CO2 LEARNING CENTER

Video One Lesson Plan

Gases in the Air

This lesson plan was produced by the CO_2 Learning Center, a project of the CO_2 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.

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.

This lesson plan was created for the CO_2 Coalition's CO_2 Learning Center by Sharon Camp, Ph.D. Analytical Chemistry; B.S., Geology, using Next Generation Science Standards (NGSS).
Understanding NGSS:

LS: Life Science PS: Physical Science ES: Earth Science

1-5 indicates the standard for grade level (1-first grade, 2-second grade, 3-third grade, 4-fourth grade, 5-fifth grade)

MS: Middle School

Please note that only the parts of the outline that are relevant to this lesson have been included. If LS1.C *or* PS3.D *(examples from this lesson plan) are shown, these NGSS segments were included as relevant to this lesson for Life Science and Physical Science.*

Lesson Plan: Video One

Grades K-8

Next Generation Science Standards (NGSS) Learning Objectives:

MS-LS1-6. Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms. [Clarification Statement: Emphasis is on tracing movement of matter and flow of energy.]

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-LS1-6)
- 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. (MS-LS1-7)

PS3.D. Energy in Chemical Processes and Everyday Life

- The chemical reaction by which plants produce complex food molecules (sugars) requires an energy input (i.e., from sunlight) to occur. In this reaction, carbon dioxide and water combine to form carbon-based organic molecules and release oxygen (*secondary to MS-LS1-6)*
- Cellular respiration in plants and animals involves chemical reactions with oxygen that release stored energy. In these processes, complex molecules containing carbon react with oxygen to produce carbon dioxide and other materials. *(secondary to MS-LS1-7)*

5-PS1-1. Develop a model to describe that matter is made of particles too small to be seen. [Clarification Statement: Examples of evidence supporting a model could include adding air to expand a basketball, compressing air in a syringe, dissolving sugar in water and evaporating salt water.]

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-PS3-1. Use models to describe that energy in animals' food (used for body repair, growth, and motion and to maintain body warmth)

PS3.D: Energy in Chemical Processes and Everyday Life.

The energy released [from] food was once energy from the sun that was captured by plants in the chemical process that forms plant matter (from air and water).

5-LS1-1. Support an argument that plants get the materials they need for growth chiefly from air and water. [Clarification Statement: Emphasis is on the idea that plant matter comes mostly from air and water, not from the soil.]

LS1.C: Organization for Matter and Energy Flow in Organisms

- Food provides animals with the materials they need for body repair and growth and the energy they need to maintain body warmth and for motion. *(secondary to 5-PS3-1)*
- Plants acquire their material for growth chiefly from air and water. (5-LS1-1)

Source: https://www.nextgenscience.org

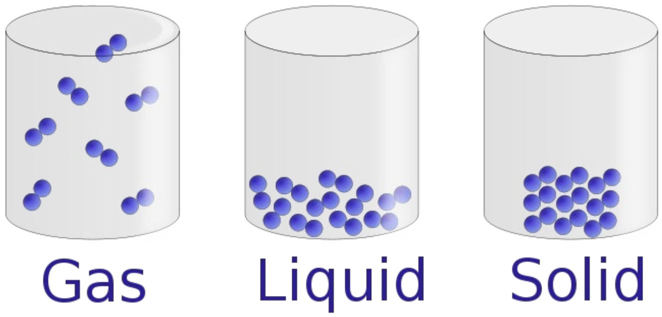
Student Learning Goals

After watching the video, students will be able to

1. Explain what air and gases are.
2. List the five most plentiful gases found in air.
3. Identify the three gases essential for life on Earth.
4. Explain why carbon dioxide is essential for plant life.
5. Explain why oxygen is essential for animal life.
6. Explain how life in water gets carbon dioxide and oxygen.

Background Information

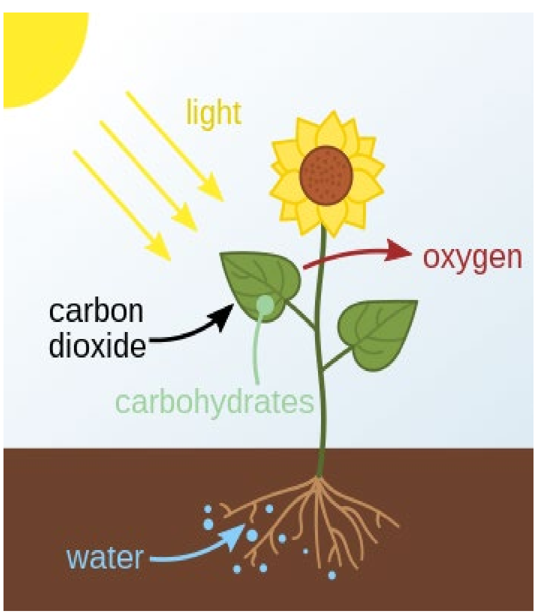
Substances exist in three main phases or states, which are solid, liquid, and gas. Solids and liquids are easy for children to understand, but gases aren't as easy because most of them are colorless and odorless. The states of matter are dependent on how closely packed the component particles are. In solids, the particles are packed as close together as possible and in gases, the particles are spaced very far apart.[1] States of matter are determined by pressure and temperature.



