Video Three Lesson Plan

Where the Gases Come From

This lesson plan was produced by the CO2 Learning Center, a project of the CO2 Coalition

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A note about our lesson plans:

Our CO_2 Learning Center lesson plans all have the same format, which includes learning standards from the Next Generation Science Standards (NGSS), student learning objectives, background information on the science concepts covered in the book or video, suggested activities including labs to enrich the lesson and reinforce use of the scientific method, and formative and summative questions.

This lesson plan was created by the CO_2 Coalition's Senior Education Advisor Sharon Camp, Ph.D. Analytical Chemistry; B.S., Geology, using Next Generation Science Standards (NGSS).

The NGSS are the standards on which most public-school systems have based their curriculum. We do not necessarily endorse the NGSS but have included the relevant standards for circumstances in which a teacher is required to use them. The lesson plans contain everything that a teacher might be required to submit in a formal lesson plan to a school administrator or science department head.

Understanding NGSS:
LS: Life Science
PS: Physical Science
ES: Earth Science
1-5 indicates standard for grade level (1-first grade, 2-second grade, 3-third grade, 4-fourth grade, 5-fifth grade)

Please note that only the parts of the outline that are relevant to this lesson have been included. If LS1.C *and* PS1.A *(example from this lesson) are shown, these NGSS segments were included as relevant to this lesson for Life Science and Physical Science.*

Lesson Plan: Video Three

Grades K-8

Next Generation Science Standards (NGSS) Learning Objectives:

5-PS1-1. Develop a model to describe that matter is made of particles too small to be seen.

- **PS1.A**: Structure and Properties of Matter. Matter of any type can be subdivided into particles that are too small to see, but even then the matter still exists and can be detected by other means. A model showing that gases are made from matter particles that are too small to see and are moving freely around in space can explain many observations, including the inflation and shape of a balloon and the effects of air on larger particles or objects.

5-LS2-1. Develop a model to describe the movement of matter among plants, animals, decomposers, and the environment.

- **LS2.B**: Cycles of Matter and Energy Transfer in Ecosystems. Matter cycles between the air and soil and among plants, animals, and microbes as these organisms live and die. Organisms obtain gases, and water, from the environment, and release waste matter (gas, liquid, or solid) back into the environment.

MS-LS1-6. Construct a scientific explanation based on evidence for Constructing Explanations and Designing Solutions

- **LS1.C:** Organization for Matter and Energy Flow in Organisms. Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use.

MS-LS1-7. Develop a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and/or release energy as this matter moves through an organism.

- **LS1.C**: Organization for Matter and Energy Flow in Organisms Within individual organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth, or to release energy.

Source: https://www.nextgenscience.org

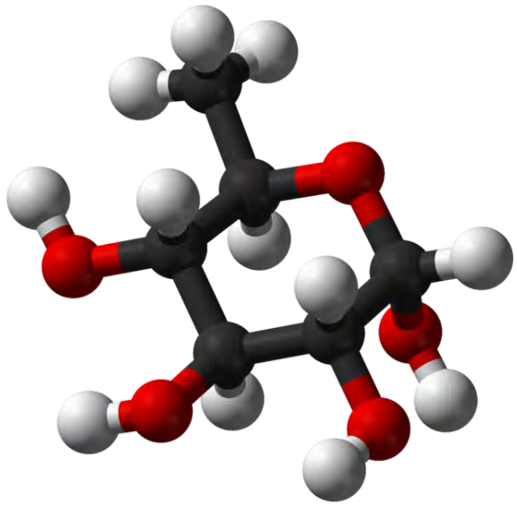
Student Learning Goals

After watching the video, students will be able to:

1. Name three common gases that are found in Earth's atmosphere.
2. Explain why oxygen and carbon dioxide are important.
3. Explain how carbon dioxide and oxygen cycle from plants to animals and back again.
4. Explain how plants form oxygen.
5. Explain how animals form carbon dioxide.

Background Information

The interaction and cycling of gases in the air through plants and animals is an important contributor to life on our planet. There are two gases in the atmosphere, specifically carbon dioxide and oxygen, that are critical to the survival of all living things. Carbon is the backbone upon which all organic molecules are built and is the essential building block of life. All carbohydrates, proteins and fats are carbon-based molecules. Only plants and other living things that contain chlorophyll, however, can make these critical molecules. They do so by using energy from the sun with carbon dioxide and water as the raw materials for a miraculous chemical reaction we call photosynthesis. Plants split water molecules, releasing the oxygen as O_2 and saving the hydrogen, which is then combined with CO_2 from the air to make the glucose molecule, $C_6H_{12}O_6$,in a complicated set of chemical reactions[1].

