

GREENHOUSE GASES

BACKGROUND

The Earth's climate depends on the amount of solar radiation received and the atmospheric abundance of clouds and greenhouse gases. The main greenhouse gases are carbon dioxide, methane, chlorofluorocarbons, nitrous oxide, water vapor, and ozone. Much of the high-energy, short-wavelength radiation from the sun passes through the Earth's atmosphere and hits the surface of the Earth. The energy that is not reflected off the surface is absorbed and re-radiated into the atmosphere, where much of it is absorbed by the greenhouse gases. This is known as the greenhouse effect. Certain gases have been increasing in concentration in the atmosphere on a timeline concurrent with increasing global temperature.

Teacher Activity: How do greenhouse gases affect heat absorption?

Objectives: Students simulate a portion of the greenhouse system using carbon dioxide.

After completing this investigation, students will be able to:

- Describe the components of the greenhouse effect.
- Explain the effect of carbon dioxide on the absorption of heat in the atmosphere.

Materials, per group:

2 clear, empty, 1-liter plastic bottles
 CO₂ cartridge with piercer*
 2 thermometers
 infrared radiation source (heat lamp)
 2 #4 rubber stoppers with 1 hole in each, or modeling clay or silly putty
 2 sheets of white paper
 transparent or masking tape and marker
 parafilm or stopper grease
 thin book, sponge or piece of wood
 glycerine, petroleum jelly or other lubricant
 graph paper
 meter stick

*CO₂ cartridges can be purchased online or at sporting goods stores. 12 gram, threaded cartridges were used in this investigation. An inflator, often carried by cyclists, was used to pierce the cartridge.

Time required: 1 class period for experiment; 1 class period for questions and class discussion

ALIGNMENT

National Framework for K-12 Science Education:

SEP 2: Developing and using models

SEP 3: Planning and carrying out investigations

SEP 4: Analyzing and interpreting data

CC2: Cause and effect: Mechanism and explanation

CC 4: Systems and system models

Core Idea ESS3: Global Climate Change

Great Lakes Literacy Principles:

#3e: The Great Lakes influence local and regional weather and climate.

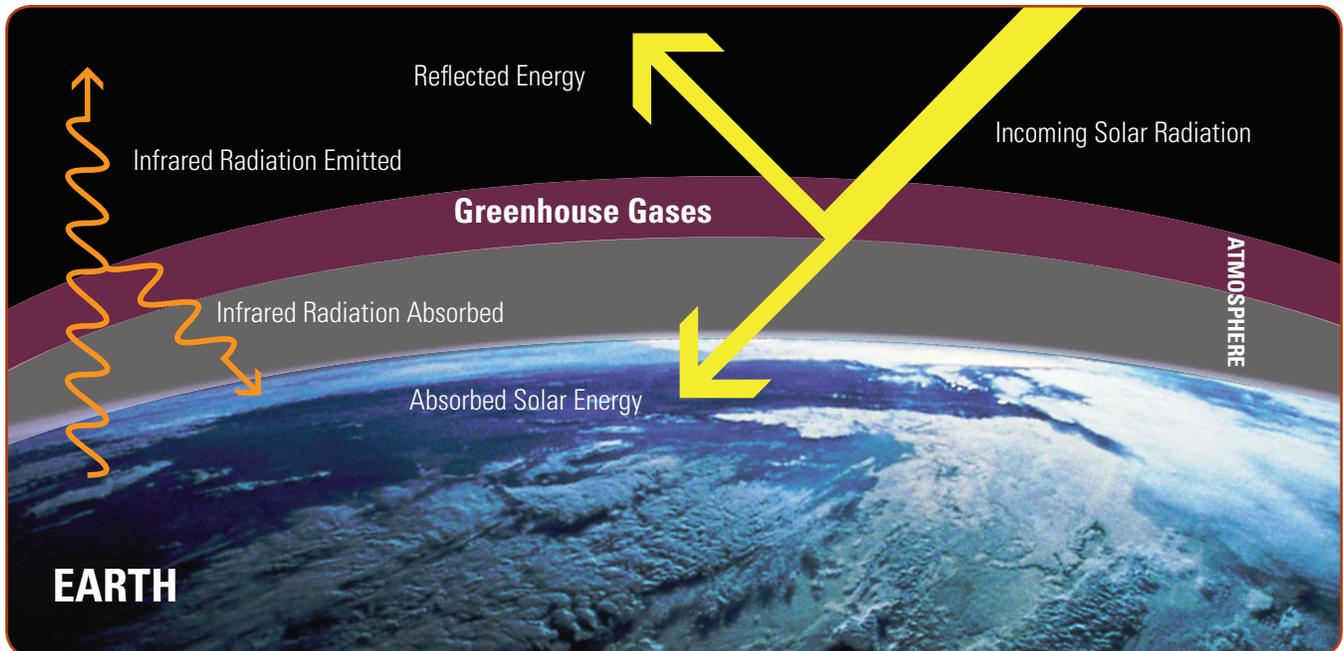
Climate Literacy Principles:

