Activity 6: I Didn't Do It...Did I?

What You Will Do: Make Your Own Greenhouse Effect (adapted from Lambert, Cottongim, and Leard, 2009)

Big Idea

Human activities are impacting the climate system.

(Climate Science Principle 6)

What You Will Need

- Adult Partner
- 1 – Scratch awl or icepick
- 3 – Clear plastic drinking water bottles, about 500 ml (1 pt) capacity
- 1 – Vinyl tubing, about 3 mm (1/8 in) inside diameter, about 60 cm (2 ft) long (tubing for aquarium air systems works well)
- 2 – Thermometers (such as Forestry Suppliers #89323; these thermometers have an aluminum case which makes them useful for field investigations as well as in your laboratory)
- Modeling clay (the kind that doesn't harden, not the kind you bake)
- White vinegar, about 250 ml (1 c)
- Baking soda, about 40 g (2 tablespoons)
- Funnel
- Safety glasses
- Felt tip marker
- Heat lamp (if you don't have a sunny location)

More than 90% of climate scientists agree that Earth's average global temperature has increased since 1950, and the cause of this increase is human activities. These scientists also agree that most of the temperature increase is due to burning fossil fuels, which has increased the levels of greenhouse gases like carbon dioxide in Earth's atmosphere.

Two things happen when sunlight reaches Earth:

1. The land, ocean, and atmosphere absorb some of the sunlight's energy; and
2. They return some of this energy back into space.

Earth's atmosphere is a mixture of many gases. The most abundant are nitrogen (about 78% of the total atmosphere) and oxygen (about 21% of the total atmosphere). Other gases are present in much smaller quantities, yet are still very important for life on Earth, because they trap some heat in the atmosphere and prevent it from escaping to outer space. Heat-trapping gases are called greenhouse gases, and include water vapor, carbon dioxide, and methane. If the amount of greenhouse gases in the atmosphere increases, then more heat is trapped and Earth becomes warmer (for a short animation about how this works see *http://epa.gov/climatechange/kids/basics/index.html*).

Since the Industrial Revolution, widespread burning of fossil fuels has increased the concentration of greenhouse gases, mostly carbon dioxide, in Earth's atmosphere, and Earth's average temperature has increased. Other human activities have also changed Earth's atmosphere, as well as its land and ocean. Climate change caused by human activities is making it difficult for some species to survive. Scientists predict that there may also be positive benefits from climate change, such as longer growing seasons in some areas and less ice to interfere with ships passing through the Arctic Ocean. Overall, though, climate change is expected to produce more problems than benefits.

How It Works

Heat-trapping gases in Earth's atmosphere are called "greenhouse gases" because they reduce the amount of heat that is lost to outer space, but this is not actually the way a greenhouse works. It is hot inside a greenhouse because the glass allows objects inside to absorb heat from sunlight and prevents wind from carrying heat away. Greenhouse gases trap heat in the atmosphere, but do not form an actual barrier like glass in a greenhouse. Ozone is also a greenhouse gas, but holes in the ozone layer have nothing to do with global warming.

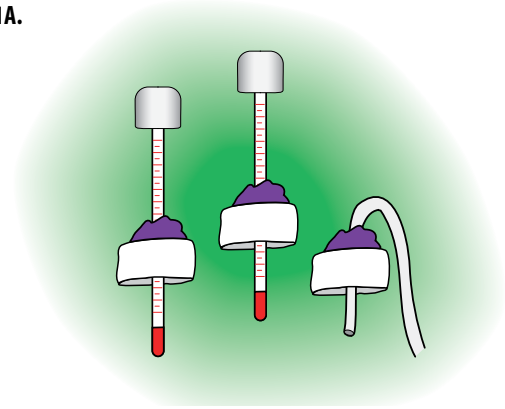
How to Do It

1. Read through all of these steps before you start!

2. Ask your adult partner to use the scratch awl to punch a hole in the caps of the drinking water bottles. The holes in two of the caps should be just large enough to fit the thermometers, and the hole in the third cap should be just large enough to fit the plastic tubing. Ask your partner to also punch a hole in the side of one of the drinking water bottles about 25 mm (1 in) from the top. Label this bottle "CO_2" with the felt tip marker.

