EARTH SCIENCE FAX!
P.O. Box 219 • Batavia, IL 60510
(800) 452-1261 • Fax (866) 452-1436
www.flinnsci.com • E-mail: flinn@flinnsci.com

FLINN SCIENTIFIC, INC
"Your Safer Source for Science Supplies"
Catalog No. AP7324
Publication No. 7324

Greenhouse Effect and Global Warming

Environmental Science Student Laboratory Kit

Introduction

What is the greenhouse effect? How does the amount of greenhouse gas in the atmosphere affect the temperature of the Earth? Where are the increased amounts of greenhouse gas originating from? Perform the following activities to gain a better understanding of the greenhouse effect and global warming.

Concepts

- Greenhouse effect
- Global warming
- Greenhouse gases

Background

Carbon dioxide, CO_2, is a colorless gas that is present in our atmosphere due to natural and man-made sources. Carbon dioxide and other greenhouse gases in the upper atmosphere, such as water vapor, ozone, methane, nitrous oxide and chlorofluorocarbons (CFCs) absorb and trap heat energy and thus act like a global blanket. The sun warms the surface of the Earth and the heat normally radiates back out into space. Because low levels of $CO_2(g)$ are naturally present in the Earth's atmosphere, a certain amount of this blanket effect is normal. However, the widespread combustion of fossil fuels and increased deforestation in our modern world has produced larger quantities of $CO_2(g)$, thus thickening the blanket. A majority of the heat energy ends up trapped in our atmosphere. This phenomenon is known as the *greenhouse effect*. In this past century, the amount of $CO_2(g)$ in our atmosphere has increased more than 20% and has reached a point where scientists are concerned that *global warming*—the increase of the Earth's temperature—is occurring.

In Part I of this activity, plastic bottles will be used to model the greenhouse effect and how a greenhouse traps heat energy. In a greenhouse, visible light (medium wavelength) and ultraviolet light (short wavelength) pass through the glass while infrared radiation (long wavelengths) are absorbed or reflected. The visible light and UV light from the Sun that pass through the glass are absorbed by dark-colored surfaces, such as plants and soil, inside the greenhouse. These dark-colored objects absorb the light energy and heat up. These dark objects inside the greenhouse then re-radiate energy from their surfaces. The re-radiated energy, however, is infrared (long wavelength) radiation and not the shorter wavelengths like those that entered the greenhouse. The longer wavelength radiation is absorbed or reflected back into the greenhouse from the glass as it tries to pass back out through the glass. Thus, the original short wave light rays have been transformed and "trapped" inside the greenhouse. The greenhouse thus acts as a one-way valve for infrared heat energy. The entire structure becomes a "heat trap."

In Part II of this activity, carbon dioxide gas from various sources will be collected and bubbled through an indicator solution to determine the relative amount of CO_2 emitted from each source. When carbon dioxide gas reacts with water, carbonic acid, H_2CO_3, is produced. Carbonic acid ionizes to give hydrogen (H^+) and bicarbonate ions (HCO_3^-). See Equation 1.

$$CO_2(g) + H_2O(l) \rightleftharpoons H_2CO_3(aq) \rightleftharpoons H^+(aq) + HCO_3^-(aq) \qquad \textit{Equation 1}$$

Hydrogen ions on the right side of the equation make the solution more acidic and lower the pH. The degree to which the pH changes is proportional to the amount of CO_2 that dissolves in the water. In Part II, a bromthymol blue indicator solution will be used to determine CO_2 concentration. Bromthymol blue is an acid–base indicator that is yellow at a pH of 6.0 or below and blue at a pH of 7.6 or higher.

Experiment Overview

In Part I of this activity, a bottle will be half-covered with black paper and then exposed to a light source. The air temperature inside this "greenhouse bottle" will be measured and compared to a normal bottle exposed to the same light source. In Part II of this activity, carbon dioxide gas from various sources will be collected and bubbled through indicator solution. The amount of base that must be added to return the solutions to their original color will be measured and compared.