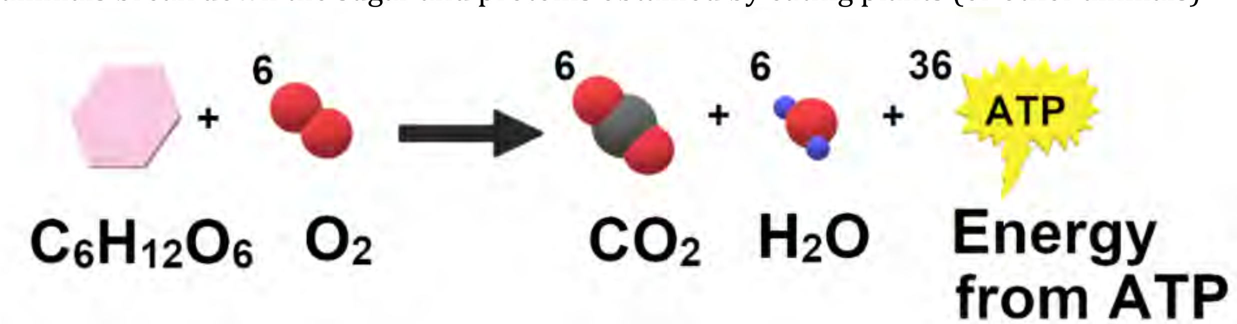


Source: Jynto and Ben Mills, Public domain, via Wikimedia Commons, https://commons.wikimedia.org/wiki/File:D-Quinovose-3D-balls.png

This reaction only occurs during daylight hours because sunlight is necessary for these reactions to take place. During dark hours, the plant undergoes chemical respiration (as do animals and other organisms). This reaction, which requires oxygen, releases the stored energy from the sun for use by the plant, and releases carbon dioxide back into the atmosphere where it is available to be used again. Almost all the oxygen in the atmosphere is a product of photosynthesis1.

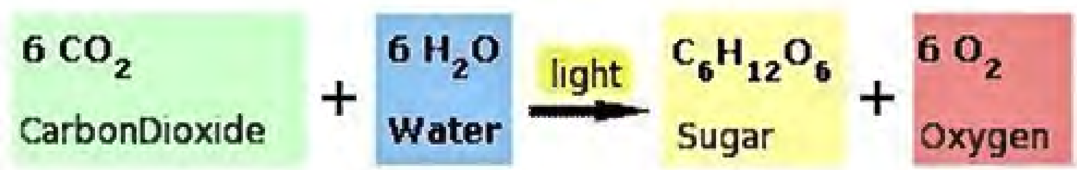
Nitrogen is only relevant to this discussion because it is the largest component gas of the Earth's atmosphere. It is absorbed directly from the atmosphere only by a small group of bacteria, which are commonly found in root nodules of certain plants such as legumes. Although it is also a critical component of many organic molecules, its importance is not a part of this lesson and will be addressed in another one.

Animals (and other organisms) can only undergo cellular respiration (not to be confused with respiration associated with breathing). In cellular respiration, cells in the bodies of animals break down the sugar and proteins obtained by eating plants (or other animals).



Source: Christinelmiller, CC BY-SA 4.0 <https://creativecommons.org/licenses/by-sa/4.0>, via Wikimedia Commons, https://commons.wikimedia.org/wiki/File:Cellular_Respiration_Simple.png

This reaction releases stored energy from the sun and allows animals to undergo homeostasis and other functions. The necessary ingredient for cellular respiration, other than a food source, is oxygen, which is obtained from the air and produced by plants. Carbon dioxide is a byproduct of cellular respiration and is given off as waste when animals exhale. Animals must have plants to survive, as they produce the necessary food and oxygen. Plants, in turn, must have carbon dioxide to survive. Without CO_2, photosynthesis could not occur, and plants would not exist.



