

6. Affect of Light on Photosynthesis Rate – Using an Oxygen Sensor

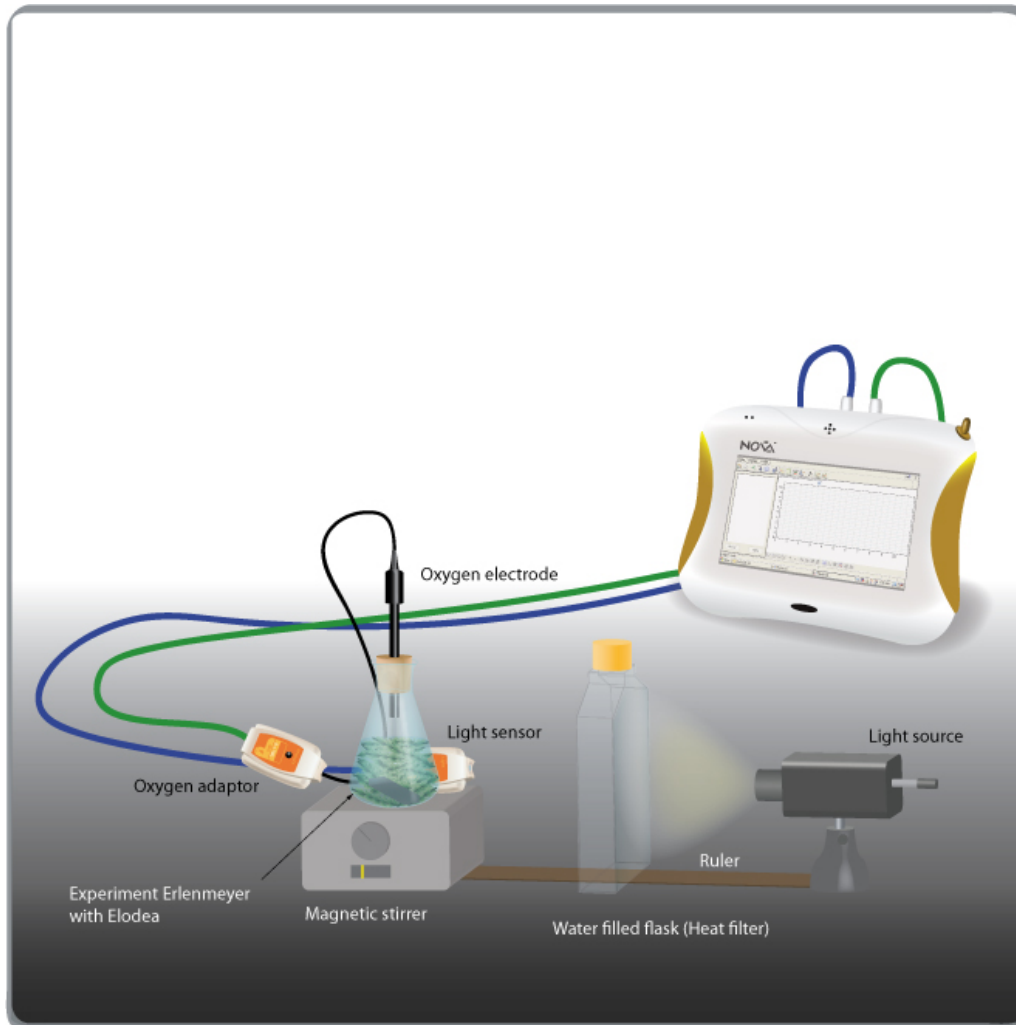


Figure 1

Introduction

Photosynthesis is the fundamental process whereby organic materials, carbohydrates, are produced from inorganic materials: carbon dioxide and water. In this process molecular oxygen is released. Light absorbed by pigments of photosynthetic organisms, such as for example, chlorophyll in green plants is the energy source for this process.



Under optimal conditions of carbon dioxide concentrations and temperature, photosynthesis rate depends on light intensity absorbed by the photosynthetic parts of the organism. Light intensity at different distances from a light source is inversely proportional to the square of the distance.

$$I \propto \frac{1}{R^2}$$

Where I is the light intensity and R is the distance from the light source

In this experiment the light intensity is modified by placing the light source at different distances from the experimental system.