Materials

Bromthymol blue solution, 0.04%, 5 mL
Sodium bicarbonate, $NaHCO_3$, 10 g
Sodium hydroxide solution, NaOH, 0.1 M, 5 mL
Vinegar, 100 mL
Water, tap
Balloon, pre-filled with automobile exhaust
Balloons, empty, 2
Bottles, soda, and caps, 2
Construction paper sheet, black
Containers and caps, plastic, 60-mL, 4
Lamp or other light source, with bulb 150 watts or higher
Permanent marker
Pipets, 3
Ruler
Scissors
Straws, 3
String, 6″ pieces, 3
Stopper, one-hole
Support stand
Tape (optional)
Thermometers, plastic-backed, 3
Twist ties, 2

Safety Precautions

The dilute sodium hydroxide solution used in this activity is irritating to skin and eyes. Avoid contact of all chemicals with eyes and skin. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Wash hands thoroughly with soap and water before leaving the laboratory. Follow all laboratory safety guidelines.

Procedure

Part I. Greenhouse Effect

1. Obtain two plastic soda bottles and caps, a sheet of black construction paper, scissors, clear tape, a ruler, three plastic-backed thermometers, three 6″ pieces of string, a support stand and a light source or lamp.
2. Tie a 6″ piece of string to the hole at the top of one of the thermometers.
3. Repeat step 2 with two additional 6″ pieces of string and two more thermometers.
4. Cut a 6″ × 6″ piece of black construction paper to fit over one-half of the outside surface of one of the bottles.
5. Tape the black construction paper on the outside of one of the bottles (see Figure 1).

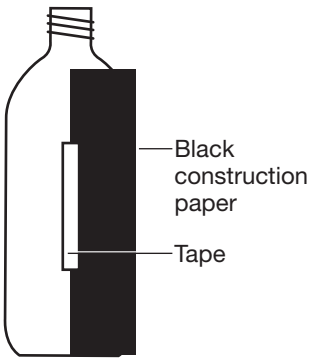

Figure 1. Black Construction Paper on Bottle

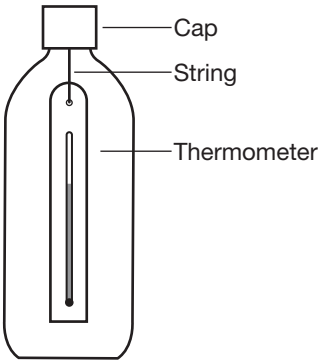

Figure 2. Thermometer in Bottle

6. Place a thermometer inside the neck of one of the bottles. Allow the string to hang over the neck of the bottle and screw on the cap. The thermometer should be suspended in the bottle (see Figure 2).
7. Repeat step 6 using another thermometer and a second plastic bottle.

8. Set up the activity as illustrated in Figure 3. Use a ring stand to position a third thermometer at 15 cm away from the lamp and the same height from the table top.