Air is a mixture of many gases, with the most plentiful being nitrogen and oxygen. Water vapor, argon, and carbon dioxide comprise a very small percentage of the total volume of air. Children, especially young children, have trouble understanding the concept of something being real if they can't see it, smell it or taste it. See the activities below to help demonstrate the presence of gases.

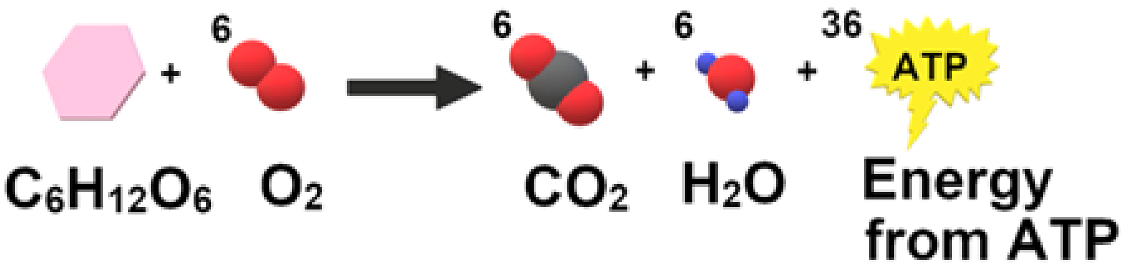
The amount of water vapor in the air varies with altitude, temperature and climate, whereas the amounts of nitrogen and oxygen stay fairly constant close to Earth's surface. Oxygen concentrations also decrease with altitude, which is why mountain climbers need oxygen tanks once they reach an altitude of roughly 23,000 feet.

Plants are unique in that they are autotrophs, meaning that they can make their own food. Using energy from the Sun, plants take carbon dioxide from the air and water from the soil and rearrange the atoms to make large molecules called carbohydrates. This complicated process has been studied by scientists for years and occurs in many different chemical steps that mostly take place in the chloroplasts of the plant cell. The specific compound used in this process is chlorophyll, which is the pigment that gives plants their green color. Sunlight is used by the plant to split a water molecule into hydrogen and oxygen. The plant uses the hydrogen from water and the carbon from carbon dioxide to create carbohydrates.[2]



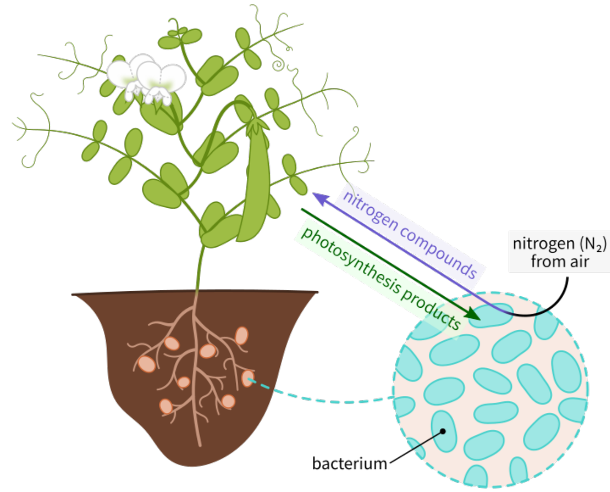
The process by which plants convert carbon dioxide and water into food is called photosynthesis,[2] which is derived from the Greek language and means "to make using light."

