Teacher Notes

Time: 90 minutes (plus 30 minutes for teacher preparation)

Student Difficult: moderate

Purpose: Design an experiment to test the effect of different light sources on the rate of photosynthesis.

Overview:

Students will test different light sources on leaf discs. They will:

- Choose a light source, such as light color or intensity, as an independent variable
- Design an experiment to test the effect of the light on photosynthesis in leaf discs
- Test disks in water rather than bicarbonate solution as a control
- Prepare leaf disks by first infusing them with CO2 and then using them in the experiment

Process Skills:

- Designing Experiments
- Analyzing
- Calculating
- Graphing
- Inferring

Supplies:

- Young leaves
- 3 100 mL beakers (clear cups or petri dishes can be substituted as well) per group (approximately 36 100 mL beakers per class)
- 300 mL of water per group (approximately 3.600 L of water per class)
- 1 drop liquid dishwashing detergent per group
- Assorted colors of cellophane sheets
- Needless, plastic 10 cc syringes
- Single-hole hole punch
- 0.6 g sodium bicarbonate (baking soda) per group (approximately 7.2 g of sodium bicarbonate (baking soda) per class)
- forceps
- strong light sources
- stopwatch
Biology – Rates of Photosynthesis

Neatly answer all questions completely for credit. Show all work.

Lab Preparation:

- Prepare sodium bicarbonate/detergent solution by dissolving 1/8 teaspoon of baking soda and 1 drop of diluted liquid dishwashing detergent in 300 mL water. Too much baking soda will cause CO₂ bubbles to form on the surface of the leaf discs, preventing them from sinking.
- Provide colored cellophane or filters for the light sources so students can test light color.

Safety: Be sure to remove the needles from the syringes.

Lab Management:

- Students may need help designing their experiments. Help them choose their independent variables and decide which variables are to be controlled. Have students write an operational definition for their dependent variable.
- Leaf disks should be placed in bicarbonate solution so they do not dry out before being used.
- Clear plastic cups or petri dishes can be substituted for beakers. If petri dishes are used, the beaker of water in Procedure step 2 is not needed. Add enough bicarbonate solution to the petri dish to cover the disks completely.
- If all the leaf disks do not sink in Procedure step 6, repeat step 5. Tell students to hold the vacuum for about 10 seconds. If discs still do not sink, add a bit more detergent to the solution.
- Tell students to avoid major veins in the leaf when making the discs.

Post-Lab Discussion:

Have students evaluate their experimental design. Ask them if they would change their procedure in any way. Ask

- What is the operational definition in this lab?
  - The number of leaf disks that floated in a measured amount of time.
- Why is this a measure of the rate of photosynthesis?
  - Floating is sign that photosynthesis is occurring.
- What is meant by the mean rate of photosynthesis?
  - The amount of photosynthesis performed by the average leaf disk.

Discuss conclusions that can be made from the results. Students who test light color should conclude that plants use red and blue light but not green.
Biology – Rates of Photosynthesis

**Answers:**

**Sample Data**

Students in the test group all tested red, blue, and green light color as the independent variable. Three sets of data are shown.

Sample 1
- red light: 5 discs/35 s = 0.14 discs/s
- blue light: 5 discs/26 s = 0.19 discs/s
- green light: 5 discs/116 s = 0.04 discs/s

Sample 2
- red light: 5 discs/32 s = 0.16 discs/s
- blue light: 5 discs/20 s = 0.25 discs/s
- green light: 5 discs/85 s = 0.06 discs/s

Sample 3
- red light: 5 discs/39 s = 0.13 discs/s
- blue light: 5 discs/35 s = 0.14 discs/s
- green light: 5 discs/95 s = 0.05 discs/s

**Analyze and Conclude**

1) The independent variable will depend upon how students tested different light sources. The dependent variable is the rate of photosynthesis.

2) Students should display calculations for all trials and then show an average for each group. For examples, red light = 0.35 disks/sec, green light = 0.27 disks/sec

3) The best graph would be a bar graph, with a bar representing the average rate of each group of the independent variable. Students should indicate that a bar graph is best because the groups are independent of one another.

4) Answers should include an explanation about the relationship between their manipulation of the independent variable and the data collected.

5) Sodium bicarbonate is used as a source of carbon dioxide gas, which is a necessary reactant of photosynthesis.

6) Answers could include change in water temperature, differences between leaf regions, and damage to leaf tissues; they account for random error in experiments.

