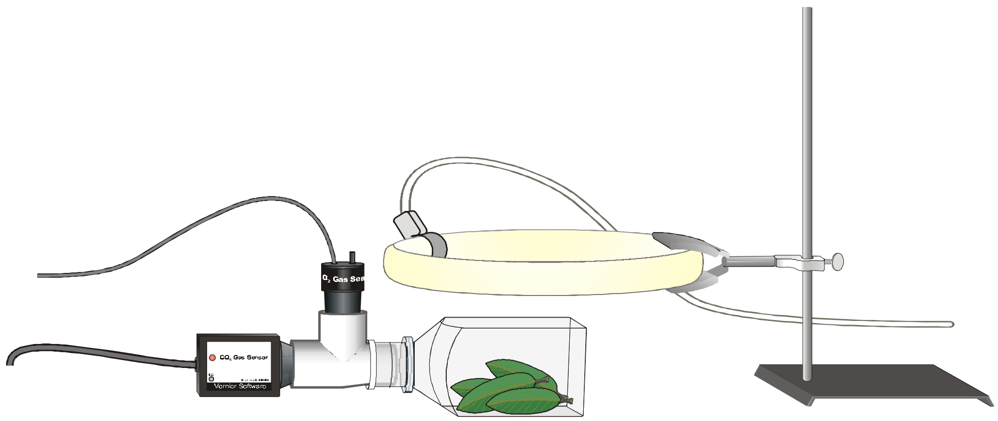
TEACHER INFORMATION

Photosynthesis and Respiration

1. 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.

2. 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.



3. 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.

4. To extend the life of the O_2 Gas Sensor, always store the sensor upright in the box in which it was shipped.

5. 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.

6. 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.

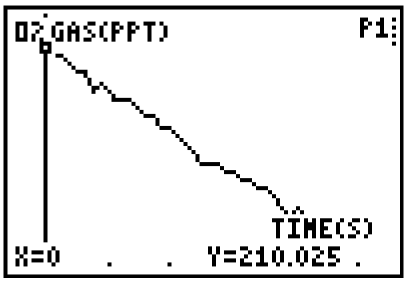
7. To conserve battery power, we suggest that AC Adapters be used to power the interfaces rather than batteries when working with the CO2 Gas Sensor. An AC Adapter is shipped with each LabPro interface at the time of purchase. If you are using the CBL 2, you can purchase a Vernier AC Adapter for $10 (order code–IPS).

SAMPLE RESULTS

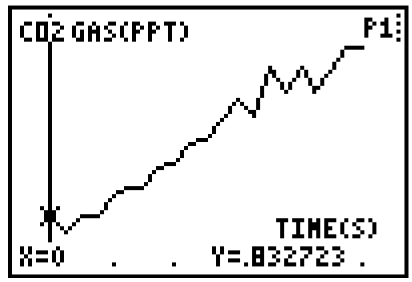
Table 1		
Leaves	O_2 rate of production/consumption (ppt/s)	CO_2 rate of production/consumption (ppt/s)
In the dark	-0.0023	0.00065
In the light	0.0045	-0.00126

GRAPHS

Darkness

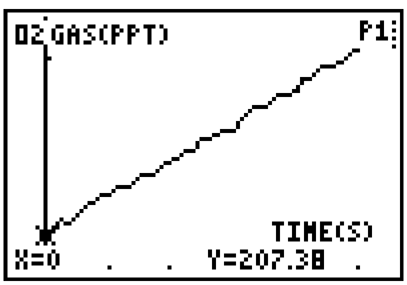


O_2 Gas vs. *Time*

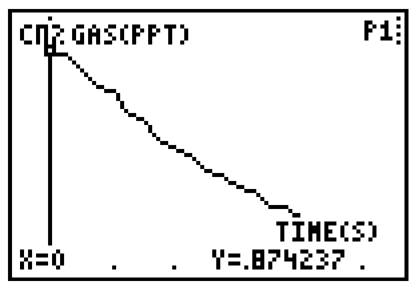


CO_2 Gas vs. *Time*

Light



O_2 Gas vs. *Time*



CO_2 Gas vs. *Time*

ANSWERS TO QUESTIONS

1. The CO_2 rate value for leaves in the dark was a positive number. The biological significance of this is that CO_2 is produced during respiration. This causes the concentration of CO_2 to increase, as sugar is oxidized and broken into CO_2, water, and energy.

2. The O_2 rate value for leaves in the dark was a negative number. The biological significance of this is that O_2 is consumed during cellular respiration. This causes the concentration of O_2 to decrease as glucose is oxidized for energy.

3. Yes, cellular respiration occurred in leaves, since O_2 decreased when leaves were in the dark and photosynthesis was not possible.

4. Yes, photosynthesis occurred in leaves, since O_2 increased when leaves were exposed to light.

5. Answers may vary. They might include:

   a. A greater number of leaves should increase the rate, since there are more chloroplasts to undergo photosynthesis and more cells to require energy through cellular respiration.
   b. A greater light intensity will increase the rate of photosynthesis. It may not affect the rate of cellular respiration, however.
   c. A cooler room may decrease both rates, as cellular metabolism decreases in cooler weather.
   d. Facing the top of the leaves toward the light should increase the rate of photosynthesis, since the chloroplasts are closer to the light source.
   e. If the plants overheat due to the heat from the lamp, they may wilt and stop functioning. This will decrease all rates.
   f. If there are too many leaves, diffusion may be restricted and prevent accurate readings. This may apparently decrease both rates.