

Experiment B-10 Photosynthesis



Objectives

- To observe changes in CO₂ levels during photosynthesis and respiration in different conditions.
- To learn about gross and net photosynthesis rates.

Modules and Sensors

- PC + NeuLog application
- USB-200 module 
- NUL-220 CO₂ logger sensor 
- BAT-200 Battery unit  (optional)

Equipment and Accessories

- | |
|--------------------------------------------------------------------------|
| ▪ Glass bottle for the CO ₂ sensor (included with the sensor) |
| ▪ Table lamp |
| ▪ Florescent bulb |

Materials

▪ Group of leaves	2
▪ 30 cm of aluminum foil	1

Introduction

Photosynthesis is a process that occurs in the chloroplasts of plants and algae, and in some bacteria species. During this process solar energy is transformed into chemical energy that can be used by biological systems.

In photosynthesis, CO₂ is reduced to carbohydrates (especially starch and sugar) in a complex set of reactions. The electrons for the reduction reaction come from H₂O, which is oxidized to O₂. Light provides the energy for that oxidation and is absorbed by pigments. In this photosynthesis reaction, the carbohydrate product is glucose:

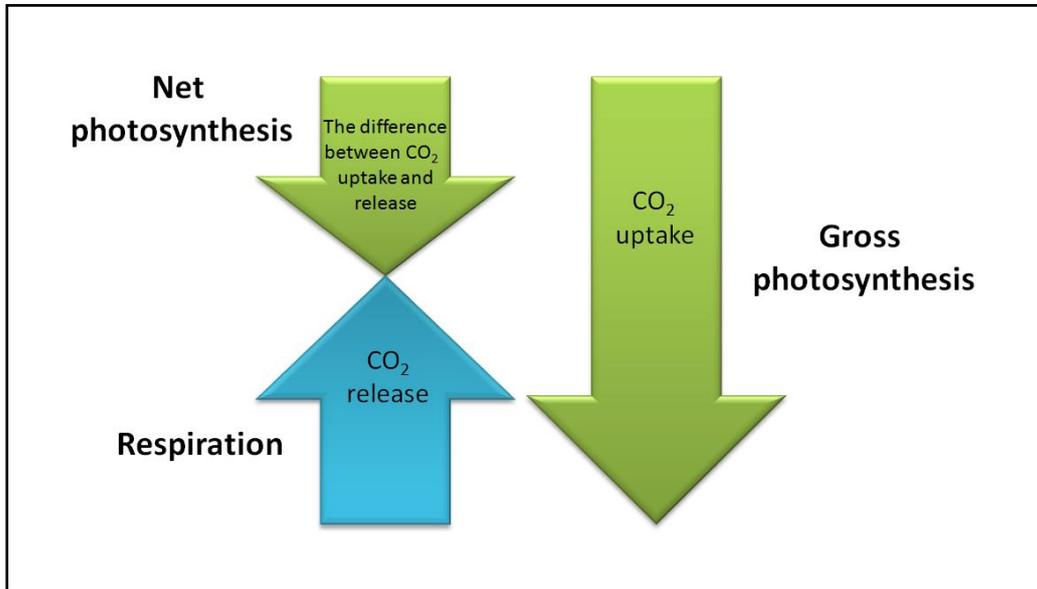


In cellular respiration, chemical energy stored in carbohydrates turns into energy that can be used by the cell in the form of ATP (adenosine triphosphate). Cellular respiration (with or without the presence of oxygen) occurs in all living cells.

The chemical reaction for cellular respiration (with glucose) is the mirror image of the chemical reaction for photosynthesis:



The rate of photosynthesis can be expressed as either gross or net rates. **Gross photosynthesis** is the total rate of carbon fixation (reduction of CO_2) without considering that some of the CO_2 is lost in respiration. **Net photosynthesis** is the carbon fixation rate minus the rate of CO_2 loss in respiration.



