Eunice Foote and the Greenhouse Effect
Lab Instructions

Time: 40-50 minutes

Materials:

- 3 identical, large, clear, plastic bottles with screw-on caps (1L water bottles will work)
  - One will measure common air, one with water-saturated air, one with carbon dioxide
- 3 thermometers to fit inside the bottles (analog, digital, digital recording will work)
  - If a digital recording probe is used, you will need to drill a hole in the cap for the wire. The holes can later be sealed with clay, hot glue, or another sealant.
- Clock or watch that displays seconds and minutes
- Hair dryer (optional)
- 150 mL vinegar
- 250 mL baking soda
- An extra bottle or beaker to prepare carbon dioxide
- 3 sponges or sponge pieces of equal dimensions to be placed in the bottle
- 3 identical light sources or direct sunlight

Preparation:

1. Assemble all materials.
2. If using digital recording thermometer with a probe, drill a small hole in the bottle caps to lace the wire through.
3. Place thermometers in the bottle to be visible from the outside.
4. Cut sponges to size if needed and place in the bottom of each bottle.
5. Prepare each bottle:
   a. *For bottle with common air:* (optional) use a hair dryer to dry out the air inside the bottle for a few minutes and tighten cap otherwise just tighten cap on bottle.
   b. *For bottle with water-saturated air:* drop enough water in the bottle to saturate the sponge and no more and tighten cap.
   c. *For bottle with carbon dioxide:* in a separate bottle or beaker, prepare the CO_2 according to the instructions below. See "Making CO_2" at the end for an explanation of the reaction.
      i. Pour 30 mL of vinegar into the separate bottle or beaker.
      ii. Spoon ½ tsp baking soda and allow the reaction to bubble.
      iii. When it stops fizzing, pour the CO_2 gas into the bottle with the sponge but do not pour any liquid. (The CO_2 will be a clear gas that looks like air but will feel colder)
      iv. Repeat this process twice more.
      v. Tighten the cap on the bottle with CO_2.

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Instructions:

1. Record room temperature by holding thermometer in the air for one minute. Be sure it is not touching any surface or someone's hand.
2. Divide the class into 3 groups, one group to monitor each bottle.
3. For each bottle, make a data chart with 3 columns corresponding to: time, temperature, and notes.
4. Place the bottles at a designated distance from the light sources 10-25 cm or 4-10 in recommended or in direct sunlight (if in direct sunlight, be mindful of shadows)
5. Turn on the light sources and start collect temperature data every minute for 15 minutes.
6. After 15 minutes, turn off the light source or move the bottles into the shade and continue collecting data for another 10 minutes.
7. Plot the data with time (minutes) on the X-axis and temperature on the Y-axis.

Post-Lab Questions:

1. Describe the plots of temperature over time for each gas.
    a. Which gas warmed most quickly? Was the increase in temperature (slope) constant or did it change?
    b. Which gas had the greatest change in temperature?
    c. How did the cooling of the gases compare to the warming? Which gas retained heat the longest?
2. Compare the gases to the composition of the atmosphere.
3. If you increased CO_2 in the atmosphere, what would happen to the Earth?
    a. How is this related to the greenhouse effect?

A Note on Making CO_2:

Vinegar (acetic acid, CH_3C00H) mixed with baking soda (sodium bicarbonate, $NaCH0_3$) produces an acid-base reaction with a carbon dioxide (CO_2) biproduct. The CO_2 gas is denser than air and will stay in the beaker, forcing out the air that was there before the reaction. The gas is cold because the reaction is endothermic, meaning energy in the form of heat leaves the system. To demonstrate the beaker has CO_2, feel the cold gas. The teacher can also light a match and hold it in the beaker. The match will be extinguished because there is no oxygen present.

References:

This lab has been adopted from a lab posted by the Science Education Resource Center at Carleton College (https://serc.carleton.edu/eslabs/weather/2d.html) which was based on a laboratory activity from the United States Geological Survey on Greenhouse Gases, created in 2011 (https://www.usgs.gov/science-support/osqi/yes/resources-teachers/greenhouse-gases).