

**Teacher’s Guide**

**Copying Nature to Fight Climate Change**

***October 2021***

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Activate students’ prior knowledge and engage them before they read the article.

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These questions are designed to help students read the article (and graphics) carefully. They can help the teacher assess how well students understand the content and help direct the need for follow-up discussions and/or activities. You’ll find the questions ordered in increasing difficulty.

[Graphic Organizer 5](#_Graphic_Organizer)

Thishelps students locate and analyze information from the article. Students should use their own words and not copy entire sentences from the article. Encourage the use of bullet points.

[Answers 6](#_Answers_to_Reading)

Access the answers to reading comprehension questions and a rubric to assess the graphic organizer.

[Additional Resources 9](#_Additional_Resources_1)

Here you will find additional labs, simulations, lessons, and project ideas that you can use with your students alongside this article.

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# Anticipation Guide

Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Directions: *Before reading the article*,** in the first column, write “A” or “D,” indicating your **A**greement or **D**isagreement with each statement. Complete the activity in the box.

As you read, compare your opinions with information from the article. In the space under each statement, cite information from the article that supports or refutes your original ideas.

|  |  |  |
| --- | --- | --- |
| **Me** | **Text** | **Statement** |
|  |  | 1. All living organisms on Earth depend on photosynthesis.
 |
|  |  | 1. Plants remove O2 from the atmosphere.
 |
|  |  | 1. Catalysts are required for photosynthesis.
 |
|  |  | 1. The carbon cycle includes carbon going back and forth between the atmosphere and rocks and soil.
 |
|  |  | 1. Today hydrogen fuel cells are produced in a process that emits CO2 into the atmosphere.
 |
|  |  | 1. To separate water into hydrogen and oxygen requires electric energy.
 |
|  |  | 1. Artificial leaf researchers are trying to produce ethanol and butanol to use as fuel.
 |
|  |  | 1. Chlorophyll makes plants appear green because it absorbs green light.
 |
|  |  | 1. Artificial leaf devices that currently exist are larger than a football field.
 |
|  |  | 1. Researchers are using non-photosynthetic bacteria to produce acetic acid to make fuels.
 |

# Student ReadingComprehension Questions

Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Directions**: Use the article to answer the questions below.

1.Write the balanced chemical equation for photosynthesis and respiration.

2. How does the process of photosynthesis work in harmony with humans to create a seesaw type balance in our world?

3. Explain how humans have affected the carbon cycle.

4. List some of the most significant challenges engineers of the artificial leaf most overcome to make synthetic photosynthesis a mainstream energy source.

**Connecting Concepts**

5. Compare and contrast oxidation and reduction and identify which element is being oxidized and reduced in the electrolysis of water equation shown below:

2H20 (l) 🡪 2 H2 (g) + O2 (g)

6. Using the balanced chemical reaction for photosynthesis from question 1, prove mass (thus matter) was conserved during the chemical equation.

7. All plants and trees start as tiny seedlings; over time they grow to their mature form. For example, the primary source of mass in a tree is from carbon. What is the source of the carbon that allows a tree to grow?

8. What are some environmental advantages artificial leaf technology has over other sources of green energy such as ethanol fuel, wind, and solar?

**Student Reading Comprehension Questions, cont.**

***Write your answers on another piece of paper if needed.***

9. The article mentions catalyst and their importance to both the natural and artificial photosynthesis process. What is a catalyst? How do catalysts increase the rate of a chemical process?

**Questions for Further Understanding and Exploration**

***Write your answers on another piece of paper if needed.***

10. The article states economists project the economic damages from climate change will reach $1.7 trillion dollars per year by 2025 and roughly $30 trillion per year by 2075. In detail, explain how global climate change can cause economic (financial) damage.

11. Artificial leaf technology has the potential to deliver a large amount of clean, sustainable energy with a small environmental footprint. Today is common to see solar panels and windmills in various parts of the country. Some people may argue that solar panels and windmills are not aesthetically pleasing. Propose a method to incorporate artificial leaf technology into the environment in an aesthetically pleasing manner. Create a model or diagram to support your answer.

12. You are hired as marketing VIP for a leading artificial leaf technology start up company. Your task is to create a 30 second TV commercial to promote your product and encourage consumers to purchase and artificial leaf system for their property to power their home. You have control over the design of the leaf system and how residents may incorporate it onto their property. Use your smartphone to record the commercial and share your finish product with your teacher.

# Graphic Organizer

Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Directions**: As you read, complete the graphic organizer below to compare photosynthesis in plants with artificial leaf technology.

|  |  |  |
| --- | --- | --- |
|  | **Green Plants** | **Artificial leaf technology** |
| **Reactants** |  |  |
| **Products** |  |  |
| **Catalysts** |  |  |
| **Energy input** |  |  |
| **Efficiency** |  |  |
| **Fuels produced** |  |  |
| **Future directions** |  |  |

**Summary:** On the back of this sheet, write a tweet (280 characters or less) to a friend about how artificial leaf technology could help alleviate climate change.

