

THINKING AND ACTING LIKE A SCIENTIST

TEACHER'S GUIDE

Rate of Photosynthesis

What is the rate of photosynthesis for spinach?

GRADES 9–12

Life Science





Rate of Photosynthesis

Grade Level/Content	9–12/Life Science
Lesson Summary	Students conduct an investigation exploring the rate of photosynthesis in a spinach leaf under given conditions. Students then identify a variable to explore its impact on photosynthesis during a follow-up investigation.
Estimated Time	3, 45-minute class periods
Materials	Spinach, light source, 1.0% solution of Sodium bicarbonate single-hole paper punch, syringe - with needle removed, transparent container with water to be used as a heat sink, Internet, Investigation Plan , journal
Secondary Resources	Nova Online Illuminating Photosynthesis simulation Loopy Cycling of Matter & Energy model Kaiser Science Photosynthesis & Respiration diagram <i>Note: Some of these links may be Adobe Flash dependent.</i>
NGSS Connection	HS-LS1-5 Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.
Learning Objectives	<ul style="list-style-type: none">• Students will investigate the light dependent reactions in photosynthesis.• Students will design an investigation to determine the effect of a change on the rate of photosynthesis.• Students will diagram photosynthesis steps including reactants, products, and necessary conditions.

What is the rate of photosynthesis for spinach?

Photosynthesis is a critically important biochemical reaction that provides the oxygen required to support respiration in nearly all non-autotrophic organisms on earth. Providing students with an opportunity to observe indicators of photosynthetic activity is one way to shed light (!) on this phenomena.

In this lesson, students use small spinach disks to observe indications of photosynthesis and determine the rate of photosynthesis. Students use this learning experience to support deeper exploration of additional factors impacting the rate of photosynthesis during student designed investigations. Students then look at the overall results of photosynthetic reactions as they relate to the transformation of light energy into storable energy in the form of sugar.

Investigation is based on the Van Andel Education Institute (VAEI) Instructional Model for Inquiry-Based Science.
In all investigations:



Students don't know the "answer" they are supposed to get.



Students play a driving role in determining the process for learning.



Teachers and students construct meaning together by journaling.



Students are working as hard as the teacher.

Part 1

INVESTIGATION SETUP

Collect the materials necessary for each student group to perform the guided investigation.

- spinach
- light source
- 1.0% solution of Sodium bicarbonate. Created by adding 10.0 grams of Sodium bicarbonate to a one liter flask. Add 990mL of distilled water to the flask and mix. Add 1-2 drops of 100mL diluted liquid dish soap to the flask and stir gently so as not to create any bubbles.
- single-hole paper punch, a craft punch, or a plastic straw
- syringe - with needle removed
- transparent container with water to be used as a heat sink
- Internet
- [Investigation Plan](#)
- journal

Part 2

INVESTIGATION FACILITATION



Question

Introduce the investigation question.

What is the rate of photosynthesis for spinach?



Personal Knowledge

Students capture what they already know about photosynthesis and reaction rates.

- Have students identify key components of the investigation question.
- Ask them to write 3-5 ideas in their journal before sharing them with their table partners and record new ideas in their journal.
- Encourage students to review their list and circle ideas and concepts that they are not sure about.

DISCOURSE

Use a Think-Pair-Share activity to have students list conditions that they think could impact photosynthesis. Have students share their thoughts with a partner and see if there are any differences in their lists. Pairs can then share their lists with the class as a whole as you list them for students to see. Have students write this list in their journal for consideration in designing their own investigation later in the lesson.

1
2
3

Investigation Plan

Students review a provided plan to understand how to conduct trials to determine the rate of photosynthesis for spinach disks.

- Have students work in teams of 2–3.
- Review the materials and preparation steps necessary to remove residual gases from the spinach disks.
- Have students follow the [Investigation Plan](#).
- Students will record the number of floating disks every minute for 12 minutes for each trial. They will conduct at least 3 trials.
- For a video explanation of how to prepare the spinach disks and why a heat sink is required, show the first four minutes of this [Bozeman Science video](#) from Paul Anderson.

CRITICAL THINKING

Use the [Fair Test](#) checklist to help students think critically about the investigation plan. Help them understand that a good investigation plan must include a test that is repeatable, generates quality data, and minimizes error. The more critically students think about their investigation plan, the more confident they will be in their results.

INVESTIGATION PLAN RATE OF PHOTOSYNTHESIS

1. Ensure that your teacher has prepared fresh green spinach by placing it in a shallow pan of water under light for 1–2 hours prior to this investigation.
2. Using a single-hole paper punch a craft punch, or plastic straw, create 10–25 disks from the prepared spinach leaves.
3. Place the disks in the barrel of a syringe and gently move the disks to the end opposite the opening.
4. Insert the plunger into the barrel as far as possible without crushing the disks.
5. Insert the syringe into a 1.0% Sodium bicarbonate solution and slowly fill the barrel about 1/3 full.
6. With the tip of the barrel pointing up, press the plunger to expel air from the top of the syringe.
7. Place a cap or your finger over the opening of the syringe and pull back on the plunger slightly to create a vacuum.
8. While continuing to pull on the syringe you should see bubbles escaping from the spinach disks. As this happens, the disks should sink to the bottom and rest on the tip of the plunger. Slowly release the plunger in order to not damage the spinach disks. You may need to repeat this step a few times and tap the side of the syringe to get all of the disks to fall to the bottom.
9. When all of the disks are on the bottom, remove the plunger over a beaker containing 150–200mL of the Sodium bicarbonate solution. Place the spinach disks from the syringe into the solution.
10. If any of the disks float, remove them from the cup.
11. Add a transparent heat sink to the top of the beaker and move both the beaker and heat sink under a light source.
12. Record the number of disks that rise to the top of the solution and are floating every minute.
13. Observe for 12 minutes or until most of the disks have risen to the top.