Source: Joeriee at nl.wikipedia, CC BY-SA 3.0 <http://creativecommons.org/licenses/by-sa/3.0/>, via Wikimedia Commons, https://commons.wikimedia.org/wiki/File:Photosynthesis.jpg

More carbon dioxide increases the growth rate of plants, which is why many nurseries blow extra CO_2 into their greenhouses to achieve a faster growth rate. In fact, plants are always in a carbon dioxide deficient mode because more CO_2 is needed than is produced by respiration[2]. Increasing carbon dioxide also explains the greening of the planet because all plants benefit from increased levels of carbon dioxide. This is why it can be considered a plant fertilizer. Also, as more CO_2 is released into the atmosphere, more will be removed by plant growth.

References

1. Ritchie, G.A. (2018). *Inside Plants: A Gardeners' Guide to Plant Anatomy and Physiology.*
2. https://extension.okstate.edu/fact-sheets/greenhouse-carbon-dioxide-supplementation.html

Suggested Activities

Linked below are websites that have activities to demonstrate photosynthesis. Several are outlined here; for more information, be sure to visit the websites.

1. **Using Manipulatives as Models for Molecules:** It is often very useful to use models to represent molecules and how they can break apart and be put back together in different arrangements. This can be easily accomplished by using beads, Legos or other items that connect interchangeably. For older students, using a separate color block for each element can work well. If you prefer, you can use Styrofoam balls to more accurately represent the shape of the molecule. Pick or paint balls in different colors and have the

students break apart CO_2 to form just O_2 and vice versa. If you wish to include water molecules, you can do so. Use this reference to get the correct shapes of the molecules:
CO_2:
https://images.fineartamerica.com/images/artworkimages/mediumlarge/2/carbon-dioxide-co2-molecule-model-and-chemical-formula-peter-hermes-furian.jpg
H_2O: https://images.fineartamerica.com/images/artworkimages/mediumlarge/2/h2o-water-molecule-model-and-chemical-formula-peter-hermes-furian.jpg

2. **The Floating Leaf Experiment:** Many pieces of a leaf, cut into the shape of a disk with a hole-puncher, are put into a baking soda solution. As the pieces absorb the baking soda solution, they become denser and sink. The carbonate in the solution, however, provides a source of carbon dioxide that the leaves then use to perform photosynthesis. As oxygen is produced by the leaves, it increases their buoyancy, and they will slowly rise to the surface of the solution. (As cellular respiration occurs in the leaves, they will consume oxygen and tend to sink.) The leaves, therefore, become an indirect measurement of the net rate of photosynthesis. Since photosynthesis does not occur in the dark, none of the leaves will rise when plunged into darkness.

   Materials: baking soda, water, glass, English ivy or spinach leaves, hole punch, plastic timer, light source, 10cc or larger plastic syringe with end cap, liquid dish detergent. (Leaves of different ages can be used to demonstrate relative rates of photosynthesis vs. age.)

   Procedure: *Start by asking the students questions about what results they expect. Put the answers on the board and use them to come up with various hypotheses to test. After the lab, revisit the hypotheses and see which one best predicted the actual results. The hypotheses should be based on whatever combination of variables you choose to include. ALWAYS include the control, which is used to verify that the results of the reaction are due to the variables and not some random, unanticipated and unrecognized experimental condition.*

   Make a weak baking soda solution by dissolving 1/8 teaspoon of baking soda in 1 1/3 cups of water. A control can be created by omitting baking soda from the water solution. Add a drop of liquid soap to the solution to allow the solution to be drawn into the leaves. Try not to generate suds! (More baking soda will remove the suds.) Punch 10 pieces of leaf using the hole punch. Force the baking soda into the leaves by putting them into the barrel of the syringe and adding some baking soda solution so that there is little air left in the syringe (less than 10%). Create a vacuum and swirl the disks, then apply pressure on the leaves until they sink and stay down after the pressure is released (this may have to be repeated several times). Put the solution with the disks into a clear glass or plastic cup and add more baking soda solution so that the leaves have plenty of room to rise noticeably. Each cup should have a depth of at least 5 cm per trial. Place the leaf disks under the light source (sunlight works best). Using a timer, at each minute, record how many leaves are floating. Wait until all are floating and record how long it takes. You can compare the results and determine the net of photosynthesis over time. The leaves will take a few minutes to rise. The brighter the light source, the faster they will rise.

Source: https://blog.udemy.com/photosynthesis-experiment/

Source: Sharon Camp

3. **Demonstration of Release of Oxygen During Photosynthesis:** An aquatic plant is used to demonstrate the formation of a gas (oxygen) during photosynthesis. If further experimentation is desired, the variables introduced could be changes in intensity of the light source (or no light at all), and changes in the amount of baking soda in solution. Both an increase in the intensity of light and the amount of baking soda should increase the rate of photosynthesis.