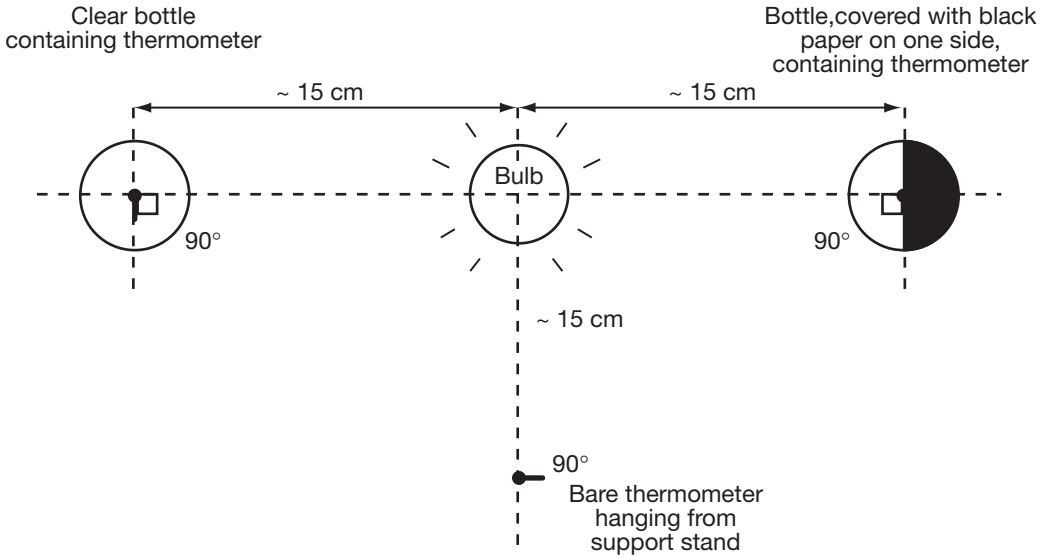

Figure 3. Top View of Activity Setup

9. Record the temperature for each of the three thermometers before the light is turned on.
10. Turn on the light and record the temperature of each thermometer every five minutes for 20 minutes.
11. Record all temperature readings in the data table.

Part II. Sources and Levels of Greenhouse Gas

12. Obtain four 60-mL plastic containers and caps, a plastic soda bottle, 5 mL of bromthymol blue solution, 5 mL of 0.1 M sodium hydroxide, 30 g (5 teaspoons) of sodium bicarbonate, 100 mL of vinegar, a one-hole stopper, three pipets, two empty balloons, a balloon filled with automobile exhaust, three straws, a permanent marker, scissors, and two twist ties.
13. Blow up one of the empty balloons with your breath. Fill the balloon until it is the size of the prefilled automobile exhaust balloon. Use a twist tie to close the neck of the balloon once it has been inflated. Label the balloon "Breath" with a permanent marker.
14. Place approximately 30 g (6 teaspoons) of sodium bicarbonate into the plastic soda bottle.
15. Cut a pipet approximately 2″ from the end of the tip. Place the tip of this pipet into a one-hole rubber stopper (see Figure 4).

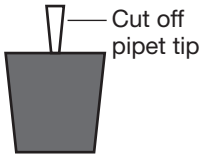

Figure 4. Pipet Tip in Stopper

16. Place the neck of the final empty air balloon over the free end of the pipet as shown in Figure 5. Wrap the neck of the balloon around the pipet. Fold over and pinch the excess portion of the neck of the balloon around the pipet with your thumb and first two fingers.

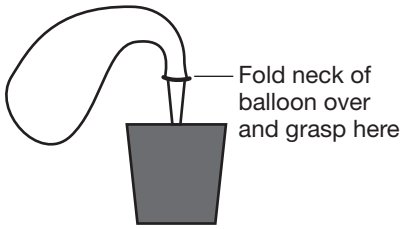

Figure 5. Neck of Balloon around Pipet

17. Pour approximately 100 mL of vinegar into the plastic bottle and quickly place the one-hole stopper into the mouth of the plastic bottle. The balloon will quickly inflate with carbon dioxide gas.
18. Allow the balloon to inflate to the size of the other two already-filled balloons. Twist the neck of the balloon to close it and secure it with a twist tie. Label the balloon "CO_2" with a permanent marker.
19. Add 10 mL of tap water to each of four 60-mL plastic containers.
20. Using a pipet, add 10 drops of bromthymol blue solution to each 60-mL container. Record the initial color of the solution for each container bottle in the data table.
21. Obtain the "breath" balloon. Place a straw into the neck of the balloon. Fold over and pinch the excess portion of the neck of the balloon around the straw with your thumb and first two fingers (see Figure 6). Tape the neck of the balloon to the straw to obtain a tight seal, if necessary.

