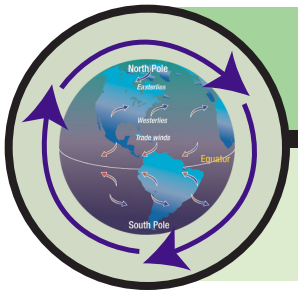


Carbon Dioxide Sources and Sinks

Unit: Cycles
Lesson: 1

Materials & Preparation

Time:
- Preparation: 40 min
- Teaching: 40 min
- Discussion: 30 min

Materials for Teacher
- Balloon filled with automobile exhaust (see Advanced Preparation)
- Beaker
- Bromothymol blue (BTB)
- Cotton ball
- Straw

Materials for Student Teams:
- Test tube rack
- Six test tubes
- One hole stopper with tubing attached
- Baking soda
- Vinegar
- Aluminum foil
- Cotton balls
- Bottle of BTB working solution
- Straws
- Sprig of Elodea (available in pet stores)
- Masking tape
- Markers

National Science Standards
- Science as Inquiry: Content Standard A
- Earth and Space: Content Standard D (Structure of the Earth System)

Learning Goals
Students will
- Be able to explain the concept of 'sources' and 'sinks' as they relate to carbon dioxide.
- Understand the use of an indicator solution (BTB) to reveal the presence of carbon dioxide.
- Understand the qualitative differences between animal and fossil fuel sources of global carbon dioxide.

What Students Do in this Lesson
Students will use a chemical indicator (BTB) to detect the presence of carbon dioxide.

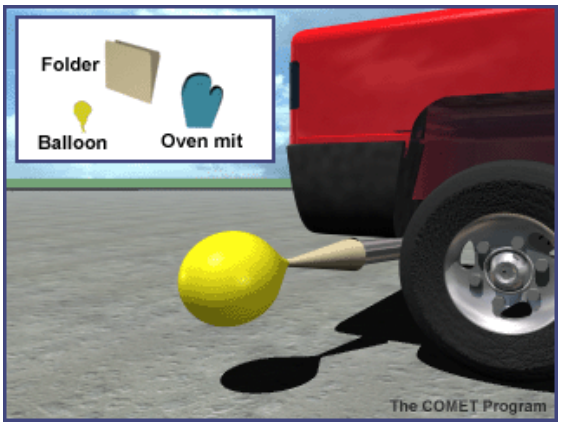
Source
Adapted from Global Climates - Past, Present, and Future. EPA Report No. EPA/600/R-93/126

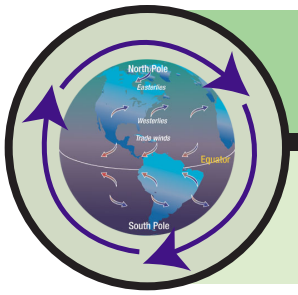
Key Concepts
- When dissolved in water, carbon dioxide forms a weak acid, called carbonic acid, which can be detected by the chemical bromothymol blue (BTB).
- Carbon dioxide is an important greenhouse gas.
- Because carbon cycles through the Earth system, carbon dioxide is constantly moving into and out of the atmosphere.
- Anything that releases CO_2 into the atmosphere (living, dead, or non-living) is considered a source.
- Anything that absorbs and holds CO_2 from the air or water is considered a sink.
- Currently, more carbon dioxide is moving into the atmosphere than out of the atmosphere.