#1a: The sun is the primary source of energy for Earth's climate system.

#2d: Climate is regulated by complex interactions among components of the Earth system.

ENGAGE

Show students the following diagram that is a part of their worksheet. Have them attempt to place the labels on the appropriate arrows on their own, before sharing the answers with them.

**EXPLORE****Teacher's Notes:**

Before the activity begins, the apparatus should be assembled by the teacher. Lubricate the bottom 1/3 of each thermometer with glycerine or petroleum jelly. Hold one of the thermometers with several layers of paper towels and gently push the thermometer through the hole in one of the rubber stoppers. Push until about 10 cm of the thermometer has passed through the other end of the stopper. Make sure that you push the bulb end of the thermometer toward the small end of the stopper and through the opening. Repeat with the other thermometer and rubber stopper. Wipe off any excess lubricant. Alternately, students can use modeling clay to seal the thermometer assembly to the bottle.

The investigation can be done outside on a sunny day instead of using heat lamps. In this case, steps 7 – 9 in the procedure and questions 1, 6 and 8 on the student worksheet may not be applicable.

1. Provide each group of students with the thermometer/stopper apparatus, 2 bottles, 2 CO₂ cartridges, and remaining supplies.
2. Students follow instructions on their paper to set up an investigation modeling the effects of having carbon dioxide in the atmosphere. They collect and graph data before returning to a class discussion.

CAUTION:
DO NOT FORCE
THE THERMOMETER
THROUGH THE HOLE.

THE THERMOMETER
MAY BREAK AND
CAUSE INJURIES.

**STRESS
SAFETY:**

STUDENTS AND TEACHERS
SHOULD WEAR GOGGLES
WHEN WORKING WITH
CO₂ CARTRIDGES.

EXPLAIN

Teachers should facilitate a class discussion while students write answers to the questions on their papers.

A simple animation of the greenhouse effect can be found at <http://earthguide.ucsd.edu/earthguide/diagrams/greenhouse>.

Answers to Student Worksheet

1. Heat from Earth's surface.
2. The atmosphere.
3. To reduce the direct warming of the bulbs by the heat source.
4. The bottle containing CO₂ should have felt warmer.
5. The bottle containing CO₂ should, because CO₂ absorbs infrared radiation more effectively than air. The CO₂ line should have a steeper slope than the AIR line.
6. Refer to the slopes of the lines. The temperature of the CO₂ should increase faster. Both lines flatten out as the system approaches equilibrium.
7. Four times – inverse square law. They should both increase.
8. The temperature of the CO₂ should increase faster than the temperature of the air.
9. Possibly not. The temperature of the CO₂ is likely to increase faster than the temperature of the air. After a certain time, both lines should flatten out.
10. Thermal equilibrium means heat is no longer moving between two regions, thus temperature remains constant. The temperature in the bottles no longer increases.
11. Global warming appears to be occurring, which suggests that the atmosphere is not in thermal equilibrium.
12. Greenhouse gases transmit short-wave radiation from the sun, but absorb long-wave radiation from the Earth. These gases absorb thermal radiation, thereby trapping it in the atmosphere.
13. Answers should address how increased amounts of greenhouse gases cause warming of the Earth's atmosphere.
14. Variables include, but are not restricted to: the strength of the heat source; the opacity of the plastic bottles; the distance between the bottles and the heat source; the concentrations of gases in the bottles; and the types of gases in the bottles.
15. Based solely on the factors listed, the temperature should be expected to increase.

EXTEND

Have students choose a variable other than the distance between the infrared heat source and the bottles (i.e., the strength of the heat source; the opacity of the plastic bottles; the concentrations of gases in the bottles; and the types of gases in the bottles), and describe how they would repeat the activity to determine how that variable affects the temperature in the bottles.