In this experiment, we will measure the respiration and photosynthesis processes of plant leaves. Respiration will be measured in the dark (photosynthesis cannot occur without any light) and net photosynthesis will be measured under two light conditions (respiration and photosynthesis occur at the same time). We will also calculate the gross photosynthesis; we will get negative values for the photosynthesis rates, so we will subtract the respiration rates from the net photosynthesis rates in order to get gross photosynthesis rates.

Procedure

Experiment setup

1. Set up the experiment as shown in the picture below.



2. Take two equal groups of green leaves from a plant (the type of leaves should be checked beforehand by the teacher). The first group is for the following experiment, and the second group is for the challenge experiment.
3. Wrap the bottle with aluminum foil so that no light can get in it.

Sensor setup

4. Connect the USB-200 module  to the PC.
5. Check that the CO₂ sensor  is connected to the USB-200 module.

Important:

You must wait at least 30 minutes after connecting the sensor to the USB-200 module or to the battery module before beginning offsetting and measurements.

Note:

The following application functions are explained in short. It is recommended to practice the NeuLog application functions (as described in the user manual) beforehand.

6. Run the NeuLog application and check that the CO₂ sensor is identified.

Settings

7. Click on the **On-line Experiment** icon  in the NeuLog main icon bar.
8. Click on the **Experiment Setup** icon  and set the:

Experiment duration to 40 minutes
Sampling rate to 30 per minute

Testing and measurements

9. When offsetting the sensor, the value is set to 380 ppm which is the outdoor air value of CO₂ in most locations. It is recommended to offset the sensor outside (you can get it out through a window) to avoid a shift in the values (if you choose to offset the sensor indoors the calculated rates will still be correct).
10. After the sensor was connected to the USB-200 module or to a battery module for at least 30 minutes, check that the values are relatively stable (remember that your breathing affects the values). If the values are not stable keep the sensor connected for a while and check again.
11. Go outside, wait a few minutes and offset it as follows (if needed, disconnect the sensor from the USB-200 module and quickly connect it to a battery module).

Press the sensor's offset button continuously (3-5 seconds).

10. Come back inside and make sure again that the CO₂ values are relatively stable (they should be higher than outside).
11. Insert the first group of leaves into the wrapped bottle.

We will measure respiration of the plant in the dark (photosynthesis cannot occur without any light).

12. Close the bottle using the CO₂ probe and wait for three minutes before starting the measurement.



13. Click on the **Run Experiment** icon  to start the measurement.
14. You should see an increase of CO₂.

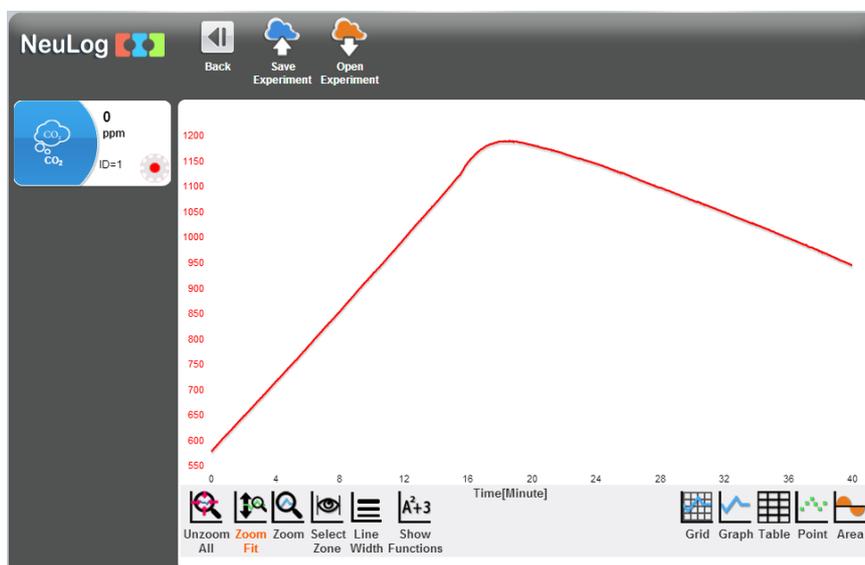
15. After around 15 minutes, take the aluminum foil off and turn on the lamp (the lamp should be around 8 cm from the bottle). The recommended CO₂ values you should see before starting the photosynthesis part are above 1000 ppm (changes among different plants). If the maximum values are less than 1000 ppm, start the experiment again and blow into the bottle before closing it.