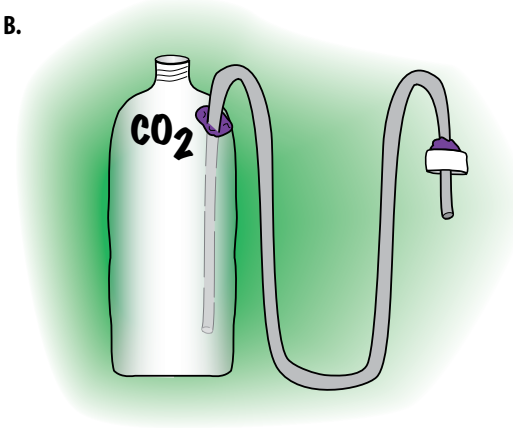
3. Put the thermometers and plastic tubing into the caps, and make a tight seal using modeling clay. The thermometers should extend about 40 mm (1.5 in) below their caps, and the tubing should extend about 25 mm (1 in) below its cap (Figure 1A).

Figure 1A.



4. Poke the free end of the plastic tubing into the hole in the side of the drinking water bottle so about 25 mm of the tubing is inside the bottle. Make a tight seal using modeling clay (Figure 1B).

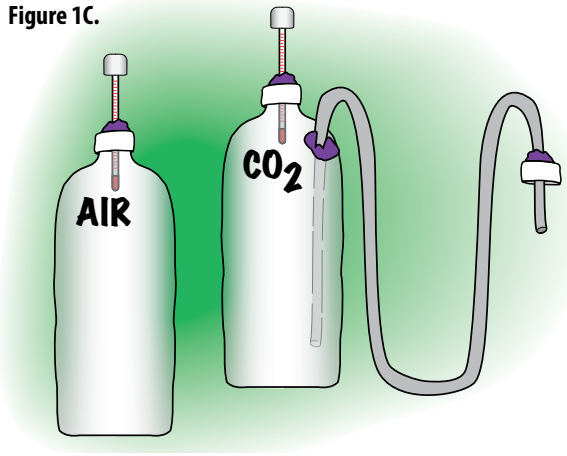
Figure 1B.



5. Put one of the caps with a thermometer onto one of the bottles that does not have the plastic tubing attached. Screw the cap on snugly. Label this bottle "Air" with the felt tip marker.

6. Put the other cap with a thermometer onto the "CO_2" bottle. Screw the cap on enough to keep it attached to the bottle, but loose enough so that air can escape if you squeeze the bottle (Figure 1C).

Figure 1C.



7. Use the funnel to place about 40 g (2 tablespoons) of baking soda in the unlabeled water bottle.

8. Get ready, because now you have to work fast. Pour about 60 ml (2 oz) of vinegar into the bottle with the baking soda, and QUICKLY fasten the cap with the tubing to the bottle. The easiest way to do this is to have one person pour the vinegar while the other person holds the bottle in one hand and the cap in the other hand. As soon as the vinegar is in the bottle, bring the cap and bottle together and twist the BOTTLE to make the seal. The mixture in the bottle will foam up vigorously, then gradually calm down. The bubbles are carbon dioxide gas, which will flow through the plastic tubing to the bottle with the hole in the side (Figure 2).

Gently swirl the bottle to move the vinegar around, and you should be able to stir up some more bubbles. When no more bubbles appear, remove the bottle from the cap, pour another 60 ml (2 oz) of vinegar into the bottle, and quickly replace the cap. Repeat this process until you have

Figure 2.

