

The Greenhouse Effect: Does the Concentration of Carbon Dioxide Affect the Air Temperature in a Closed Environment?

Lesson Type:
Experiment

Estimated Time:
45 - 50 minutes

Vocabulary

- amplified greenhouse effect
- natural greenhouse effect

Materials (per team)

- 2 empty plastic or glass water bottles
- 4 Alka-Seltzer tablets
- 2 rubber bands
- 2 thermometers
- 2 sheets of plastic wrap
- 200 mL of water (100 mL for each bottle)
- lamp (with 100-watt bulb)
- clay
- timer

PURPOSE

The purpose of this lesson is to investigate the effect of carbon dioxide (CO₂) concentration on air temperature in a closed environment.

LEARNING OBJECTIVES

By the end of the lesson students will be able to

- Explain how the greenhouse effect works.
- Differentiate between Earth's natural greenhouse effect and an amplified greenhouse effect.
- Compare and contrast a model of the greenhouse effect to Earth's greenhouse effect.

SCIENCE STANDARDS

Climate and/or Energy Literacy Principles

(See <http://cleanet.org/clean/literacy/index.html>)

- Greenhouse gases affect energy flow through the Earth system. Greenhouse gases in the atmosphere, such as carbon dioxide and water vapor, are transparent to much of the incoming sunlight but not to the infrared from the warmed surface of Earth. These gases play a major role in determining average global surface temperatures. When Earth emits the same amount of energy as it absorbs, its average temperature remains stable. (Energy Principle 2.6)
- The amount of solar energy absorbed or radiated by Earth is modulated by the atmosphere and depends on its composition. Greenhouse gases – such as water vapor, carbon dioxide, and methane – occur naturally in small amounts and absorb and release heat energy more efficiently than abundant atmosphere gases like nitrogen and oxygen. Small increases in carbon dioxide concentration have a large effect on the climate system. (Climate Principle 2.C)

Next Generation Science Standards

(See <http://www.nextgenscience.org/next-generation-science-standards>)

- The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space. (HS-ESS2-2)(HS-ESS2-4)
- Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate. (HS-ESS2-6), (HS-ESS2-4)

PREPARATION

- Prior to class, gather the materials for each team of students.
- Divide students into small teams of 4 (depending on availability of materials). Each team will need a set of materials.
- Explain the purpose and introductory background of the lesson and purpose of the activity.
- Ask each team to read through the procedure and write a hypothesis that includes both the independent and dependent variables.
- Have each team conduct the experiment.

For an excellent review on graphing, direct them to **Paul Andersen's Bozeman Science Website:**

<http://www.bozemanscience.com/beginners-guide-to-graphing-data>

<http://www.bozemanscience.com/graphing-data-by-hand>

<http://www.bozemanscience.com/graphing-data-by-spreadsheet>

BACKGROUND

As 1827, French mathematician and physicist, Joseph Fourier, wondered why Earth's average temperature is approximately 15°C (59°F) instead of (-18°C or 0°F). His calculations indicated that Earth should actually be much colder. To have an average temperature of 15°C (59°F), Fourier knew that there had to be another process occurring in the atmosphere—something similar to the way a greenhouse retains heat. A greenhouse's glass enclosure allows visible light to enter and be absorbed by the plants and soil. The plants and soil then emit the absorbed heat energy as infrared radiation. The glass of the greenhouse then absorbs that infrared radiation, emitting some of it back into the greenhouse and thus keeping the greenhouse warm even when the temperature outside is lower.

Earth experiences a similar phenomenon, known as the greenhouse effect. The sun's visible wavelengths of radiation pass easily through the atmosphere and reach Earth. Approximately 51% of this sunlight is absorbed at Earth's surface by the land, water, and vegetation. Some of this energy is emitted back from the Earth's surface in the form of infrared radiation. Water vapor, carbon dioxide, methane, and other trace gases in Earth's atmosphere then absorb the longer wavelengths of infrared radiation from Earth's surface. These gases re-emit the infrared radiation in all directions, both outward toward space and downward toward Earth. This process creates a second source of radiation to warm to surface (visible radiation from the sun and infrared radiation from the atmosphere), which causes Earth to be warmer than it otherwise would be. This process is known as the **natural greenhouse effect** and keeps Earth's average global temperature at approximately 15°C (59°F). Fourier's calculations indicated that Earth should actually be much colder (-18°C or 0°F) if it did not have a natural greenhouse effect, but what if Earth's greenhouse effect were amplified?