Organisms, including plants, along with some bacteria, insects and animals, use oxygen to do just the reverse: In their cells are organelles called mitochondria, which also use complicated chemical reactions that use oxygen to release the energy stored in the carbohydrates. This reaction, called cellular respiration (not to be confused with breathing), releases carbon dioxide and water back into the air. Students can see the water vapor that is released through respiration when they exhale while breathing onto a mirror. The water vapor condenses onto the mirror to form water droplets, which can be easily seen. Plants undergo both photosynthesis and cellular respiration, and so release oxygen, water and carbon dioxide into the air.[3]



(In nature, oxygen does not exist as a single atom but rather is formed from a molecule comprised of two oxygen atoms bound together. Nitrogen also exists as two nitrogen atoms bound together. These are called diatomic molecules.) Animals eat plants and other animals to get the energy they need to live. (Herbivores eat plants, carnivores eat other animals, and omnivores eat both.) Plants, however, only need carbon dioxide and water (along with other trace elements) to store energy from the Sun. Since only plants can store and use the Sun's energy later, animals are totally dependent on them. *Without carbon dioxide, life would not exist on the planet.*

Oxygen enters water environments by two different pathways: through aquatic plants and by contact with the air. Aquatic plants release oxygen directly into the water. Water that is agitated, like that in creeks and rivers or in choppy water on lakes and oceans, will absorb air quickly from the surface. Since the oxygen in the air dissolves in water, it is available to the aquatic organisms that need it. Carbon dioxide is also soluble in water, so the carbon dioxide in aquatic ecosystems comes from both the air and aquatic plants. Rainwater absorbs carbon dioxide from the air as it falls, adding to the carbon dioxide that is already in the water. In areas where volcanic activity is common, carbon dioxide can also dissolve in water as it bubbles up from underground sources. Aquatic plants can take carbon dioxide through the pores in their leaves just like land plants do. Aquatic animals use gills to remove oxygen from the water.



Nitrogen is also a substance that is necessary for life, but neither plants nor animals can use it in its gaseous state like they can with water, carbon dioxide and oxygen. This is because the bond that joins the two nitrogen atoms together is extremely hard to break. The only organisms that can split the nitrogen (N_2) molecule are bacteria that are found in the soil and in the root nodules of certain plants, such as legumes and alfalfa.[4] These plants are said to be nitrogen-fixing, which means they can take nitrogen from the air and fix it into the ground. Actually, they host bacteria that can take nitrogen from the air and break the strong bond. Breaking the bond allows the bacteria to produce nitrogen compounds that can be absorbed by plant roots. This chemical process is complicated and poorly understood. Even though nitrogen is essential for life, we will not consider atmospheric nitrogen in the discussion of gases in the air because it cannot be utilized unless it is changed into a different nitrogen compound.

References

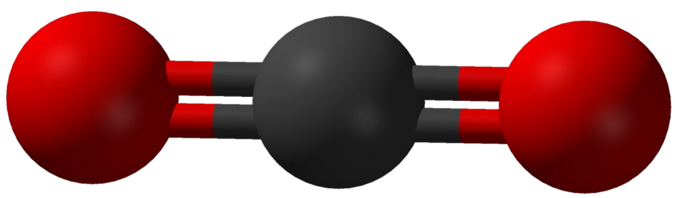
1. https://upload.wikimedia.org/wikipedia/commons/8/89/States_of_matter_En.svg
2. Ritchie, G.A. (2018). *Inside Plants: A Gardeners' Guide to Plant Anatomy and Physiology*.
3. https://upload.wikimedia.org/wikipedia/commons/6/67/Cellular_Respiration_Simple.png
4. https://upload.wikimedia.org/wikipedia/commons/3/31/Nitrogen_fixation_Fabaceae_en.svg

Suggested Activities

There are several websites that have activities to demonstrate photosynthesis, which are included in the links below. Several are outlined here; for more information, be sure to visit the websites or the provided hard copies.

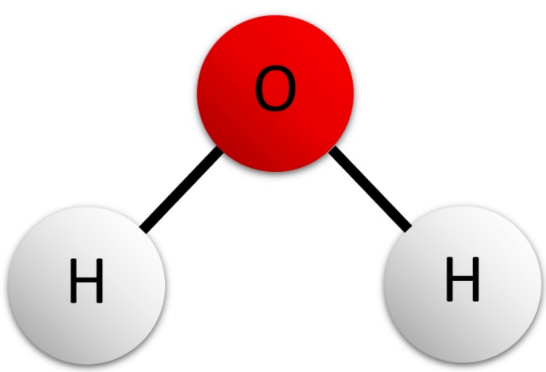
1) Using Manipulatives as Models for Molecules: It is often very useful to use models to represent molecules and how they can break apart and be put back together in different arrangements. This can be easily accomplished by using beads, Legos, or other items that connect interchangeably. For older students, using a separate color block for each element can work well. If you prefer, you can use Styrofoam balls connected with toothpicks to represent the shape of the molecule more accurately. 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://commons.wikimedia.org/wiki/File:Carbon-dioxide-3D-balls.png



H_2O:

https://upload.wikimedia.org/wikipedia/commons/4/43/Water_Molecule_Ball_and_Stick.png



2) Demonstrating that Air is Made of Gas:

a) This simple demonstration easily illustrates that the air takes up space. By taking a cup, turning it upside down and inserting it into a bowl of water, you can show that the air in the cup takes up space and prevents the water from going into the cup.