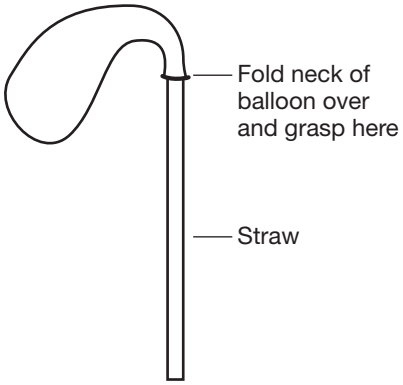

Figure 6. Neck of Balloon around Straw

22. Place the other end of the straw into the bromthymol blue solution in the bottom of one of the 60-mL containers.
23. Untwist the twist tie and bubble the air from the balloon through the straw and into the bromthymol blue solution until the balloon has deflated.
24. Place the cap on this container and record the color of the solution in the data table.
25. Repeat steps 21–24 for the balloon filled with automobile exhaust and the balloon filled with carbon dioxide. Record the color of the solutions in each 60-mL container in the data table.
26. Perform step 27 for any of the bottles that had solutions that underwent a color change.
27. Uncap the first container. Using a clean Beral-type pipet, add 0.1 M sodium hydroxide solution drop-by-drop to the indicator solution, swirling the solution with each added drop. Count the number of drops required for the indicator to change back to its original color. *Note:* Use the fourth small container with the original bromthymol blue solution as the color control. Wait a minute or two before recording the final drop counts as the color may revert slightly.
28. Record the number of drops and observations in the data table.
29. Answer the *Post-Lab Questions*.

Disposal

Consult your instructor for appropriate disposal procedures.

Name: _____

Greenhouse Effect and Global Warming Worksheet

Data Tables

Part I. Greenhouse Effect

All temperatures in degrees C

Time (min)	Open	Clear Bottle	Bottle with Construction Paper
0			
5			
10			
15			
20			

Part II. Sources and Levels of Greenhouse Gas

Source of CO_2	Initial Solution Color	Color after Adding Gas	Number of Drops of NaOH Required
Breath			
Automobile Exhaust			
CO_2			

Post-Lab Questions

1. Compare and contrast the temperature results obtained for the different thermometer setups in Part I.

2. Define the greenhouse effect and global warming. Describe how they are related.

3. How do the temperature results observed for the different bottles in Part I relate to the greenhouse effect?

4. What additional experiments could be performed using the basic setup in Part I to further investigate the greenhouse effect?

5. Which indicator sample(s) in Part II revealed the presence of carbonic acid after the balloon gases were bubbled through them?

6. Compare the number of drops of NaOH required to return to the original control color for each solution. What do these results mean?

7. Which balloon sample contained the largest amount of CO_2? Which contained the least?

8. Describe possible sources of experimental error that may affect the results for Part II.

9. Name a few ways to decrease the amount of greenhouse gas that is released into the atmosphere.

Teacher's Notes

Greenhouse Effect and Global Warming

Materials Included in Kit (for 5 groups of students)

Bromthymol blue solution, 0.04%, 100 mL
Sodium bicarbonate, $NaHCO_3$, 100 g
Sodium hydroxide solution, NaOH, 0.1 M, 150 mL
Vinegar, 800 mL
Balloons, 20
Construction paper, black, 5 sheets
Containers and caps, plastic, 60-mL, 20
Folders, 2 (for teacher use)
Pipets, 15
Soda bottles and caps, 10
Straws, 50
Stoppers, one-hole, 5
String, 400 ft
Thermometers, plastic-backed, 15
Twist ties, 20

Additional Materials Needed (for each lab group)

Water, tap
Light source, with bulb 150 watts or higher
Oven mitt (for teacher use)
Permanent marker
Ruler
Scissors
Support stand
Tape, clear
Tape, masking or duct (for teacher use)

Pre-Lab Preparation

1. The automobile exhaust balloons should be prefilled by the instructor before class. Make sure to perform the following preparation steps outdoors in a well-ventilated area.
2. Blow up and allow five balloons to be used for the automobile exhaust collection to deflate. Doing this will prime the balloons and help them inflate more readily.
3. Roll the folder lengthwise into a cone as shown in Figure 7. One end of the rolled up folder should be just large enough to fit over the car's tailpipe, and the other end should be small enough to accommodate the neck of the balloon.