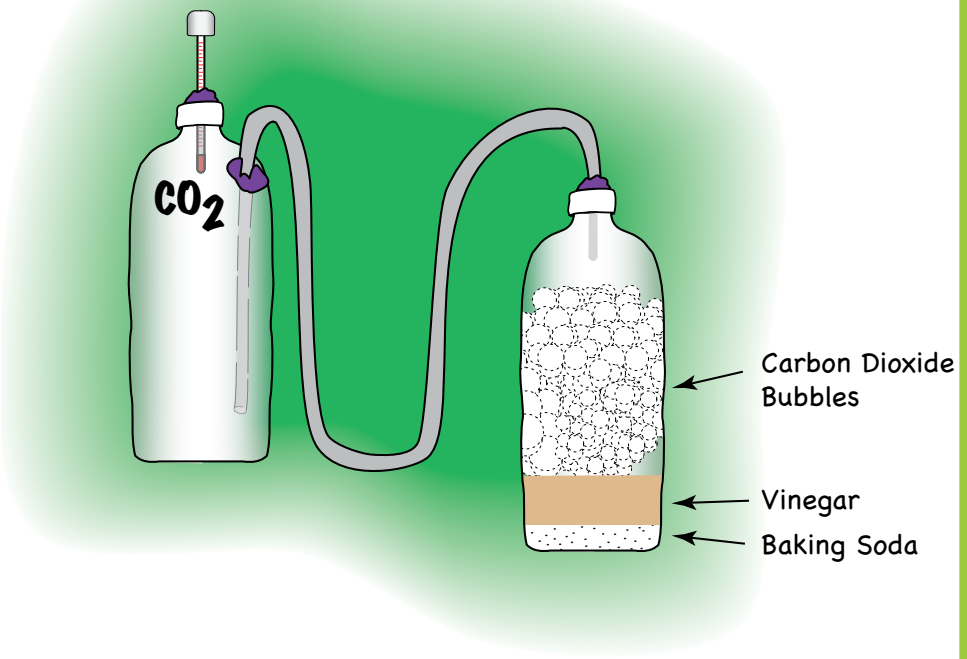


Table 1. Record Your Data

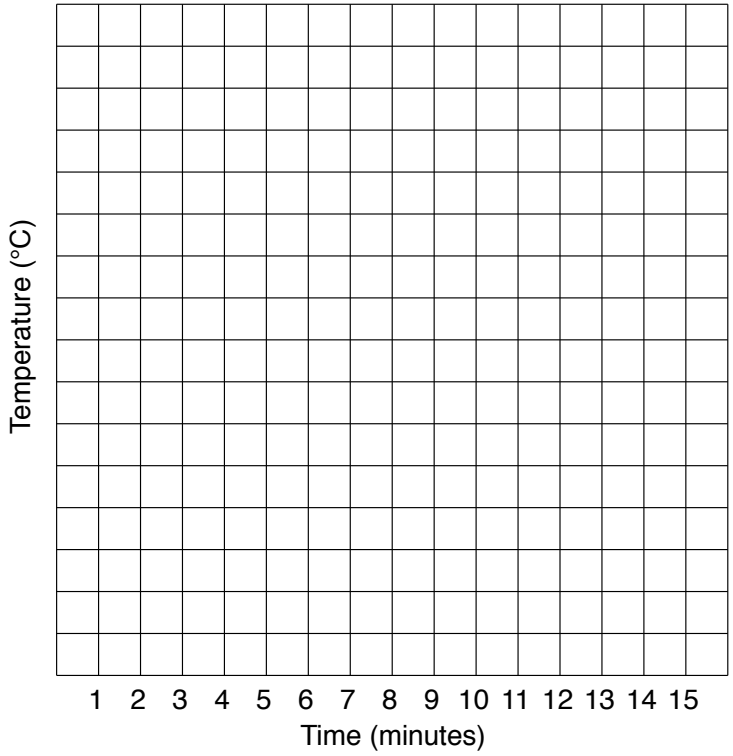
Temperature (°C)

Time (min):	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Air																
CO_2																

added about 250 ml (1 c) of vinegar to the bottle. You should notice that the baking soda is gradually disappearing.

9. Remove the plastic tubing from the side of the bottle with the hole, and quickly seal the hole with modeling clay. Tighten the cap on the bottle.
10. Place both bottles in the sun, or near a heat lamp. Immediately record the temperature of both thermometers in the left column (labeled "0") of Table 1. Record the temperature every minute for 15 minutes. It doesn't matter if the two thermometers have different readings at the beginning, because the important thing is how quickly and how much the temperature changes in each bottle.
11. When you have recorded data for 15 minutes, construct a graph of these data. Your data should show that temperature increased in both bottles; but the temperature changed most quickly in the bottle with carbon dioxide, and the total temperature increase was greater in this bottle as well. Both bottles had a greenhouse effect, but adding carbon dioxide increased this effect; just as carbon dioxide added to the atmosphere by human activities has increased the greenhouse effect on Earth!