Materials: A clear plastic cup or beaker; a paper towel, a large bowl, preferably clear, filled with water; food coloring to make the water visible from a distance. **Procedure:** Start by asking the students what they expect to happen when you take the cup, stuff the bottom with the paper towel, and insert the cup upside down into the water. Put the answers on the board, then perform the demonstration, or have the students do the experiment themselves. Ask the students to come up with other tests, such as putting the cup in sideways or upside down and predict what they expect. Ask the students for possible explanations for their observations. http://simpleplayideas.com/science-magic-keep-paper-dry-in-water

b) Using your breath to blow up a balloon is another easy way to show that air exists and is also an easy way to demonstrate that the shape and volume of gases change with temperature and pressure. You can manipulate the balloon by squeezing it to show that gases change shape and size with pressure. You can also plunge the balloon into a bowl or aquarium full of ice water to demonstrate how gases change their volume according to temperature. Even though your breath is not visible, it clearly takes up space because it fills the balloon.

c) Show how air fills an empty bottle by trying to pour water into it. A description of the experiment is here: https://frugalfun4boy s.com/science-demonstration-air-takes-up-space/
Materials: a bottle with a squeeze top, such as an empty salad dressing bottle; a funnel; clay or Playdough©; food coloring to give the water some color. **Procedure: Start by asking the students what they expect to happen when you try to pour water from the funnel into the bottle, then demonstrate that it does.** Next, wrap the clay around the base of the funnel and insert it into the top of the bottle, ensuring that you have an air-tight seal. This is important because the demonstration will not work otherwise. Ask the students again what they expect to see. Pour the water quickly into the funnel so that the water stays in the funnel and does not go into the bottle.(You may want to practice first.)
Now ask the students to explain why water went into the bottle the first time but not the second. If you squeeze the bottle gently; they will be able to see air from the bottle going back up into the water in the funnel. This will allow some water to flow into the bottle, but only an amount equal to the air that was squeezed out of the bottle. Ask them if they can devise another experiment to test their hypothetical explanation of why water would not go into the bottle in the second demonstration.

3) 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 float again. (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, all of the leaves will sink if plunged into darkness.

Materials: baking soda, water, glass, thick leaves such as those from English ivy or something similar, hole punch, plastic timer, light source (sunlight works best), 10cc or larger plastic syringe, liquid dish detergent. (Leaves of different ages can be used to demonstrate relative rates of photosynthesis vs. age.) Make a weak baking soda solution by dissolving 1/8 teaspoon of baking soda in 1 1/3 cups of water. Add a drop of liquid soap to the solution to allow the solution to be drawn into the leaves. Try not to generate suds! If necessary, more baking soda can be added to remove any suds. Punch ten pieces of leaf; pick one that is not too thick and fairly smooth without much hair. English Ivy and spinach work well.

Procedure: Start by asking the students questions about what results they expect when you put the leaves in a container of water. Put the answers on the board and use them to come up with various ideas (hypotheses) to test. After the lab, revisit the hypotheses and see which one best predicted and explained 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. Force the baking soda into the leaves by putting them into the barrel of the syringe, 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 (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 3 cm per trial. A control can be created by omitting baking soda from the water solution. Place the leaf disks under the light source. 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 rate of photosynthesis over time. Further experimentation could include a comparison of rates vs. intensity of light source, age of leaves or types of leaves (as long as the leaves are thick and sturdy).

Source: https://www.sciencebuddies.org/stem-activities/photosynthesis-floating-leaves

4) 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 include 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 is extremely invasive and can destroy aquatic ecosystems if released into a body of water); glass jar, drinking glass, or beaker; glass or clear plastic 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 ideas (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 below. Fill a test tube with the same water and invert it over the end of the funnel so that there are no air bubbles 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 (oxygen); 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 setups 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. The control would be the setup that does not have a light source.

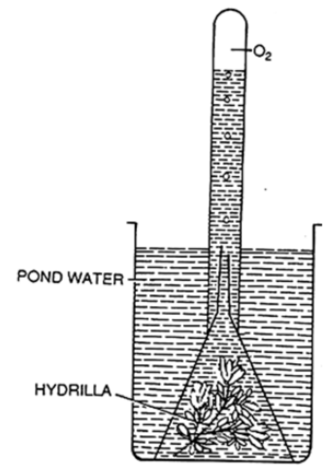


Fig. 5.22. Liberation of oxygen in photosynthesis. Demonstration of the phenomenon.