If N₂O is available, have students conduct the same investigation for comparison purposes.

Venus is a planet whose orbit around the sun is closest to Earth's orbit. It has experienced greenhouse warming for many thousands of years and has a mean surface temperature of 464°C. Research how Venus' atmosphere formed. Could this happen to Earth if the gas composition of the atmosphere alters? Support your answer with evidence.

EVALUATE

Sample evaluation tasks:

Water vapor is actually the most abundant greenhouse gas. Assume you conduct the same investigation, but replace the CO₂ bottle with a WATER VAPOR bottle in which you used a mister to add moisture to the inside of the bottle. Predict how temperature would change in the WATER VAPOR bottle. Construct a graph to show the general trend in data (from both bottles) you would expect to see. Explain whether the results of this experiment would be similar to or different from the results of your original investigation.

Create a concept map illustrating the process of heat absorption in the atmosphere and the consequences that it could produce on the various Earth systems and human society.

REFERENCES

Steffe, W., A. Sanderson, P.D. Tyson, J. Jäger, P.A. Matson, B. Moore III, F. Oldfield, K. Richardson, H.J. Schellnhuber, B.L. Turner II, R. J. Wasson. Global Change and the Earth System: Executive Summary. Online at http://www.igbp.net/download/18.1b8ae20512db692f2a680007761/IGBP_ExecSummary_eng.pdf. Accessed 3 May 2012.

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*Additional Great Lakes Climate Change lessons are available from Ohio Sea Grant.
Please call 614.292.8949 for more information.*

Student Activity: How do greenhouse gases affect heat absorption?

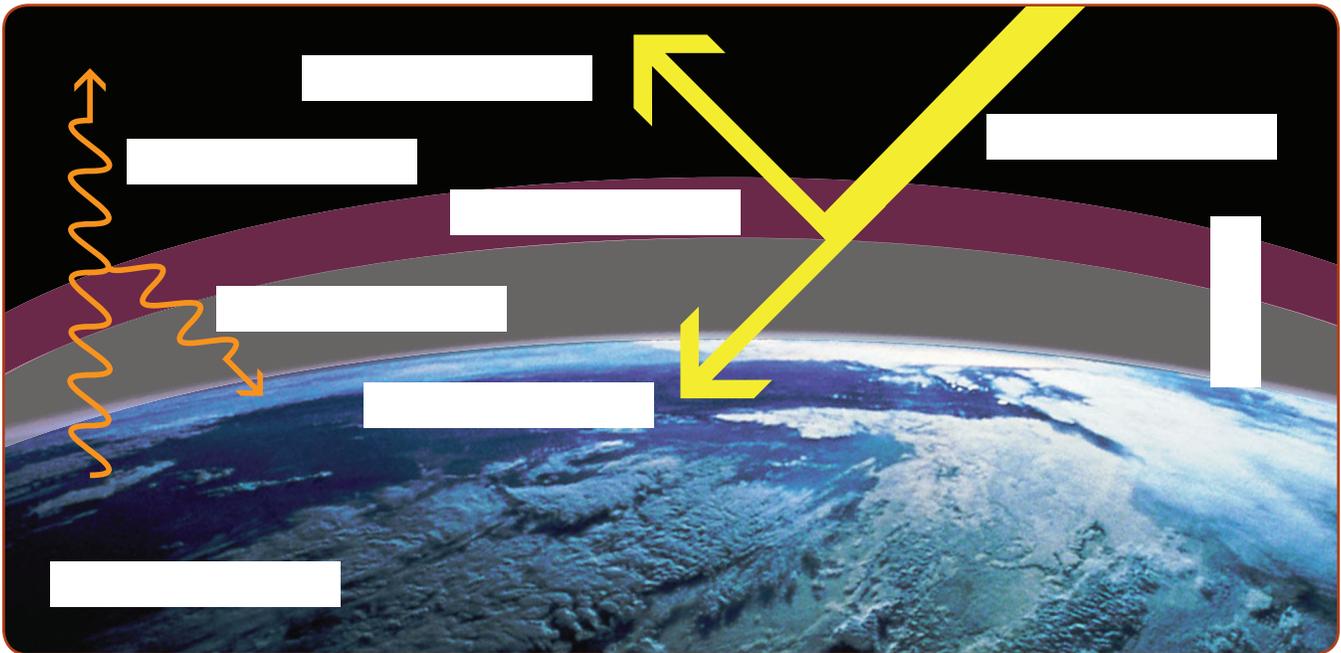
BACKGROUND

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BACKGROUND

Use the following terms to label the diagram below.