Graph 1. Graph Your Data



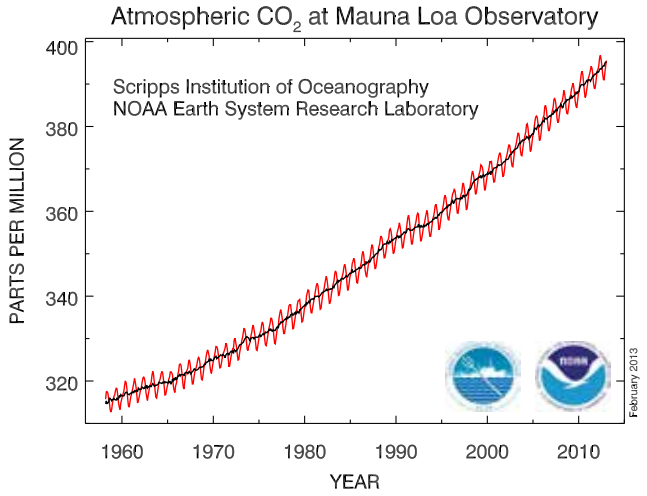
Note to Adult Partners

Lambert, Cottongim, and Leard (2009) describe an alternative method for this demonstration using dry ice to supply carbon dioxide. This may be somewhat quicker than the baking soda/vinegar method described here, but introduces additional hazards. If you want to use this method, be sure that your young partner understands the dangers of severe cold, and NEVER put dry ice and water into a sealed container. Closed plastic bottles containing dry ice and water can easily explode, creating dangerous shrapnel that can seriously injure anyone nearby.

Dry Ice can be DANGEROUS!!!

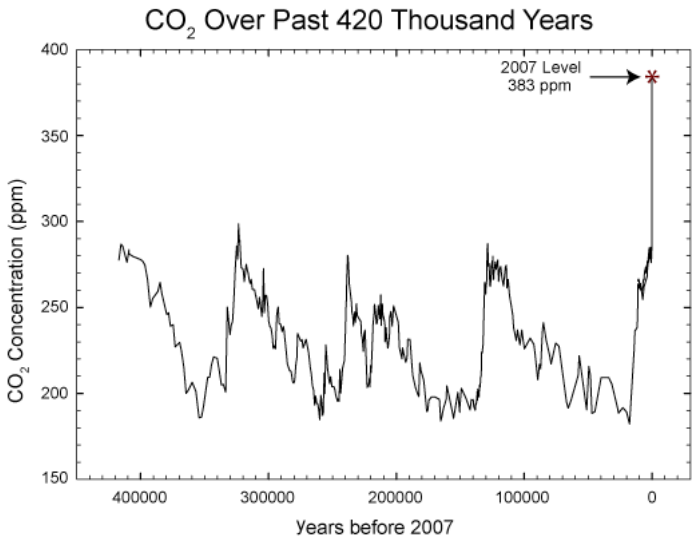
Lambert, J., Cottongim, L, & Leard, C. (2009). Investigating the greenhouse effect *Oceanography*. Published activity. (*http://www.oceanography.org/hands-on/activities/lambert_hands-on.pdf*)

Graph 2. Measurements of carbon dioxide in the atmosphere at the Mauna Loa Observatory since 1957.



http://www.esrl.noaa.gov/gmd/ccgg/trends/

Graph 3. Atmospheric carbon dioxide concentrations over the last 420,000 years.



http://scrippsco2.ucsd.edu/program_history/keeling_curve_lessons_4.html

More About Carbon Dioxide

Here are two famous graphs. Graph 2 shows measurements of carbon dioxide in the atmosphere at the Mauna Loa Observatory that began in 1957. This graph shows annual variations in carbon dioxide concentration caused by changing growth rates of plants during the seasons of the Northern Hemisphere, and also shows a steady increase in atmospheric carbon dioxide that has continued every year since the measurements began. Graph 3 shows atmospheric carbon dioxide concentrations over the last 420,000 years based on studies of polar ice cores. During ice ages, carbon dioxide levels were around 200 ppm, and rose to about 280 ppm during the warmer periods between the ice ages. Since the Industrial Revolution, atmospheric carbon dioxide concentrations have risen to much higher levels. The evidence contained in these two graphs is why most climate scientists agree that human activities have increased the concentration of carbon dioxide in Earth's atmosphere.

Is the greenhouse effect a bad thing? Definitely not, because life on Earth would not exist without it! But too much greenhouse effect can also cause problems. Venus has a thick atmosphere made of 96% carbon dioxide (compared to Earth's atmosphere that contains less than 0.04% carbon dioxide). The greenhouse effect on Venus is much larger than on Earth, and Venus has a surface temperature of about 450°C! Mars, on the other hand has a very thin atmosphere, only 1/100th as dense as Earth's. Most of Mars' atmosphere is carbon dioxide (95%), but the greenhouse effect is insignificant because the atmosphere is so thin. As a result, the surface temperature of Mars is around -53°C. These facts are summarized by the "Goldilocks Principle": Venus is too hot, Mars is too cold, and Earth is just right.

Want To Do More?

Find out about Charles David Keeling, the science hero behind the atmospheric carbon dioxide measurements at Mauna Loa Observatory: *http://scrippsco2.ucsd.edu/index.php*