EXPERIMENTAL DESIGN

In this experiment, students will construct two models (one with a natural greenhouse effect and another with an amplified greenhouse effect to answer the following question:

Does the Concentration of Carbon Dioxide Affect the Air Temperature in a Closed Environment?

Hypothesis

After reading through the methods section below, write a hypothesis that includes the independent and dependent variables in the experiment.

Hypothesis: The air temperature inside the bottle with the Alka-Seltzer tablets will increase more than the air temperature inside the control.

Methods

1. Fill each bottle with 100 mL of water.
2. Label the bottles as “control” and “CO₂.” (The bottle labeled as CO₂ will have 4 Alka-Seltzer tablets in the water).
3. Cover the opening of the bottle with a clump of clay. Insert a thermometer into each bottle through the clay. Make sure the thermometer is hanging in the air above the water.
4. Place the two bottles under the light at the same distance and angle.
5. Tear 2 sheets of plastic wrap and set aside.
6. Drop 4 Alka-Seltzer tablets into the water bottle labeled CO₂.
7. Immediately cover the top of each bottle (including the thermometer inserted in the clay) loosely with the plastic wrap. Use a rubber band to secure the plastic wrap around the top of the bottle.
8. Turn on the light and take an initial temperature reading.
9. Record your data and construct a graph in the Results section below.

Results

Record the air temperature (°C) in each bottle at 2-minute intervals for 20 minutes. Write your results in the table and include a title for the table.

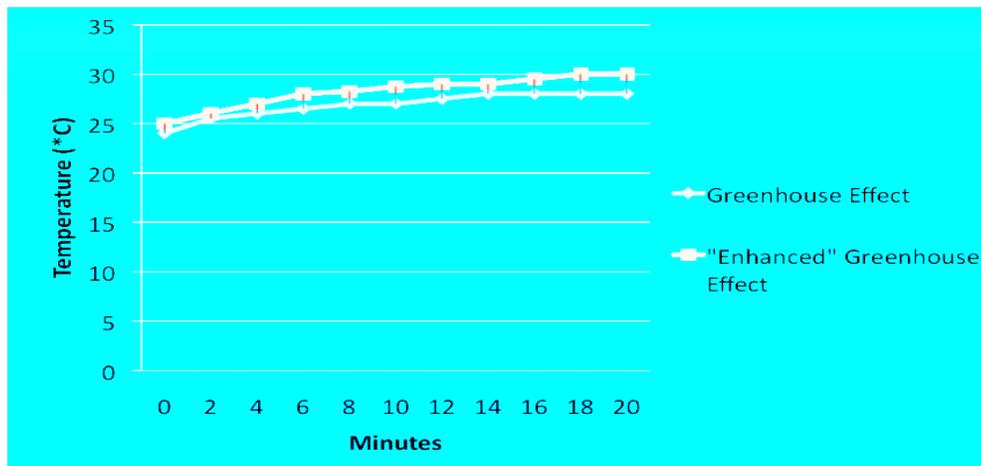
Title: _____

Air Temperature (°C)	Initial Temp	2 min	4 min	6 min	8 min	10 min	12 min	14 min	16 min	18 min	20 min
Control/ 0 Alka-Seltzers	<i>Students should observe that the temperature of the air inside the controlled environment (without an Alka-Seltzer tablet) increases slightly by 1 or 2°C. They should observe the air temperature in the bottle with the 4 Alka-Seltzer tablets increases by more than 2°C.</i>										
Experimental/ 4 Alka-Seltzers											

Graph your Data

Construct a line graph that summarizes your results. Include a title, label the axes and include a legend.

Title: _____



Example from Student Experiment

Summary of Results

Write a summary of your results.

Answers will vary. Students should observe that the temperature of the air inside the "control" (bottle without Alka-Seltzer tablets) increased slightly by 1 or 2°C. Students should have observed an increase of more than 2°C for the air temperature in the bottle with the 4 Alka-Seltzer tablets.

CONCLUSIONS: DEVELOPING EXPLANATIONS FROM EVIDENCE

1. Was your hypothesis supported by the data or evidence?

Answers will vary. The data should support the hypothesis that the air temperature in the bottle with the Alka-Seltzer tablets increased more than the air temperature in the control. If students did not obtain these results, they may need to conduct the experiment longer or conduct repeated trials.