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

5) Demonstration of the Release of Carbon Dioxide during Cellular Respiration: Plants take the food they created in the presence of sunlight and convert it back to energy when they are in darkness. By using the same setup as in 3 but leaving the plant in darkness overnight instead of allowing it access to light, the plant will automatically undergo only cellular respiration. A gas will collect in the test tube that is colorless and odorless but is a substance other than oxygen as can be demonstrated by showing that it has different chemical properties (e.g., carbon dioxide will put out a flame instead of making it grow).

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. Set up the experiment the same as above, except put the setup in a closet or under a large cardboard box to prevent exposure to light. Leave the plant in darkness overnight. The next day, test the gas in the test tube using a burning splint. The flame should be extinguished by the gas instead of allowing the splint to burn. Since oxygen facilitates combustion, the gas in the test tube cannot be oxygen.

6) Observation of Carbon Dioxide Gas: Dry ice is frozen carbon dioxide. It is called dry ice because it never melts to a liquid. Frozen carbon dioxide sublimates, which means is changes phase from a solid directly to a gas without turning into a liquid first. This is one reason why it is frequently used to keep items cold because it doesn't melt as does water ice. Students love to play with dry ice, but young children can seriously injure themselves by handling it, so this activity should be a demonstration only for young students. Please watch this video first before handling dry ice: Dry Ice Do's and Don'ts, by Penguin Dry Ice Company

Materials: Dry ice, 10- or 20-gallon aquarium, clear cup or bowl with water, splints and matches or a cigarette lighter, tongs, a hammer or other device to break off pieces of dry ice, protective gloves and eyewear; cloth towel.

Procedure: Start by asking the students questions about what results they expect. There are several different demonstrations you can do, so ask the students what they expect to see before you do each demonstration.

a) Take a large chunk of the dry ice, put it in the aquarium and let it sublimate until it has disappeared. Discuss what is happening. Revisit the aquarium after the vapor is no longer visible.

b) Break off a piece of dry ice and hold it with a pair of tongs up high where all the students can see it. Ask them what the white stuff is coming off the dry ice and why it disappears quickly. Also tell them to notice that the vapor falls to the floor instead of rising up as does steam. [The white vapor is actually water vapor from the air that instantly freezes (called deposition) as it comes in contact with the frozen carbon dioxide. It is not necessary to clarify this fact unless you want to. The vapor falls for two reasons—its density is greater than air because carbon dioxide is naturally denser than air, and its cold temperature also makes it denser than the warmer air surrounding it.] The vapor disappears quickly because the water vapor evaporates again once it gets warm enough.

c) Fill a clear cup or bowl halfway with water, then drop a piece of dry ice into the water. Ask the students why the vapor is rising this time instead of falling. [The cold vapor is still less dense than water, so will rise to the top.]

d) Go back to the aquarium. Once the dry ice has sublimated, it will occupy the bottom of the aquarium while pushing the air up. This is because carbon dioxide is denser than air. You may be able to see a clear boundary between the cold carbon dioxide at the bottom of the aquarium and the ambient air on top of it. [When the concentration of carbon dioxide is very high, it will push the air out of low-lying areas and will cause suffocation of any animals that are unfortunate enough to wander in to the area.[1]] Take a burning splint (or lighter) and put it into the bottom of the aquarium; it will immediately go out because there is no oxygen in the bottom of the aquarium. Carbon dioxide is used as a fire extinguisher because it will remove oxygen from the fire source. This demonstration nicely reinforces the observations from Experiment 4.

Source: https://www.usgs.gov/programs/VHP/volcanic-gases-can-be-harmful-health-vegetation-and-infrastructure#:~:text=Carbon%20dioxide%20gas%20can%20collect,that%20causes%20most%20volcanic%20eruptions

Formative and Summative Assessment

1. What is air and how do you know it's there?
2. What is a gas?
3. What are the five most plentiful gases in air?
4. Of these gases, which are the most important for life on Earth?
5. What is the gas that plants must have to live, and why do they need it?
6. What is the gas that animals must have to live, and why do they need it?
7. Why do animals need plants to live, but plants don't necessarily need animals?
8. How do gases get into water?
9. How do aquatic plants get the gas they need when they are underwater?
10. How do aquatic animals get the gas they need when they are underwater?
11. Why would there be no life on Earth if there were no carbon dioxide?

CO2COALITION

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, policymakers, 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.