Carbon Dioxide Sources and Sinks

Advanced Preparation

- This activity has significant set up time. Part 3 will require set up the previous day. You may want to do Part 5 (fossil fuels) as a demonstration as it involves automobile exhaust which contains carbon monoxide (CO).
- Make BTB working solution at concentration according to product directions.
- Preparation of Part 3
- Since the set-up for Part 3 will need to sit overnight, either students can put it together during class and note results the next day, or you can prepare this portion for students the day before. Directions for the set-up are in the Part 3 section on the following page.
- Procedure for collecting automobile exhaust (for Part 5):
    - Important note: Carbon monoxide is an odorless, moderately toxic, poisonous, and flammable gas. In a well ventilated room, students could do this activity. In that case, teachers should provide students with balloons full of car exhaust. It is not recommended that students participate in filling the balloons with car exhaust. An adult assistant (or two) is necessary, however.
    - Blow up and allow the balloons to deflate. This will stretch the rubber and make them easier to fill with the relatively low-pressure exhaust.
    - Prepare a cone to collect the car exhaust by rolling up a manila folder lengthwise. One end must be larger than the opening for the car's tail pipe and the other end must be small enough for the balloon to fit over it.
    - Use plenty of tape to hold the cone in shape and to make the sides of the cone fairly airtight. Note: the paper funnel will work for several fillings without burning. DO NOT use a plastic funnel. As the exhaust pipe heats up, the plastic may melt. You may use a metal funnel, but be VERY careful to avoid any skin contact with the hot metal.
    - Have an assistant turn on the car (make sure brake is on).
    - Put the balloon on the small end of the cone.
    - Using the heat resistant mitts, approach the exhaust pipe from the side. Place the large end of the cone over the tail pipe. Use the gloved hand to help form a seal between the cone and the exhaust pipe. DO NOT BREATHE THE EXHAUST. The balloon should fill quickly; if not, have your assistant step lightly on the accelerator.
    - When the balloon is filled, have an assistant use a twist tie or two to tightly seal the balloon. Do this by twisting the neck several times and doubling it over once, then place the twist tie around the constricted area.
    - You will want to have at least one balloon for each group of students. It is useful to prepare a few extra filled balloons.





Carbon Dioxide Sources and Sinks

Introducing the Lesson

- Discuss the impact of carbon dioxide (CO_2) and other greenhouses gasses in the atmosphere in terms of their effect on Earth's climate.
- Tell students that in this experiment they will discover some ways that CO_2 gets into the atmosphere and ways that it is taken out of the atmosphere.
- Outline the parts of the experiment for student teams:
    - In Part 1, students will gain experience in detecting CO_2 through the BTB reaction by using a pure CO_2 gas made from the reaction of baking soda and vinegar.
    - In Part 2, students will determine if animals are a source of CO_2
    - In Part 3, students will determine if plants are a source of CO_2 (through respiration).
    - In Part 4, students will determine if plants are a sink for CO_2 (through photosynthesis).
    - In Part 5, students will determine if fossil fuels are a source of CO_2.

Facilitating the Lesson

Part 1: Detecting CO_2 Gas

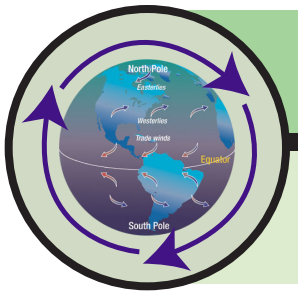
1. With masking tape, label 5 test tubes A thru E. A will serve as the control. One test tube will be left unmarked.
2. Gather the unmarked test tube and test tubes A and B, a test tube rack, a test tube stopper with a length of tubing attached, BTB solution, vinegar, baking soda, 1 inch square of aluminum foil, and a cotton ball.
3. Fill test tubes A and B approximately 1/3 full with the BTB solution and place in the rack. Test tube A will be used as a control.
4. Fill the unmarked test tube approximately 1/4 full of vinegar.
5. Using the foil, make a small "boat" for the baking soda - fill 1/2 full of baking soda.
6. The 'boat' should be small enough to easily fit into the test tube and float on the vinegar.
7. Carefully slide the foil boat inside the unlabeled vinegar test tube (it is useful to tilt the tube at an angle to accomplish this)
8. Plug the tube with the stopper and tubing.
9. Place the free end of the tubing in tube with BTB, making sure the end of the tubing reaches the bottom of the tube.
10. Place a cotton ball into the neck of the tube with BTB.
11. Mix the vinegar and soda together by GENTLY swirling the tube from side-to-side. Don't shake it upside down! Gas bubbles will begin to bubble rapidly out of the tubing into the test tube with BTB
12. Note the color change. Discuss what happened.