   Materials: Either distilled or boiled and cooled water (or water from the store where the plant was purchased); hydrilla or elodea (please destroy these plants when finished with the experiment or keep them in an aquarium. Hydrilla especially is extremely invasive and can destroy aquatic ecosystems if released into a body of water); glass jar, glass or beaker; glass funnel; test tube (can be purchased on Amazon); baking soda, light source (optional).

   Procedure: *Start by asking the students questions about what results they expect. Put the answers on the board, and use them to come up with various hypotheses to test.* After the lab, revisit the hypotheses and see which one best predicted the actual results. The hypotheses should be based on whatever combination of variables you choose to include. Always include the control, which is used to verify that the results of the reaction are due to the variables and not some random, unanticipated and unrecognized experimental condition. Fill the beaker with water and place the plant at the bottom of the beaker. Completely cover the plant with the funnel as shown in the diagram. Fill a test tube with the same water and invert it over the end of the funnel so that there is no air bubble present in the test tube. Either put the beaker in the window so that it gets bright light or purchase a bright light source. Measure the time it takes to fill the test tube with gas; this can be used to calculate the rate of photosynthesis. It might be helpful if marks are drawn at regular intervals onto the test tube with a permanent marker, or to use a small, graduated cylinder instead of a test tube. To test for oxygen in the test tube, get a wooden splint (or a Popsicle stick), ignite it, let it burn for a few seconds, then blow it out and insert it into the still upside-down test tube. The splint will either glow very brightly or burst into flame in the presence of oxygen.

   Variations: You can determine if carbon dioxide from the baking soda impacts the rate of photosynthesis. Set up several of the same arrangements with varying amounts of baking soda (the control will not have any baking soda). Measure the relative rates of photosynthesis by measuring how long each test tube takes to reach an equal amount of oxygen. Use the light source as a constant for this experiment. Another variation is to change the amount of light. Using the same light source as the original experiment, expose different set ups to differing intensities of light and no light at all. Use the baking soda concentration that provided the fastest rate of photosynthesis as a constant for this experiment.

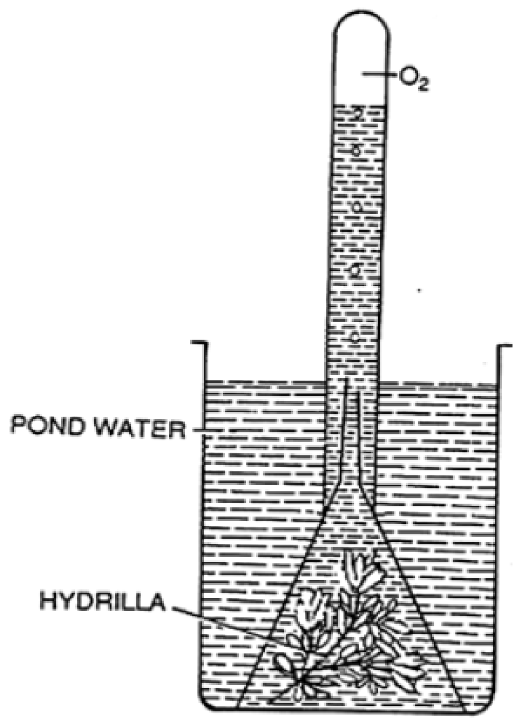


Fig. 5.22. Liberation of oxygen in photosynthesis. Demonstration of the phenomenon.

Source: https://www.yourarticlelibrary.com/experiments/photosynthesis-experiments/top-10-experiments-on-photosynthesis-with-diagram-botany/90902

Demonstration of Cellular Respiration: Cellular respiration occurs when cells use mitochondria to break down glucose and release the stored energy from the molecule that was stored from the Sun during photosynthesis. In a very real sense, respiration is the opposite of photosynthesis, although the chemical pathways are different. Because CO_2 is necessary for photosynthesis and O_2 is a waste product, when the chemical reaction is reversed, CO_2 becomes the waste product and O_2 becomes the necessary gas. (This is the reason why in the above experiment, even though the aquatic plant produced a gas when in the dark, the gas did not test positive for O_2. This is because the plant underwent cellular respiration in the dark and produced CO_2 instead.) Humans exhale CO_2 with every breath. Even microorganisms, such as bacteria and yeast used in bread making, release a hefty amount of CO_2 when undergoing cellular respiration. For this experiment, you will make a solution of limewater using calcium hydroxide, then bubble CO_2 through the solution by bubbling your breath through the solution by exhaling into a straw that has been put into the solution. The solution will turn cloudy. This is because the CO_2 in your breath reacts with the calcium hydroxide to form calcium carbonate, which does not dissolve in water. It will come out of solution (precipitate) as a white suspended solid, making the solution look milky.