Rate of photosynthesis at various light intensities is measured by following the concentration of oxygen released to the air in the process.

Equipment


- Nova5000
- 9 g of fresh Elodea
- Bright light source (e.g. 150 W halogen lamp)
- 250 ml glass Erlenmeyer
- Rubber cork with a hole that fits the Oxygen sensor or plasticine
- A laboratory jack
- 1 liter flat water jar (glass or plastic) or tissue culture bottles (2)
- Oxygen sensor
- Optional Temperature sensor (-25 °C to 110 °C)
- Light sensor (0 - 300 Klx)
- 0 - 2% Bicarbonate solution

Equipment Setup Procedure

1. Launch MultiLab.
2. Connect the Oxygen sensor (in the range of 25%) to Input 1 (I/O-1) of the Nova5000.

3. Connect the Light sensor to Input 2 (I/O-2) of the Nova5000.
4. Assemble the equipment as illustrated in Figure 1.

The experimental system consists of the following components:

- a. 250 ml transparent glass Erlenmeyer filled with 1% Bicarbonate solution and about 9 g. of fresh Elodea.
 - b. The rate of photosynthesis may vary with the species of plant available and the season of the year. Therefore it is recommended to run one experiment under optimal conditions of light (about 20 cm distance between the light source and the Erlenmeyer) and Bicarbonate concentration (0.5% - 1.0%), before measuring the effect of light intensity on photosynthesis rate.
 - c. Concentration of oxygen released to the free air above the Bicarbonate solution with the plant is followed using the Oxygen sensor in the range of 25%.
 - d. In order to receive a reasonable rate, about 5 ml of free air should be kept in the Erlenmeyer, just enough to fit the Oxygen sensor's tip.
 - e. Keep the tip of the sensor above the solution.
 - f. The Erlenmeyer should be tightly closed to prevent leakage of oxygen, either by a rubber cork with a hole that fits the Oxygen sensor or by covering the Erlenmeyer opening by other means (such as plasticine).
 - g. The Light sensor is mounted behind the Erlenmeyer to measure the light intensity that the Elodea is exposed to.
 - h. Two water jars are placed between the light source and the Erlenmeyer to prevent heating of the Bicarbonate solution, heating that can affect the rate of the process.
5. Click **Setup**  on the main toolbar. Uncheck **Auto Detect Sensors** and select **Oxygen O₂ 0-25%** from the Input 1 drop-down menu. Program the data logger according to the setup specified below.



Data Logger Setup

Sensors:

Input 1: Oxygen (0 – 25%)

Input 2: Light (0 – 300 klx)

Input 3: Temperature (-25 °C to 110 °C)


Rate:



Every second

Samples:

5000 samples

Experimental Procedure

1. In this experiment, rate of photosynthesis is measured at various concentrations of Bicarbonate solution. Choose four to five concentrations of Bicarbonate in the range of 0% - 2%. Start the experiment with 0.5% Bicarbonate solution.
2. Follow temperature levels in the water jar throughout the experiment. If water temperature rises sharply (more than 5 °C in five minutes), stop the measurements and change the water in the jars.
3. Mark a line, about 5 cm below the Erlenmeyer edge.
4. Insert the Elodea to the Erlenmeyer: cut the plant to short pieces and arrange them in parallel to each other to ensure maximal exposure to the light.
5. Fill the Erlenmeyer with Bicarbonate solution up to the line marked.
6. Place the Oxygen sensor and tightly close the Erlenmeyer.
7. It is recommended to illuminate the Erlenmeyer containing the Elodea, for five minutes before the experiment is started. Thereby the solution is saturated with oxygen and oxygen release can be measured immediately when the experiment starts. Otherwise, a lag period of about six minutes is observed.
8. Click **Run**  on the upper toolbar to begin recording data.

