Greenhouse Effect

Introduction

What is the greenhouse effect? How does the amount of greenhouse gas in the atmosphere affect the temperature of the Earth? Perform the following activity to gain a better understanding of how greenhouse gases influence temperature.

Concepts

- Greenhouse effect
- Global warming
- Greenhouse gases

Background

Carbon dioxide, CO_2, is a component of the Earth's atmosphere that can absorb and hold heat energy. These types of molecules are called *greenhouse gases* because, like a greenhouse, they increase the overall temperature of the atmosphere by holding the heat for a short period before releasing it back to space. This is called the *greenhouse effect* and it makes the earth livable. Without it, the daily temperature would be much lower and nights would be extremely cold. While many molecules are greenhouse gases, including methane, water vapor and nitrous oxide, CO_2 is the most important. This is not because it actually traps the most heat – water vapor does that – rather, the widespread burning of fossil fuels and deforestation have led to a trend of increasing CO_2 concentration in the atmosphere and oceans.

When solar energy enters the atmosphere, about 30% is reflected back into space, 20% is absorbed by molecules in the atmosphere and 50% hits the Earth's surface. Nearly 75% of the energy that hits the surface is re-radiated back to the atmosphere as heat. Greenhouse gases trap some of that heat, while the rest is emitted to space. The higher the concentration of greenhouse gases, the more heat energy that can be trapped. As of 2015, the average atmospheric concentration of CO_2 is 400 ppm. This is a 30% increase from 100 years ago, and more than a 40% increase from the average before widespread use of fossil fuels.

In 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 as it tries to pass back out through the glass. Thus, the original short wave length 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."

Materials

Bottles, soda, and caps, 2
Construction paper sheet, black
Lamp or other light source, with bulb 150 watts or higher
Ruler
String, 6″, 3
Support stand
Tape, clear
Thermometer, metal backed, 3

Safety Precautions

The items used in this activity are considered non-hazardous. Follow all classroom guidelines.

Procedure

1. Obtain two plastic soda bottles and caps, a sheet of black construction paper, scissors, clear tape, a ruler, three metal-backed thermometers, three 6″ pieces of string, a support stand and a light source or lamp.

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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)*.
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)*.

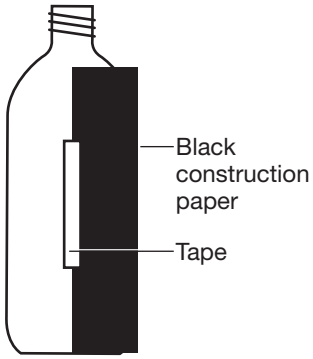

Figure 1. Black Construction Paper on Bottle

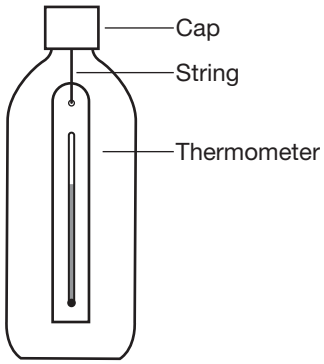

Figure 2. Thermometer in Bottle

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.

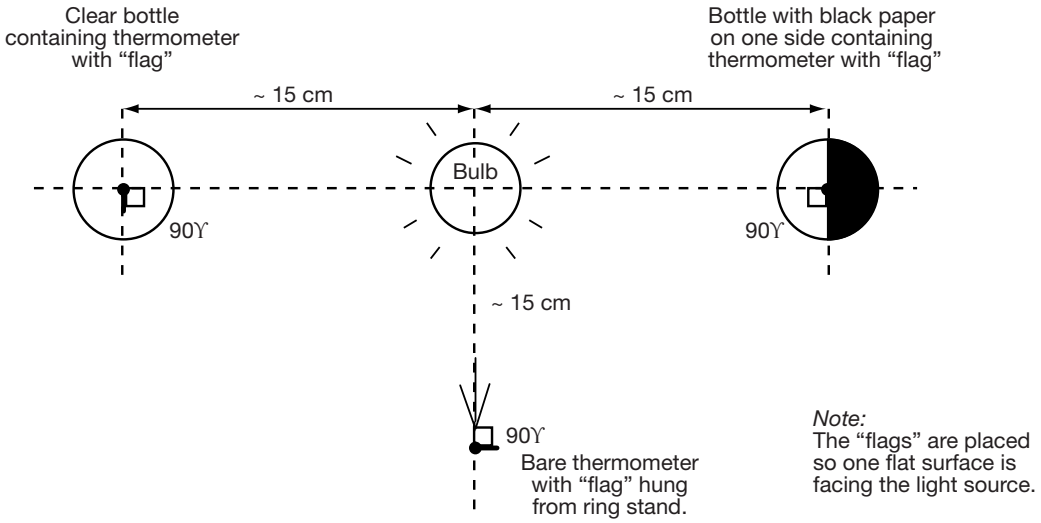

Figure 3. Top View of Activity Setup

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 a data table.

Disposal

All items may be saved and reused for future classes or disposed of according to Flinn Disposal Method #26a.

Alignment to the NGSS

This laboratory activity relates to the following Next Generation Science Standards (2013):

Disciplinary Core Ideas: Middle School
MS-ESS3 Earth and Human Activity
ESS3.C: Human Impacts on Earth Systems
ESS3.D: Global Climate Change

Disciplinary Core Ideas: High School
HS-ESS3 Earth and Human Activity
ESS3.C: Human Impacts on Earth Systems
ESS3.D: Global Climate Change

Science and Engineering Practices
Developing and using models
Planning and carrying out investigations

Crosscutting Concepts
Systems and system models
Energy and matter
Stability and change

Tips

- This activity can be performed as a demonstration or student group activity.
- 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 blackened, is very efficient at absorbing and converting the short wavelengths into long wavelengths. Energy will be efficiently trapped inside the bottle and dramatically increase the internal temperature.

References

Diugokencky, Ed and Pieter Tans, NOAA/ESRL www.esrl.noaa.gov (accessed June 26, 2015).

Riebeek, Holly. (2011) The Carbon Cycle. NASA Earth Observatory. www.earthobservatory.nasa.gov/features/carboncycle (accessed June 2015).

Materials for *Greenhouse Effect* are available from Flinn Scientific, Inc.

Catalog No.	Description
AP5406	Metal-backed Thermometer, Celsius/Fahrenheit
AP7669	Plastic Bottle, 1-Liter
AP7324	Greenhouse Effect and Global Warming – Environmental Science Student Laboratory Kit

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