- incoming solar radiation
 - Earth
 - atmosphere
 - absorbed energy
 - reflected energy
-
- infrared radiation absorbed
 - infrared radiation emitted



PROCEDURE

1. Obtain 2 1-liter bottles, stopper-thermometer assemblies and a CO₂ cartridge, as well as the other necessary materials, from your teacher.
2. Tape a small piece of white paper over one side of the bulb of each thermometer. The purpose of this paper is to shield the bulbs from the heat source. Make sure you affix the paper so that you can read the scale accurately.
3. Hold one of the 1-liter bottles with the mouth upward. Using the inflator, pierce 1 CO₂ cartridge and “pour” the CO₂ from the cartridge into the bottle. One student should use their hand to make a seal around the mouth of the bottle while another student “pours” the CO₂ into the bottle. Make sure to empty the cartridge completely.
4. Stopper the bottle containing CO₂ with one of the thermometer/stopper assemblies. Seal it with stopper grease or parafilm. Stopper the other 1-liter bottle in the same way. This bottle will have air in it.
5. Label the first bottle “CO₂” and the second bottle “Air.”
6. Lay the two bottles down on their sides together on a white piece of paper. Support the necks of the two bottles with a thin book, sponge or piece of wood. It is important that the pieces of paper you taped to the bulbs of the thermometers are on top and will shield the bulbs from the infrared heat source. Make sure that you can read the scale of each thermometer without moving the bottles.
7. Place the infrared heat source 0.5 m above the two bottles. Make sure that both bottles are equidistant from the heat source.
8. Record the temperatures in each bottle before adding the heat lamp. Then turn on the infrared source and record the temperatures in the two bottles at 2-minute intervals for a total of 16 minutes. (You should have 8 readings in addition to your original reading.)
9. At the end of 16 minutes, lower the infrared source to 0.25 m above the bottles and continue to record the temperatures in the two bottles at 2-minute intervals for another 16 minutes. (You should have 16 readings in addition to your original reading.)
10. After you have completed recording the temperatures for a total of 32 minutes, turn off the infrared heat source and feel the two bottles to see if you can detect a difference in temperature.
11. Construct a line graph to show how the temperatures in the two bottles changed over time. Be sure to add a title to your graph and label the lines to indicate which line represents the “Air” bottle and which line represents the “CO₂” bottle.