9. Start the experiment with the light source at the maximal distance chosen. Make sure the light is directed to the Erlenmeyer.
10. Switch on the light and follow the oxygen percentage level.
11. Follow photosynthesis rate for 5-8 minutes, until a straight line is received. At large distances of the light source the rate may be very low.
12. After 5-8 minutes, turn off the light.
13. Click **Stop**  on the upper toolbar to stop collecting data and save your data by clicking **Save**  on the upper toolbar.
14. Move the light source to the second distance and turn the light on again.
15. Repeat stages 10 - 13 at three to four additional distances.

Data Analysis

1. In this experiment, for 5% Bicarbonate solution a set of linear segments are obtained. Each represents a different distance of the light source from the Erlenmeyer.
2. Use the cursors to select the first segment of the difference graph.


The Cursor: You can display up to two cursors on the graph simultaneously.

Use the first cursor to display individual data recording values, to select a curve or to reveal the hidden Y-axis.

Use two cursors to display the difference between two coordinate values or to select a range of data points.

To display the First cursor: Double click on an individual data point or click First cursor




on the graph toolbar. You can drag the cursor with the mouse onto any other point on the plot, or onto a different plot. For finer cursor movements click **Forward** 



and **Backward**  cursor.

The coordinate values of the selected point will appear in the information bar at the bottom of the graph window.




To display the Second cursor: Double click again anywhere on the graph area or click **Second cursor** .

The information bar will now display the difference between the two coordinate values.

To remove the cursors: Click  to remove the Second cursor and click  to remove the First cursor.

3. Apply a linear fit to the selected segment of the graph:

a. Click **Linear fit**  on the main toolbar. The fit equation will be displayed in the information bar at the bottom of the graph window.

b. The slope of the fit line is the net reaction rate.

4. Repeat steps 1 and 3 for each linear segment of the graph.

An example of the graph, obtained in this experiment, is shown below:

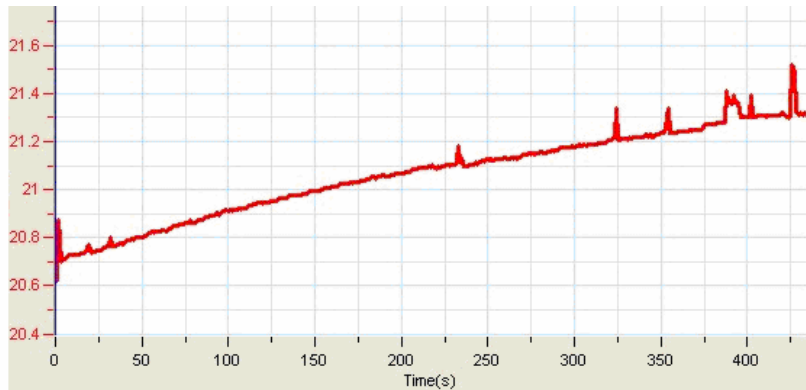


Figure 2

5. Use the cursor to read from the Light graph the light intensity and fill in the following table:

Exp. no	Distance from Light Source (cm)	Slope	Light Intensity (Klx)
1			
2			
3			
4			
5			



6. Use PlanMaker to draw a graph describing the relationship between light intensity and the rate of photosynthesis (slope).
7. Repeat stages 1-6 for each concentration of Bicarbonate solution in the range of 0% - 2%.

Questions

1. How is light intensity modified in this experiment?
2. Describe the effect of light intensity on the rate of photosynthesis.
3. Does the rate depend on light intensity in the whole range of intensities examined?
4. Define the range of intensities in which light is a limiting factor.
5. What can be the effect of a temperature rise in the Erlenmeyer during the experiment?

Further Suggestions

1. The rate of photosynthesis can be followed by measuring oxygen release into the solution. The Oxygen sensor should be defined as DO₂ (Dissolved Oxygen) and a magnetic stirrer should be used to ensure an even distribution of oxygen in the solution. If DO₂ is measured, a successive measurement at various wavelengths is impossible. The solution must be replaced and a different measurement for each wavelength should be performed.
2. Examine the effect of light wavelength on photosynthesis. Place suitable filters (blue, green, red) between the bottles and the light source. Cover the bottles compartment with cartridge box, to prevent penetration of light from sources other than the light source.
3. How will an increase in the mass of Elodea affect the rate of photosynthesis at limiting light intensities?
4. Design an experiment to examine your assumptions.