Investigation Plan



Observation

Students record their data.

- Ask students to create a data table to record the number of floating disks each minute for three trials.
- Encourage them to include qualitative observations as well. For example: *The Sodium bicarbonate solution was clear. Disks moved slowly from the bottom of the cup as they began to float.*

SELF-DIRECTION

This investigation requires students to prepare spinach disks for their own investigation. If gases are not removed from each disk, resulting observations and data will be negatively impacted. They also need to record an appropriate amount of high quality data. To obtain three trials of data, students must be focused and diligent in conducting their investigation.

Part 3

INVESTIGATION ANALYSIS AND DEVELOPMENT OF CLAIM



Data Analysis

Students make sense of their data by organizing it and representing it visually.

- Have students analyze their data. They may wish to use the [Data Analysis](#) prompt as a guide.
- Have students **evaluate** their data for trustworthiness.
- Then, have them analyze their data to find patterns and trends. They may **organize** the data and/or **represent** it visually to construct meaning.

Continued

- Ask students how they could calculate the rate of photosynthesis. Facilitate a discussion explaining that their collected data allows them to use the number of floating disks as an indicator of photosynthetic activity with the following formula:

$$\frac{\text{change in floating spinach disks}}{\text{time}}$$

- Encourage students to create graphs and charts that represent their observed rate of photosynthesis. Push them to consider whether combining and/or averaging data would be beneficial or not.
- Have students **interpret** what the identified patterns or trends mean.
- Ensure they have enough data that it can be used as evidence to support a claim.

CRITICAL THINKING

Have students dig deeper into their data by considering possible errors or unaccounted factors impacting their trials. Remind students that these ideas should be included in their reasoning when developing their explanation.



Secondary Knowledge

Students use secondary sources to understand the chemical nature of photosynthesis.

- Use these resources (or your own) to help students understand the chemical nature of photosynthesis.
 - [NOVA Online Illuminating Photosynthesis](#) simulation
 - [Light Reactions and Calvin Cycle](#) – Read through light reactions
 - [Light Reactions of Photosynthesis](#) (Where does the oxygen come from? Watch until 4:40)
 - [Bioflix visualization](#)
 - [Kaiser Science Photosynthesis & Respiration](#) diagram
- Students use this information in the reasoning portion of their explanation.

Note: Some of these links may be Adobe Flash dependent.



Explanation

Students write a claim and provide evidence and reasoning to support.

- Have students use what they've discovered from their analyzed data to write an explanation that answers their investigation question.
- Students may wish to use the [Explanation](#) prompt as a guide. Have them write their explanation in their journal.
- Have students develop a **Claim** to answer the question: What is the rate of photosynthesis for spinach?
- Then, have them add **Evidence** (the analyzed data) to support their claim.
- Finally, have them add **Reasoning** to their claim. Reasoning should include the information obtained from this investigation as well as science principles they have learned.

Claim

The data shows that at room temperature, the rate of photosynthesis from our spinach disks floated an average of 5 disks for each of the first 4 minutes before slowing down to an average of one disk for minutes 5–12.

Continued

Evidence

Once placed under the light source, the spinach disks began a chemical process that resulted in the production of a gas. We saw bubbles and watched the disks float to the top of the Bicarbonate solution.

Reasoning

Investigation: We followed the investigation plan carefully and conducted 3 trials. The data is fairly consistent in all of the trials and there are no outliers. Therefore, we believe our data is valid and reliable.

Science: From our class discussions and readings, we learned that the chloroplasts in a plant leaf produce oxygen gas during photosynthesis. This reaction requires Carbon dioxide and water, in addition to light energy. The Carbon dioxide and water was provided by the Sodium bicarbonate solution while the light energy was provided by the light source. This means that the rate of reaction for our investigation could be measured by counting the number of leaf disks floating to the surface.

- Once the explanation is written, have students discuss their results using a [Present and Defend](#).

DISCOURSE

Select 2 groups to conduct a [Present and Defend](#). This helps develop presentation and audience participation skills. Research teams present a summary of their investigation to the class. The class analyzes the information presented and asks clarifying questions, challenges and/or supports the arguments made, and even presents alternative explanations as appropriate. Research teams defend their explanation with evidence and reasoning.



Evaluation

Students reflect on the investigation.

Have students discuss:

- What surprised me?
- What question would I like to investigate next?
- What alternative explanations should be considered for the data I collected?

Part 4

INVESTIGATION ASSESSMENT AND EXTENSION

Students demonstrate their understanding by designing a new investigation exploring the rate of photosynthesis and by modeling the transformation of light energy to stored chemical energy.



Application

- Have students brainstorm variables they can change and measure to design and conduct their own investigation focused on the rate of photosynthesis.
- Instruct students to use the investigation they just completed as the control. Have them change a variable to determine the effect of that on the rate of reaction.

Some suggested variables:

- Distance of light from spinach disks
- Color of light
- Light source
- Amount of Sodium bicarbonate
- Type of leaf used
- Temperature of bicarbonate solution
- Have students illustrate or model the inputs and outputs of matter and the energy transfer and transformation resulting from photosynthetic activity by photosynthesizing organisms.

Note: This illustration should focus on the chemical components of photosynthesis, how these components are related, and the impact of these energy transformations on the photosynthetic organism and its environment.

Assessment

Determine how well students:

- investigate the light dependent reactions in photosynthesis.
- design an investigation to determine the effect of a change on the rate of photosynthesis.
- diagram photosynthesis steps including reactants, products, and necessary conditions.

For additional lessons or to customize this lesson, go to www.nexgeninquiry.org.

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INVESTIGATION PLAN

RATE OF PHOTOSYNTHESIS

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