Materials: 2 clean glass jars with lid (up to 1 gallon in size, but smaller works well too), clear plastic cups, water, teaspoon measure, coffee filter(s) or filter paper(s), straw(s), calcium hydroxide, available from https://www.homesciencetools.com/product/calcium-hydroxide-30-g-lime/?_ga=2.237697664.1255874967.1631646283-128737735.1631646283

Procedure: *Start by asking the students questions about what results they expect. Put the answers on the board, and use them to come up with various hypotheses to test. After the lab, revisit the hypotheses and see which one best predicted the actual results. The hypotheses should be based on whatever combination of variables you choose to include. ALWAYS include the control, which is used to verify that the results of the reaction are due to the variables and not some random, unanticipated and unrecognized experimental condition.* Put a teaspoon of calcium hydroxide into one of the jars and fill with water. Fasten the lid onto the jar and shake it vigorously for several minutes, then let the jar sit overnight. Not all the solid will dissolve, but enough will dissolve to form a saturated solution. The next day, filter the calcium hydroxide solution by very carefully pouring the clear liquid through the coffee filter into the second glass jar without disturbing the solid at the bottom. If necessary, filter the solution again to ensure that it is completely clear. You now have a saturated solution of calcium hydroxide. You may store this solution in the jar indefinitely. To perform the experiment, pour some of the limewater solution into a plastic cup, take the straw and blow through it while it is immersed in the solution. It should turn milky white. The control would be a cup of plain water. This experiment should demonstrate that CO_2 is exhaled when a person breathes.
Source: https://learning-center.homesciencetools.com/article/making-limewater-solution-science-lesson/

4. **Using a Carbon Dioxide Detector to Demonstrate the Presence and Amount of CO2:** Carbon Dioxide is always present in the air, but its amount varies depending on the location of the air. Generally, the average amount of CO_2 in the atmosphere is roughly 415 parts per million, or ppm. This means that out of every 1 million air particles of all types, only 415 of them will be CO_2 molecules. https://gml.noaa.gov/ccgg/trends/ But what are the levels in a room full of people? In the air outside your home or school? What if you took a bucket, placed it upside down over some garden or forest soil, and left it there for a while. Would the levels of CO_2 rise? If so, by how much? The easiest

way to find out is to use a CO_2 meter. These meters can be as easy to use as a thermometer or as sophisticated as a probe that can measure actual amounts and the rate of increase. The following meters can be purchased and used for any kind of experiment you can think of or that your students can design.

Sources:

1. **https://www.vernier.com/product/labquest-3/** (data logger only), and https://www.vernier.com/product/go-direct-co2-gas-sensor/ or https://www.vernier.com/product/co2-gas-sensor/
2. https://www.amazon.com/Amprobe-CO2-100-Handheld-Carbon-Dioxide/dp/B0046HEFEU

Formative and Summative Questions

1. Name three gases found in Earth's atmosphere that are essential for life.
2. Which gas is the one we breathe in when we inhale?
3. What does our body use the gas we inhale for?
4. What is the main gas found in our breath when we exhale?
5. How do we make the gas found in our breath?
6. What other living things breathe out this gas (from question 4)?
7. What happens in photosynthesis?
8. Where does the gas we need to breathe come from (from question 2)?
9. How do plants use the gas given off when we breathe?
10. How do we use the gas given off by plants?

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What is the CO_2 Coalition?

The CO_2 Coalition was established in 2015 as a 501(c)(3) for the purpose of educating thought leaders, policy makers and the public about the important contribution made by carbon dioxide to our lives and the economy.

The CO_2 Coalition is a group of the top scientists, engineers and energy experts who study and report on the important contribution made by carbon dioxide to our lives and the economy.

Learn more at **CO2Coalition.org** and **CO2LearningCenter.com**.