2. Explain your rationale for the results.

The amount of Alka-Seltzer tablets influences the amount of CO₂ that is released in to the bottle's environment, which affects the overall temperature in each environment. The bottle without the tablets has a smaller temperature increase than the bottle with the Alka-Seltzer tablets. This rise in temperature is caused by the absorption of heat by the CO₂ gas molecules in the air.

3. What recommendations do you have for improving the experiment and for further study?

Answers will vary. Student may recommend conducting the experiment over a longer period of time or conducting repeated trials.

4. Compare and contrast the model of the greenhouse effect to Earth's greenhouse effect.

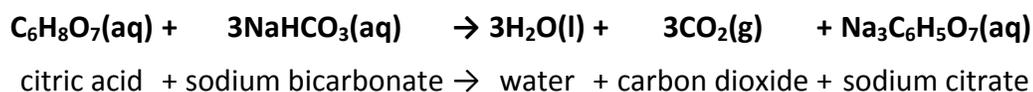
The model of the greenhouse effect without Alka-seltzer tablets represents Earth's natural greenhouse effect. This bottle contained water vapor and some small amount of CO₂, so it is similar to Earth's natural greenhouse effect. The bottle with the 4 Alka-Seltzer tablets represents an environment with an increased concentration of CO₂ (or an amplified greenhouse effect). The simple models constructed in this experiment are different from Earth's actual greenhouse effect because they have the physical

*barrier of the clay and plastic cover, which also prevents warmer air from flowing out of the bottle.
(This is also how a greenhouse functions to keep plants warmer during winter months.)*

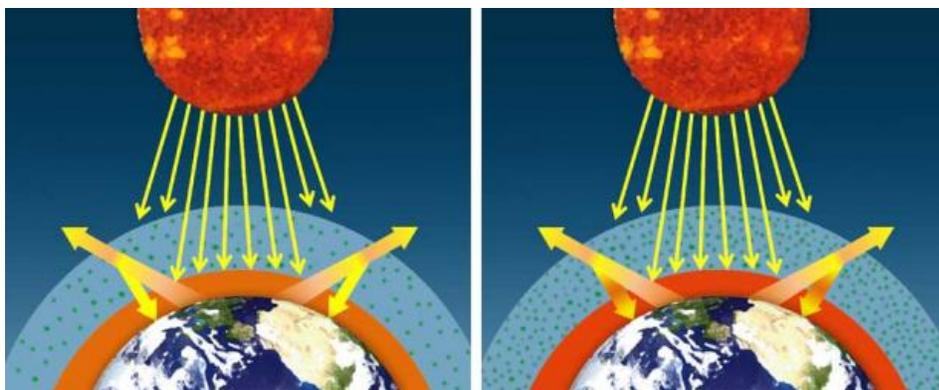
5. What do you predict will happen to the global temperature of Earth as more CO₂ is added to the atmosphere?
An increased concentration of atmospheric CO₂ will cause more infrared radiation to be absorbed, resulting in a warming atmosphere.
6. What is the current (past month) concentration of CO₂ in Earth's atmosphere? ____ ppm (parts per million)
What was the concentration of CO₂ the year that you were born.
You may use: <http://co2now.org/> .
Answers will vary. Students should see the increase in CO₂ concentration over the past decades

THE SCIENTISTS' EXPLANATION

The control represents a natural greenhouse effect. This bottle contains water vapor and some small amount of CO₂. The bottle with the 4 Alka-Seltzer tablets represents an environment with an increased concentration of CO₂. When Alka-Seltzer is dissolved in water, CO₂ is released and carried to the surface by small bubbles. As bubbles reach the surface, CO₂ is released into the air above the water's surface. This equation explains what happens when an Alka-Seltzer tablet is dissolved in water.



Carbon dioxide is the major greenhouse gas because of its relatively long lifetime in the atmosphere (approximately 100 years), and ability to absorb infrared radiation. When agitated by infrared radiation, the CO₂ molecule vibrates and absorbs heat. It then re-radiates or emits heat in all directions, including back toward Earth. Carbon dioxide absorbs infrared radiation emitted from Earth's surface before re-emitting the same infrared radiation as was absorbed.



If the concentration of greenhouse gases increases, then more infrared radiation will be absorbed and emitted back toward Earth's surface, creating an **amplified greenhouse effect**.

When averaged over the course of a year, the amount of incoming solar radiation received from the sun has balanced the amount of outgoing energy emitted from Earth. But relatively small changes in the amounts of greenhouse gases in Earth's atmosphere can greatly alter that balance between incoming and outgoing radiation. Earth then warms or cools in order to restore the radiative balance at the top of the atmosphere.

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