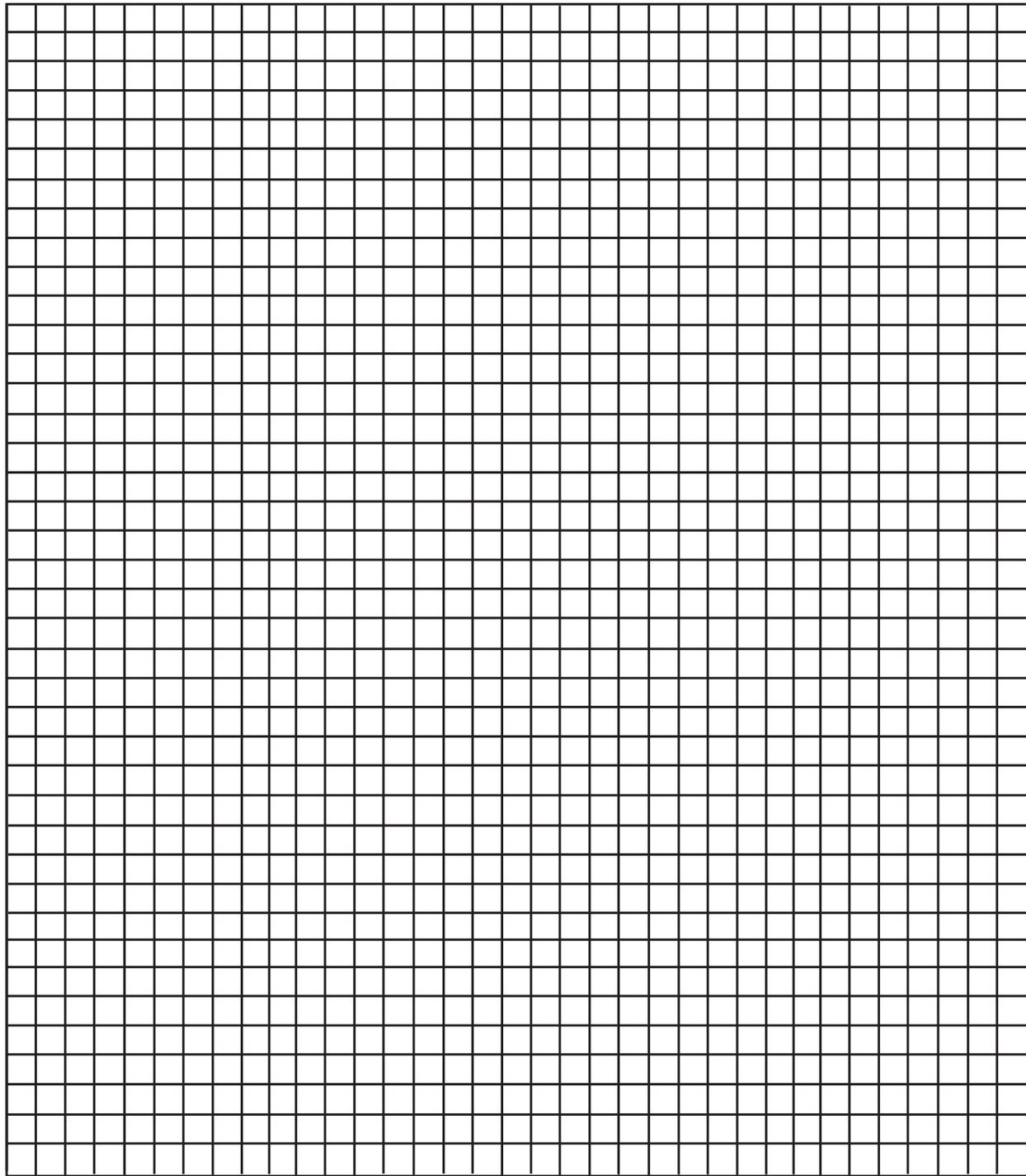
DATA

Heat lamp 0.5 m from bottles

| Time (min) | 0 | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 |
|---------------------------|---|---|---|---|---|----|----|----|----|
| AIR Temp (°C) | | | | | | | | | |
| CO ₂ Temp (°C) | | | | | | | | | |

Heat lamp 0.25 m from bottles

| Time (min) | 18 | 20 | 22 | 24 | 26 | 28 | 30 | 32 |
|---------------------------|----|----|----|----|----|----|----|----|
| AIR Temp (°C) | | | | | | | | |
| CO ₂ Temp (°C) | | | | | | | | |



Temperature (°C)

Time (Minutes)

QUESTIONS

1. What part of the greenhouse effect system does the infrared source represent?
2. What part of the greenhouse effect system is being represented by the 1-liter bottles?
3. Why was it necessary to shade the bulbs of the thermometers with pieces of white paper?
4. When the heating of the bottles was completed, which bottle felt warmer?
5. In which bottle did the temperature increase faster? How does your graph illustrate this idea?
6. Was the rate of temperature increase for each bottle the same throughout the first 16 minutes? Explain why or why not. Keep in mind what the different parts of the apparatus represent.
7. How many times more heat energy was striking the two bottles after you lowered the infrared source to 0.25 m? How did this affect the temperatures in the two bottles?
8. Was the rate of temperature increase for each bottle the same during the second 16 minutes? Explain why or why not. Keep in mind what the different parts of the apparatus represent.

9. Is the pattern of change of temperature in each bottle the same? Explain why or why not.

10. What is meant by thermal equilibrium? How would you know when the apparatus is in thermal equilibrium?

11. Is Earth's atmosphere in thermal equilibrium at present? Explain.

12. Explain how the presence of CO₂ and other "greenhouse" gases in the atmosphere affects the heating of the atmosphere from an infrared source.

13. Explain fully how this activity relates to the greenhouse effect in Earth's atmosphere.

14. In this activity, what variables help to determine the temperature of the gases in the bottles?

15. If human activity continues to add CO₂ and other greenhouse gases to Earth's atmosphere through burning of fossil fuels, deforestation, and other practices, predict how the average temperature of the atmosphere will change in the future.