# Answers to Reading Comprehension Questions & Graphic Organizer Rubric

**1.Write the balanced chemical equation for photosynthesis and respiration.**

*Photosynthesis: 6 CO2 + 6 H2O + energy 🡪 C6H12O6 + 6 O2*

*Respiration: C6H12O6 + 6 O2 🡪 6 CO2 + 6 H2O + energy*

**2. How does the process of photosynthesis work in harmony with humans to create a seesaw type balance in our world?**

*Humans produce a large amount of carbon dioxide through respiration (breathing) and the consumption of fossil fuels. Plants, through photosynthesis, consume the carbon dioxide, and produce oxygen. As we know, oxygen is essential for humans and animals for the respiration process. Together, when balanced, plants and humans provide useful fuel for one another to maintain a healthy and productive environment.*

**3. Explain how humans have affected the carbon cycle.**

*Humans have released increasing amount of carbon dioxide into the atmosphere which otherwise would have been contained in carbon form beneath layers of earth by burning fossil fuels. Humans have also decreased the number of plants and trees on the planet by using them for commercial uses or clearing large areas for development. These activities have caused unbalanced in carbon dioxide and oxygen seesaw and has resulted in increased carbon dioxide levels in the atmosphere and climate change.*

**4. List some of the most significant challenges engineers of the artificial leaf most overcome to make synthetic photosynthesis a mainstream energy source.**

*The chemical reactions inside an artificial leaf require catalysts. A major challenge is finding catalysts and materials that only produce the desired chemical products. Another challenge is the size of the leaf itself. In order for artificial leaf technology to become a mainstream reliable energy source is must be scaled up to produce an amount of energy comparable with other green energy sources which is proving to be a challenge for scientists.*

**Connecting Concepts**

**5. Compare and contrast oxidation and reduction and identify which element is being oxidized and reduced in the electrolysis of water equation shown below:**

**2H20 (l) 🡪 2 H2 (g) + O2 (g)**

*Oxidation is caused by the loss of electron(s) during a chemical reaction resulting in a positive oxidation state. Reduction is caused by the gain of electron(s) during a chemical reaction resulting in a negative oxidation state. In the electrolysis of water equation hydrogen is being reduced from a +1 oxidation state in water to a 0 oxidation state in hydrogen gas. Oxygen is being oxidized from a -2 oxidation state in water to a 0 oxidation state in oxygen gas.*

**6. Using the balanced chemical reaction for photosynthesis from question 1, prove mass (thus matter) was conserved during the chemical equation.**

*6 CO2 + 6 H2O + energy 🡪 C6H12O6 + 6 O2*

*Answers may vary. Example:*

*Reactant side totals: 6 carbons x 12 g = 72 grams*

*18 oxygen x 16 g = 288 grams*

*12 hydrogen x 1 g= 12 grams*

*Total = 372 grams*

*Product side totals: 6 carbons x 12 g = 72 grams*

*18 oxygen x 16 g = 288 grams*

*12 hydrogen x 1 g = 12 grams*

*Total = 372 grams*

*Since the total mass is 372 grams on both sides of the equation, mass is conserved.*

**7. All plants and trees start as tiny seedlings; over time they grow to their mature form. For example, the primary source of mass in a tree is from carbon. What is the source of the carbon that allows a tree to grow?**

*The source of carbon is from the carbon dioxide in air. A common misconception is the mass of a tree comes from the dirt/soil.*

**8. What are some environmental advantages artificial leaf technology has over other sources of green energy such as ethanol fuel, wind, and solar?**

*Unlike ethanol fuel which requires large amount of energy, land, and even fossil fuels to produce, artificial leaf technologies are made from clean and sustainable resources. Artificial leaf technologies, due to their small size, do not leave a large footprint on the environment unlike solar panels and windmills which consume a significant amount of land or rooftops to produce energy.*

**9. The article mentions catalyst and their importance to both the natural and artificial photosynthesis process. What is a catalyst? How do catalysts increase the rate of a chemical process?**

*A catalyst is compound that speeds up a chemical process by lowering the activation energy required for a reaction to take place by providing an alternative mechanism for the reaction. Catalysts are also not consumed during the chemical process and leave the process ready to further catalyze future reactions.*

**Questions for Further Understanding and Exploration**

**10. The article states economists project the economic damages from climate change will reach $1.7 trillion dollars per year by 2025 and roughly $30 trillion per year by 2075. In detail, explain how global climate change can cause economic (financial) damag**e.