Figure 7. Folder Rolled Lengthwise

4. Tape the cone securely with masking or duct tape.
5. Wearing an oven mitt, place the large end of the rolled up folder over the tailpipe of a car and the neck of a balloon over the small end of the folder cone.
6. Make sure the car is in the park position, and have an assistant start the car. C*aution:* Do not do this in an enclosed space. Do not breathe in the exhaust!
7. The balloon should fill rapidly. Fill the balloon until it is approximately 10 to 11 cm in diameter. Make sure that a tight seal is formed between the car's tailpipe and the folder cone.
8. When the balloon is full, twist the neck of the balloon several times and seal using a twist tie.
9. Repeat with the required number of balloons. Fill a couple extra balloons with exhaust in case of leakage or breakage.

Teacher's Notes *continued*

Safety Precautions

The dilute sodium hydroxide solution used in this activity is irritating to skin and eyes. Avoid contact of all chemicals with skin and eyes. Use extreme caution when filling balloons with car exhaust. Use an oven mitt to hold the folder and make sure the car is in the "park" position. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Remind students to wash their hands thoroughly with soap and water before leaving the laboratory. Please review current Material Safety Data Sheets for additional safety, handling, and disposal information.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures, and review all federal, state and local regulations that may apply, before proceeding. The indicator solutions may be rinsed down the drain with plenty of excess water according to Flinn Suggested Disposal Method #26b.

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
Evidence, models, and explanation
Constancy, change, and measurement
Content Standards: Grades 5–8
Content Standard D: Earth Science, structure of the Earth system
Content Standard F: Science in Personal and Social Perspectives; populations, resources, and environments; natural hazards; risks and benefits; science and technology in society
Content Standards: Grades 9–12
Content Standard D: Earth and Space Science, energy in the Earth system, geochemical cycles
Content Standard F: Science in Personal and Social Perspectives; personal and community health; natural resources, environmental quality, natural and human-induced hazards

Alignment with AP Environmental Science Topics and Scoring Components

Topic: Global Change. Global Warming (Greenhouse gases and the greenhouse effect; impacts and consequences of global warming; reducing climate change; relevant laws and treaties).

Scoring Component: 10-Global Change, Global Warming.

Teaching Tips

- The temperatures in the bottles in Part I will change quickly if the bulb is intense, unshielded, and at the right distance from the bottles. This procedure works best if the bulb is at table level. A "clamp-on" style unshielded bulb works well. Try the actual setup before having students start Part I. A 150-watt bulb or stronger at a distance of 15 cm will give optimal results.
- In Part I, the bottle, with one-half of its surface black, is very efficient at absorbing and converting the short wavelengths to long wavelengths and will very efficiently trap the energy inside the bottle and dramatically increase the internal temperature.
- Use extreme caution when filling the balloons with automobile exhaust. Wear an oven mitt and make sure the car is in the "park" position. The rolled up folder should withstand the small amount of heat that is generated during the filling procedure very well. An extra folder is included just in case.
- Only the instructor should fill the balloons with automobile exhaust.
- As an extension, fill additional balloons with exhaust from different vehicles and compare the titration results in Part II. Once again, only the instructor should fill these balloons.
- Have students inflate and deflate the balloon for the CO_2 collection before use. This will allow the balloon to inflate more readily.