7) Differences in methods between groups, random error, measurement error
Rates of Photosynthesis

Photosynthesis converts some of the energy absorbed from sunlight into the chemical energy of sugars. The process is also the major source of oxygen in Earth's atmosphere. By measuring oxygen production indirectly, you can measure the rate of photosynthesis. Remember that a rate describes how one quantity changes compared with another. In this lab you will design an experiment to determine the effect of different light sources on the rate of photosynthesis in leaves.

Problem:

How does a light source affect the rate of photosynthesis?

Safety: Goggles and gloves are required for this laboratory investigation.

Materials:

- young ivy leaves
- hole punch
- 100 mL beakers
- sodium bicarbonate/detergent solution
- water
- plastic 10 cc syringe
- forceps
- strong light sources
- stopwatch

Procedure:

1) Use the hole punch to make five disks from an ivy leaf.
2) Fill one beaker halfway with the sodium bicarbonate/detergent solution. Fill a second beaker with water.
3) Remove the plunger from the syringe and place the ivy leaf disks into the syringe. Insert the plunger and draw 5 cc (5 mL) of the sodium bicarbonate/detergent solution into the syringe as shown below.
4) Hold the syringe so that the tip is pointing upwards. Push on the plunger to squirt out any air in the syringe.
5) Place your finger on the tip of the syringe, as shown below. Withdraw the plunger to form a vacuum, but be careful to not pull the plunger all the way out of the syringe. When the vacuum is formed, the gases in the air spaces in the leaf disks move into the syringe and the solution diffuses into the air spaces. Shake the syringe several times while your finger is on the tip.

6) Take your finger off of the tip of the syringe. This causes the leaf disks to sink to the bottom of the syringe because they become more dense from the diffusion of solution into the air spaces.

7) Open the syringe by pulling the plunger almost all the way out. Place your finger over the tip of the syringe and turn it so the tip is pointing down. Carefully remove the plunger and pour the contents of the syringe into the beaker of water. Use the forceps to remove the leaf disks if they stick to the walls of the syringe.

8) Place the beaker with the leaf disks under the light source and immediately start the stopwatch. As the leaf disks begin to photosynthesize, the production of oxygen replaces the solution in the air spaces and the disks become less dense and float to the top of the water. Record the time it takes for each leaf disk to float to the top of the water. Use the rate at which the disks float as an indirect measurement of the rate of photosynthesis.

**Design** (To be written completely in scientific notebooks)

1) Decide how to test different light sources on the rate of photosynthesis. Identify your independent variable. Have your teacher approve your choice.

2) Identify your control condition and the constants in the experiment. Examples of constants are the distance between the light and the beaker, and the temperature of the water.

3) Write the procedure for your experiment.
4) Record and organize your results in data table below.

<table>
<thead>
<tr>
<th>Time (sec)</th>
<th>Type of light (number of disks)</th>
<th>Type of light (number of disks)</th>
<th>Type of light (number of disks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

5) Gather the additional materials you need for your experiment.

6) Test the rate of photosynthesis using the procedure on the previous page. Be sure not to get any water on the light sources. Record your results. Continue collecting data until all five disks float in each experimental condition. (Note: If you test more than one condition at once, record a time and disk count for all of the beakers every time a disk floats in any of the beakers.)

7) Conduct three trials of your experiment if time allows.
Cells and Energy

Biology – Rates of Photosynthesis

Neatly answer all questions completely for credit. Show all work.

**Analyze and Conclude**

1) **Identify**: What are the independent and dependent variables in your experiment?

2) **Calculate**: Determine the mean rate of photosynthesis in each condition of your experiment. To calculate the rate of photosynthesis, use the formula below:

\[
\frac{5 \times \text{(\# of disks floating)}}{\text{total time (sec)}} = \text{rate of photosynthesis disks/sec}
\]

3) **Analyze**: Determine the best type of graph to use to represent your data. Explain your choice and construct the graph. Be sure to carefully label the axes of the graph.
4) **Conclude**: Based on your data, what can you conclude about how your independent variable affects the rate of photosynthesis?

5) **Infer**: Why do you think sodium bicarbonate was used in this investigation? (Hint: Think about the equation for the overall process of photosynthesis.)

6) **Experimental Design**: What are possible sources of unavoidable error in your design? Explain why they were present.

7) **Experimental Design**: Identify possible reasons for inconsistent results.