Photosynthetic Floatation

sead : stem

Subjects

Biology

Topics

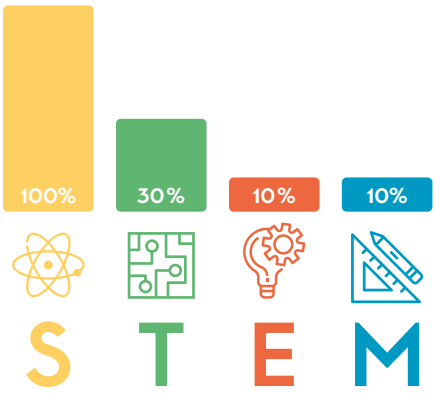
Ecology | Scientific Inquiry | Molecular & Cellular Biology | Measurement | Science as a Process | Physics | Energy | Light

Key Words

Photosynthesis | nature | respiration | buoyancy | plant

Connection to SDG

STEM Chart



Time for Activity

45 minutes

Introduction

Plants occupy a fundamental part of the food chain and the carbon cycle due to their ability to carry out photosynthesis, the biochemical process of capturing and storing energy from the sun and matter from the air. At any given point in this experiment, the number of floating leaf disks is an indirect measurement of the net rate of photosynthesis.

In photosynthesis, plants use energy from the sun, water, and carbon dioxide (CO_2) from the air to store carbon and energy in the form of glucose molecules. Oxygen gas (O_2) is a byproduct of this reaction. Oxygen production by photosynthetic organisms explains why earth has an oxygen-rich atmosphere.

Key Objectives

1. Photosynthetic organisms capture energy from the sun and matter from the air to make the food we eat, while also producing the oxygen we breathe. In this activity, oxygen produced during photosynthesis makes leaf bits float like bubbles in water.

Guiding Questions

1. How long does it take for the first disk to float?
2. How long does it take for half the disks to float? All the disks?

Materials/Preparation

1. Baking soda (sodium bicarbonate)
2. Gram scale
3. Water
4. Liquid dish soap
5. Spoon or other implement (for mixing solution)
6. Soda straw or hole punch
7. Spinach leaves or ivy leaves

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8. 10-mL syringe (without a needle)
9. Clear plastic cup (1-cup size) or 250-mL beaker
10. Incandescent or 100-watt equivalent light-bulb in fixture (preferably with a clamp)
11. Timer
12. Notepaper and pencil (or similar) to record results
13. Optional: ring stand, foil, thermometer, ice, hot water, colored gel filters

Fig 1

Fig 2

Tasks/Procedure

1. Make a 0.1% bicarbonate solution by mixing 0.5 grams baking soda with 2 cups (500 mL) water. Add a few drops of liquid dish soap to this solution and mix gently, trying to avoid making suds in the solution.
2. Using the straw or hole punch, cut out 10 circles from your leaves (see photos below). (Straws work best with spinach; hole punches work best with ivy.)
3. Remove the plunger from the syringe, and remove the cover from the tip, if there is one. Put the leaf disks into the barrel of the syringe, and tap them down to the tip. If you have a straw, you can blow the discs gently into the plunger (see photos below).

Fig 3

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4. Replace the plunger into the syringe, being careful not to touch or damage the leaf disks (see photo).

Fig 4

5. Pour 150 mL of bicarbonate solution into the cup. Try to avoid making suds.

6. Draw about 6–8 mL of bicarbonate solution into the syringe. The leaf disks should float in the solution

Fig 5

7. Hold the syringe with the tip up, and expel the air by gently pushing on the plunger.

8. Plug the tip of the syringe tightly with your finger, and gently pull on the plunger, creating a slight vacuum. You should see tiny bubbles coming out of the leaf disks. Hold the vacuum for a few seconds, and then release the plunger, letting it snap back. Some of the disks should begin to sink.

9. Repeat the previous step several times, until all of the disks have sunk to the bottom of the solution. (You may need to tap on the plunger to release the bubbles in order to make all the leaf disks sink.)

Fig 6

10. When all the leaf disks have settled to the bottom of the solution, carefully remove the plunger and pour the disks and solution into the cup. They should settle to the bottom of the cup. If any leaf disks float, remove them from the beaker.