*Climate change, particularly an increased global temperature, can result in more frequent natural disasters such as tornados, flooding, and hurricanes which are capable of catastrophic damage. Climate change can also impact crop yields, affect animal and insect populations, increased energy consumption due to the increased use of heating and air conditioning units due to more extreme temperatures (which also results in more pollution)*

**11. Artificial leaf technology has the potential to deliver a large amount of clean, sustainable energy with a small environmental footprint. Today is common to see solar panels and windmills in various parts of the country. Some people may argue that solar panels and windmills are not aesthetically pleasing. Propose a method to incorporate artificial leaf technology into the environment in an aesthetically pleasing manner. Create a model or diagram to support your answer.**

*Answers will vary. Student answers must include a diagram or model (visual component)*

**12. You are hired as marketing VIP for a leading artificial leaf technology start up company. Your task is to create a 30 second TV commercial to promote your product and encourage consumers to purchase and artificial leaf system for their property to power their home. You have control over the design of the leaf system and how residents may incorporate it onto their property. Use your smartphone to record the commercial and share your finish product with your teacher.**

*Answers will vary. Student commercials may completed individually or in groups. The commercials should include a prototype, visuals, company name, and be energetic and fun!*

**Graphic Organizer Rubric**

If you use the Graphic Organizer to evaluate student performance, you may want to develop a grading rubric such as the one below.

|  |  |  |
| --- | --- | --- |
| **Score** | **Description** | **Evidence** |
| 4 | Excellent | Complete; details provided; demonstrates deep understanding. |
| 3 | Good | Complete; few details provided; demonstrates some understanding. |
| 2 | Fair | Incomplete; few details provided; some misconceptions evident. |
| 1 | Poor | Very incomplete; no details provided; many misconceptions evident. |
| 0 | Not acceptable | So incomplete that no judgment can be made about student understanding |

# Additional Resources

**Lessons and lesson plans**

The Downside of Catalysts: Catalyst lesson plan. In this lesson students will make observations of a colorful homogenous catalyst and intermediate in a reaction demonstration that will spark their interests.

<https://teachchemistry.org/classroom-resources/the-downside-to-catalysts>

Exploring Automotive Corrosion: Electrochemistry Lesson plan. In this lesson students will investigate the galvanic corrosion that can occur when different metals come in contact with each other in modern cars.

<https://teachchemistry.org/classroom-resources/exploring-automotive-corrosion>

Color Solar Power: Solar Power Lesson plan. Students will make a dye-sensitized solar cell (also known as DSC or Gratzel cell) using extracts from produce.

<https://teachchemistry.org/classroom-resources/color-solar-power>

**Other resources**

Green Chemistry: Webinar. Annette Sebuyira shares her experience using green chemistry as a platform to teach core chemistry concepts, in a way that inspires students to seek solutions to real-world environmental challenges.

<https://teachchemistry.org/professional-development/webinars/green-chemistry>

# Chemistry Concepts, Standards, and Teaching Strategies

**Connections to Chemistry Concepts**

The following chemistry concepts are highlighted in this article:

* Chemical change
* Electrochemistry
* Catalysts
* Intramolecular forces

**Correlations to Next Generation Science Standards**

This article can be used to achieve the following performance expectations of NGSS:

|  |
| --- |
| **HS-LS1-5.** Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.**HS-PS1-3.** Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles. **HS-ETS1-3.** Evaluate a solution to a complex real-world problem based on prioritized criteria and tradeoffs that account for a range of constraint, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts. |

**Disciplinary Core Ideas:**

* LS1.C: Organization for Matter and Energy Flow in Organisms
* PS1.A: Structure and Properties of Matter
* ETS1.C: Optimizing the Design Solution

**Crosscutting Concepts:**

* Structure and function
* Systems and system models
* Energy and matter

**Science and Engineering Practices:**

* Planning and carrying out investigations

**Nature of Science:**

* Science investigations use a variety of methods
* Scientific knowledge assumes an order and consistency in natural systems.

**Correlations to Common Core State Standards**

See how *ChemMatters* correlates to the[**Common Core State Standards** online](https://www.acs.org/content/acs/en/education/resources/highschool/chemmatters/teachers-guide.html).

**Teaching Strategies**

Consider the following tips and strategies for incorporating this article into your classroom:

* **Alternative to Anticipation Guide:** Before reading, ask students what they know about photosynthesis and how it relates to climate change. Their initial ideas can be collected electronically via Jamboard, Padlet, or similar technology.
	+ As they read, students can find information to confirm or refute their original ideas.
	+ After they read, ask students what they learned about artificial leaf technology and how it could help fight climate change.
* After reading and discussing the article, consider sharing the ACS Reactions video “What If Humans Could Photosynthesize?” (4:04) at <https://youtu.be/z3RGwdJGzOo> to learn more about requirements and tradeoffs for