Part 2: Are animals a source of CO_2?

1. Fill a test tube C approximately 1/3 full of BTB
2. Place a straw in the test tube.
3. Place a cotton ball in the test tube opening.
4. Gently blow in the straw
5. Note the color change. Discuss what happened.

Part 3: Are plants a source of CO_2?

1. Fill test tube D approximately 1/3 full of BTB
2. Place a sprig of Elodea into the test tube (Use a pencil to push it all the way into the bottom of the tube)
3. Wrap the tube in foil so that no light can get in.
4. Place in test tube rack and leave for at least 24 hours.
5. Unwrap the foil and note the color change. Discuss what happened.



Carbon Dioxide Sources and Sinks

Part 4: Do Plants take up CO_2?

1. Using the now-unwrapped test tube with Elodea from Part 3, leave in the light and observe the BTB color change.
2. Discuss what happened.

Part 5: Are Fossil Fuels a Source of CO_2? (Recommended as a teacher demonstration)

1. Instructor fills the beaker approximately 1/3 full of BTB
2. Instructor takes the exhaust filled balloon, carefully untwist the tie while holding the neck of the balloon so that the gas does not escape. Twist and pinch the neck of the balloon to prevent air from escaping, but don't tie it.
3. While still preventing the gas from escaping, insert a straw into the neck of the balloon up to the twisted portion. Seal the opening of the balloon tightly to one side by pinching it off with fingers. (You may need to practice this a few times with a regular air-filled balloon.)
4. Insert the straw into beaker.
5. Insert a cotton ball at the top of the beaker to help hold the straw steady.
6. Gently release air from the balloon by slowly untwisting the neck. Allow the gas to bubble out at a steady rate until the balloon is empty.
7. Provide each group with a sample of BTB from the beaker in their test tube marked 'E' for comparison with the other test tubes.
8. Discuss what happened.

Summarizing and Reflecting

After finishing all five parts of this activity, compare the colors in all the tubes. Are they different? If so, why?
Discuss the test results. What are some sources and sinks of carbon dioxide?
In this activity, the students have examined several sources of carbon dioxide. Ask them the following questions:

- If you wished to reduce the amount of increase in the atmosphere, which source would be most important to control? Explain why.
- Would there be problems with such controls? If so, what might they be?
- Ask students to devise their own experiment to test other sources and sinks of carbon dioxide (e.g. carbonated beverages, lime based chalk)

Background Information

Carbon dioxide (CO_2) has a characteristic that enables students to detect it in a classroom setting. When dissolved in water, carbon dioxide forms a weak acid, called carbonic acid. The chemical bromothymol blue (BTB) is a sensitive indicator of the presence of acid. When gas containing CO_2 is bubbled through a BTB solution, carbonic acid forms and the indicator turns from dark blue to green, yellow, or very pale yellow depending on the CO_2 concentration (lighter colors mean higher concentrations).

Carbon dioxide (CO_2) provides the bubble in your soda pop and the "rise" in your baked goods. But it is also a very significant greenhouse gas. CO_2 is important in maintaining the earth's average temperature of about 15°C (59°F). The CO_2 traps infrared energy emitted from the earth's surface and warms the atmosphere. Without water vapor, CO_2, and methane (the three most important naturally produced greenhouse gases), the earth's surface would be about -18°C (0°F). At this temperature, it is doubtful that complex life as we know it would ever have evolved.

Where does CO_2 come from? Plants and animals give it off when they extract energy from their food during cellular respiration. CO_2 bubbles out of the earth in soda springs, explodes out of volcanoes, and is released when organic matter burns (such as during forest fires).