11. Set up your light fixture so that it is suspended about 12 inches (30 cm) above the table. You may want to use a ring stand for this.

12. Place the beaker under the light fixture (see photo).

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Fig 7

Fig 8

Turn on the light, start a timer, and watch the leaf disks at the bottom of the cup. Notice any tiny bubbles forming around the edges and bottoms of the disks. After several minutes, the disks should begin floating to the top of the solution. Record the number of floating disks every minute, until all the disks are floating.

When all the disks have floated, try putting the cup in a dark cabinet or room, or cover the cup with aluminum foil. Check the cup after about fifteen minutes. What happens to the disks?

Try changing other factors that might affect photosynthesis and see what happens. How long does it take for the disks to float under different conditions? For example, you can compare the effects of different types of light sources—lower- or higher-wattage incandescent, fluorescent, or LED bulbs. You can change the temperature of the solution by placing the beaker in an ice bath or a larger container of hot water. You can increase or decrease the concentration of sodium bicarbonate in the solution, or eliminate it entirely. You can try to identify the range of wavelengths of light used in photosynthesis by wrapping and covering the beaker with colored gel filters that remove certain wavelengths.

Fostering Discussions

The equation for photosynthesis can be written as follows:

$6CO2 + 6H2O + \text{light energy} \rightarrow C6H12O6 + 6O2$

In the leaf-disk assay, all of the components necessary for photosynthesis are present. The light source provides light energy, the solution provides water, and sodium bicarbonate provides dissolved CO_2.

Plant material will generally float in water. This is because leaves have air in the spaces between cells, which helps them collect CO_2 gas from their environment to use in photosynthesis. When you apply a gentle vacuum to the leaf disks in solution, this air is forced out and replaced with solution, causing the leaves to sink.

When you see tiny bubbles forming on the leaf disks during this experiment, you're actually observing the net production of O_2 gas as a byproduct of photosynthesis. Accumulation of O_2 on the disks causes them to float. The rate of production of O_2 can be affected by the intensity of the light source, but there is a maximum rate after which more light energy will not increase photosynthesis.

To use the energy stored by photosynthesis, plants (like all other organisms with mitochondria) use the process

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of respiration, which is basically the reverse of photosynthesis. In respiration, glucose is broken down to produce energy that can be used by the cell, a reaction that uses O_2 and produces CO_2 as a byproduct. Because the leaf disks are living plant material that still require energy, they are simultaneously using O_2 gas during respiration and producing O_2 gas during photosynthesis. Therefore, the bubbles of O_2 that you see represent the net products of photosynthesis, minus the O_2 used by respiration.

When you put floating leaf disks in the dark, they will eventually sink. Without light energy, no photosynthesis will occur, so no more O_2 gas will be produced. However, respiration continues in the dark, so the disks will use the accumulated O_2 gas. They will also produce CO_2 gas during respiration, but CO_2 dissolves into the surrounding water much more easily than O_2 gas does and isn't trapped in the interstitial spaces.

Possible Extensions

This experiment is extremely amenable to manipulations, making it possible for students to design investigations that will quantify the effects of different variables on the rate of photosynthesis. It is helpful to have students familiar with the basic protocol prior to changing the experimental conditions.

Ask your students to think carefully about how to isolate one variable at a time. It is important to hold certain parts of the experimental setup constant—for example, the distance from the light source to the beaker, the type of light bulb used, the temperature of the solution, the height of the solution, and so on. Certain treatments may eliminate photosynthesis altogether—water with no bicarbonate, very low temperature, and total darkness.

A typical way to collect data in this assay is to record the number of disks floating at regular one-minute time intervals. This is easily graphed, with time on the x-axis and number of floaters on the y-axis.

To make comparisons between treatments, the number traditionally used is the time point at which half of the disks in the sample were floating, also known as the E50.

Authors/Source

This experiment was originally described in Steucek, Guy L., Robert J. Hill, and Class/Summer 1982. 1985. "Photosynthesis I: An Assay Utilizing Leaf Disks." The American Biology Teacher, 47(2): 96–99.

Exploratorium Teacher Institute
https://www.exploratorium.edu/snacks/photosynthetic-floatation