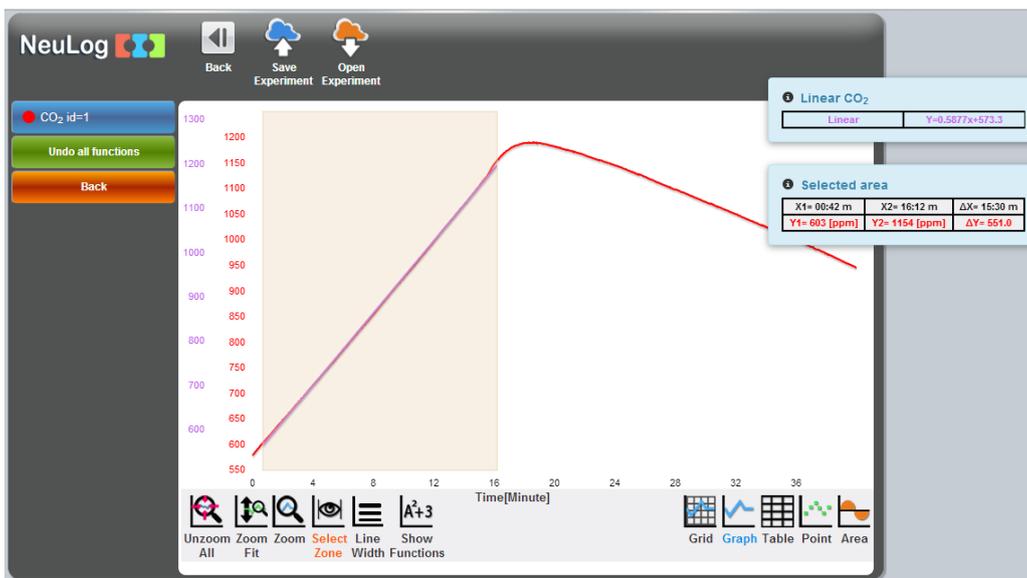
16. Wait until the end of the measurement.

17. Click on the **Zoom fit** icon .

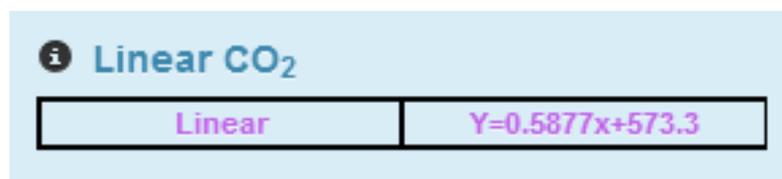
18. Your graph should be similar to the following:



19. Save your graph.
7. To determine the rate of respiration, click on the **Select Zone** icon  and select the linear increase part as in the picture below.
20. Click on the **Show functions** icon , and then click on the CO₂ sensor button on the left of the screen.
21. Click on the **Linear fit** button to get the equation.