Teacher's Notes *continued*

- If time allows have students test the carbon dioxide level of ambient air by filling a balloon with a bicycle pump and repeating Part II. Ambient air will not turn the bromthymol blue solution yellow.
- Have students visit the Web site, http://www.americanforests.org/resources/ccc (last accessed May 2009) after these experiments have been performed. This Web site has an easy-to-use tool called the Personal Climate Change Calculator that will measure an individual's climate-affecting carbon dioxide (CO_2) emissions.

Sample Data Tables *(Student data will vary.)*

Part I. Greenhouse Effect

All temperatures in degrees C

Time (min)	Open	Clear Bottle	Bottle with Construction Paper
0	*22.2*	*22.2*	*22.2*
5	*26.1*	*27.2*	*30.0*
10	*27.2*	*30.0*	*33.3*
15	*27.8*	*31.1*	*35.0*
20	*27.8*	*31.1*	*36.1*

Part II. Sources and Levels of Greenhouse Gas

Source of CO_2	Initial Solution Color	Color after Adding Gas	Number of Drops of NaOH Required
Breath	*Blue*	*Green*	*1*
Automobile Exhaust	*Blue*	*Yellow*	*5*
CO_2	*Blue*	*Yellow*	*16*

Answers to Post-Lab Questions *(Student answers will vary.)*

1. Compare and contrast the temperature results obtained for the different thermometer setups in Part I.

   The air temperature in the bottle half-covered with black construction paper increased the most rapidly. The standard bottles' temperature rose but not as quickly as the bottle with black construction paper. The control temperature (open thermometer) initially rose and then leveled off.

2. Define the greenhouse effect and global warming. Describe how they are related.

   The greenhouse effect is the heat-trapping effect of various greenhouse gases in our atmosphere. Global warming is the increase in the Earth's surface temperatures. The heat being trapped by the excess greenhouse gas blanket is gradually increasing the Earth's surface temperature.

3. How do the temperature results observed for the different bottles in Part I relate to the greenhouse effect?

   Both bottles showed a variation of the greenhouse effect. Both bottles were closed off which caused the inside air temperature to steadily increase. However, the temperatures in the bottle with black construction paper rose the most rapidly. Its black surface was very efficient at absorbing and converting the short wavelengths to long wavelengths and very efficiently trapped the energy inside the bottle and increased the internal temperature. The black surface of this bottle represents the Earth's surface.

Teacher's Notes *continued*

4. What additional experiments could be performed using the basic setup in Part I to further investigate the greenhouse effect?

   Student answers will vary. Examples of other variables are: add CO_2 one of the bottles, change the color of the construction paper, add soil or water to one of the bottles, cut the bottles in half and cover one of them with plastic wrap.

5. Which indicator sample(s) in Part II revealed the presence of carbonic acid after the balloon gases were bubbled through them?

   Results will vary. All three of the samples will most likely change the color of the bromthymol blue solution.

6. Compare the number of drops of NaOH required to return to the original control color for each solution. What do these results mean?

   The higher the number of NaOH drops required, the greater the CO_2 levels in the solution.

7. Which balloon sample contained the largest amount of CO_2? Which contained the lowest?

   The CO_2 sample from the vinegar and sodium bicarbonate should contain the highest amount of CO_2, followed by the car exhaust and the breath samples.

8. Describe possible sources of experimental error that may affect the results for Part II.

   Results will vary. A few examples are the size of the inflated balloon samples, leakage around the straw and balloon neck, inaccuracy in the number of drops of sodium hydroxide, etc.

9. Name a few ways to decrease the amount of greenhouse gas that is released into the atmosphere.

   Walk or bike to work or school, take public transportation, drive a car with good gas mileage, wash clothes in cold water, don't overheat or overcool rooms, replace air filters, reduce waste, recycle, plant trees, etc.

The *Greenhouse Effect and Global Warming—Environmental Science Student Laboratory Kit* is available from Flinn Scientific, Inc.

Catalog No.	Description
AP7324	Greenhouse Effect and Global Warming— Environmental Science Student Laboratory Kit

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.