Carbon Dioxide Sources and Sinks

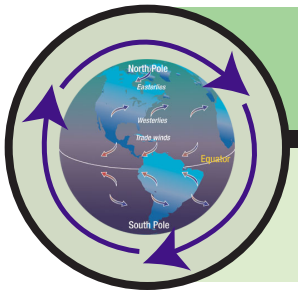
- Anything that releases CO_2 into the atmosphere (living, dead, or non-living) is considered a source
- Anything that absorbs and holds CO_2 from the air or water is considered a sink (because, like a sink in your home, it acts as a "holding reservoir")

Over geologic time, CO_2 sources and sinks generally balance. In today's atmosphere, however, CO_2 levels are climbing in a dramatic and easily measurable fashion, providing evidence that there are now more CO_2 sources than sinks.

Plants and animals give off CO_2 while alive and respiring and when dead and decaying (bacteria that consume the dead bodies respire too, after all). Plants (both terrestrial plants and marine phytoplankton) are important carbon sinks, taking up vast quantities of CO_2 through the process of photosynthesis. While plants also release CO_2 through the process of respiration, on a global, annual basis, the amount of CO_2 taken up by plants through photosynthesis and released through respiration approximately balances out.

Additional Resources

- Project LEARN: Cycles of the Earth and Atmosphere
  http://www.ucar.edu/learn/
- Windows to the Universe: Earth's Atmosphere
  http://www.windows.ucar.edu/tour/link=/earth/Atmosphere/overview.html
- Bromothymol Blue: Materials Safety Data Sheet
  http://www.jtbaker.com/msds/englishhtml/b5380.htm



Carbon Dioxide Sources and Sinks

Name _____

Date _____ Class _____

What's carbon dioxide?

Carbon dioxide (CO^2) provides the bubble in your soda pop and the "rise" in your baked goods. But it is also a very significant greenhouse gas. CO^2 is important in maintaining the earth's average temperature of about 15°C (59°F). The CO^2 traps infrared energy emitted from the earth's surface and warms the atmosphere. Currently, the amount of carbon dioxide and other greenhouses gasses in the atmosphere is increasing causing global warming. In this activity you will discover some of the ways that carbon dioxide gets into and out of the atmosphere.

What you'll need:

Six test tubes and a rack
One hole stopper with tubing attached
Baking soda
Vinegar
Aluminum foil
Cotton balls
Straws
Bottle of BTB working solution
Sprig of Elodea (a water plant)
Masking tape and a marker

Part 1: Detecting CO^2 Gas

1. Use a small piece of masking tape to label two of the test tubes A and B (a third will be unlabeled). Fill tubes A and B approximately 1/3 full with the BTB solution. (Tube A will be the control, tube B will be the treatment.) Place the tubes in the rack.
2. Fill an unlabeled tube approximately 1/4 full of vinegar.
3. Using the foil, make a small "boat" (small enough to easily fit into the test tube and float on the vinegar) and fill it 1/2 full of baking soda.
4. Carefully slide the foil boat inside the unlabeled vinegar test tube (it is useful to tilt the tube at an angle to do this) and plug the vinegar tube with the stopper and tubing.
5. Place the free end of the tubing into tube B. Make sure that the end of the tubing reaches the bottom.
6. Place a cotton ball into the neck of tube B.
7. Mix the vinegar and soda together by GENTLY swirling the tube from side-to-side. Don't shake it upside down! Gas bubbles will begin to bubble rapidly out of the tubing into the BTB solution in tube B.
8. After a minute or so, compare the color of tubes A and B. ***What happened?***

Part 2: Are animals a source of CO^2?

1. Fill a test tube C approximately 1/3 full of BTB
2. Place a straw in the test tube and place a cotton ball in the test tube opening.
3. Gently blow in the straw.
4. Note the color change. ***What happened?***

Part 3: Are plants a source of CO^2?

1. Fill test tube D approximately 1/3 full of BTB
2. Place a sprig of Elodea into the test tube (Use a pencil to push it all the way into the bottom of the tube)
3. Wrap the tube in foil so that no light can get in.
4. Place in test tube rack and leave for at least 24 hours.
5. Unwrap the foil and note the color change. ***What happened?***

Part 4: Are plants a sink for CO^2?

1. Using the now-unwrapped test tube with Elodea from Part 3, leave in the light and observe the BTB color change.