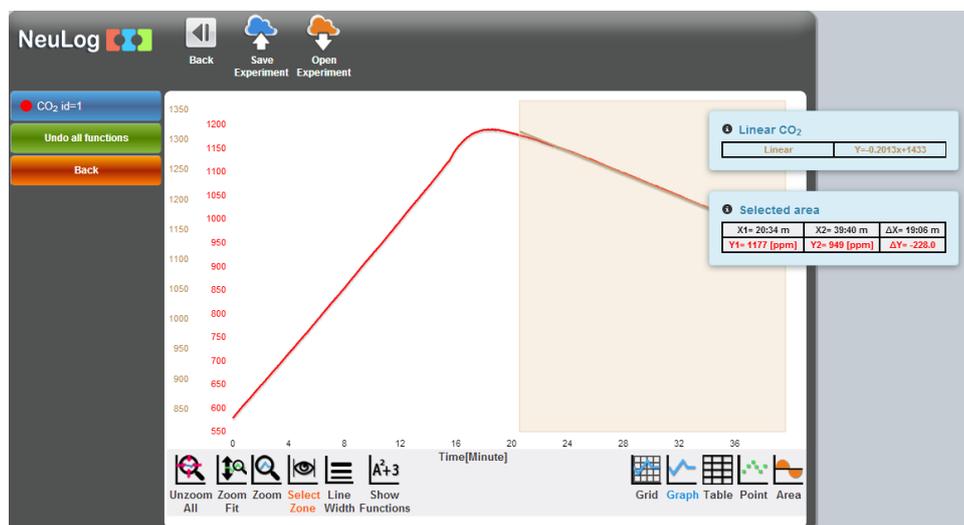


22. The respiration equation for the sample experiment:

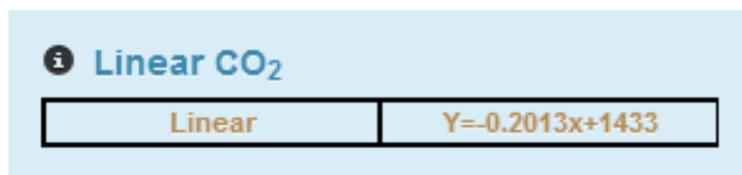


23. The slope of the graph is the rate of respiration in ppm/min.

24. To determine the rate of the net photosynthesis, click on the **Select Zone** icon  and select the linear decrease part as in the picture below.
25. Click on the **Show functions** icon , and then click on the CO₂ sensor button on the left of the screen.
26. Click on the **Linear fit** button to get the equation.



27. The net photosynthesis equation for the sample experiment:



28. The slope of the graph is the rate of net photosynthesis in ppm/min.

In our example the respiration rate is 0.59 ppm/min and the net photosynthesis rate is -0.2 ppm/min. The photosynthesis rate is with a minus sign because the CO₂ decreased.

The gross photosynthesis rate is:

$$-0.2 \text{ ppm/min} - 0.59 \text{ ppm/min} = -0.79 \text{ ppm/min}$$

29. Insert your data into the following table (the challenge part will be explained further on):

Process	Rate of CO ₂ increase/ decrease [ppm/min]
Dark Respiration	
Net photosynthesis	
Gross photosynthesis	
Dark Respiration (Challenge)	
Net photosynthesis (Challenge)	
Gross photosynthesis (Challenge)	

We can see that when leaves are exposed to light, CO₂ production (dark respiration) changes to CO₂ consumption because of the process of photosynthesis (respiration still occurs).

For this experiment we will assume that respiration in the dark is equal to respiration in the light. A linear photosynthesis rate means that the plant has enough CO₂ (above the plants saturation point).

Challenge research

33. Remove the sensor's probe and the leaves from the bottle, shake the bottle a few times for gas exchange with the surrounding air.
34. Observe how the CO₂ reading in the sensor's module box changes back to the initial value (or close to it).
35. Repeat the experiment but now put the lamp closer to the bottle. Before the beginning of the measurement, write at least two hypotheses about the possible effects of changing the distance of the lamp from the leaves on the results. What do you think will actually happen?
36. We measured the respiration and photosynthesis rates of the whole group of leaves. Usually photosynthesis rates are calculated in ppm/min per g. If possible, weigh each group of leaves and calculate the rates per gram.

Summary questions

1. Calculate the gross photosynthesis rate for the first experiment and for the challenge experiment, insert your results into the table.
2. Explain the results of the challenge experiment using your hypotheses.
3. Explain the importance of plants to humans and the environment.