Activity #5
How Do Atmospheres Change Over Time?
The Greenhouse Effect *[Adult]*

Adapted from: *Global Warming & The Greenhouse Effect, Great Explorations in Math and Science (GEMS)* Lawrence Hall of Science, 1997, by the Regents of the University of California
ISBN: 0-912511-75-3. Unless otherwise noted, all images are courtesy of SETI Institute.

1. Introduction

In this activity, Cadettes will observe how the greenhouse effect can change an atmosphere on Mars or on Earth. They will "Think like a scientist. Be a scientist!"

2. Science Objectives

You will:

- construct models to test ideas about processes that cannot be directly studied on Earth or Mars;
- appreciate that the atmosphere is a large and complex system, so experiments concerning it are difficult to perform; and
- use skills you have learned about atmospheric composition and apply that knowledge to new situations.

3. Materials

For each group of 4–6 Cadettes.

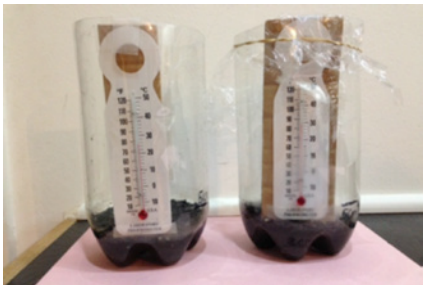
- [2] 2 liter (0.5 gal) clear soda bottles with labels removed and tops cut off. These are the **Atmosphere Model Chambers**. *Advance preparation required* (see page 2).
- [1] pair of scissors for constructing a set of **Atmosphere Model Chambers**
- [1] black permanent marker for constructing a set of **Atmosphere Model Chambers**
- [2] identical thermometers, one for each chamber; view on Amazon.com: http://tinyurl.com/lkrvzvq
- sufficient cardboard to prepare backing for each thermometer
- 5–10 cm (about 4 in) of clear tape to attach thermometers to cardboard and to inside of each chamber
- [1] piece of plastic wrap approximately 15 cm x 15 cm (6 x 6 in)
- [1] rubber band large enough to fit the circumference of chamber and secure plastic wrap
- chart of electromagnetic spectrum of light (EMS); print in advance
- 250-watt infrared heat lamp (bulb) in a fixture with hood. Lamp gets very hot — metal hood remains cool and is required for safety during experiment. Option: conduct outside on a sunny day.
- 500 ml (2.1 cups) dark, very moist soil (approximately 1 cup for each of two chambers)
- colored pencils in red, orange, yellow, green, violet, and blue
- [1] palm-sized piece of temperature-sensitive film available from Edmund Optics: http://tinyurl.com/o94kc6j (30 to 35 °C) or Amazon.com: http://tinyurl.com/nsbrxsp
- eye protection: safety glasses; view on Amazon.com: http://tinyurl.com/pjd8bp9

4. Safety Precautions

4.1. Heat lamp bulbs can get very hot. Do not touch when bulbs are turned on.

4.2. Handle bulbs with care. Do not drop or bang against hard objects. They are fragile.

Advance Preparation



Atmosphere Model Chambers — one set up per group of 4–6 Cadettes.

a. Remove labels from [2] 2 liter (0.5 gal) clear, colorless soda bottles.

b. Measure about 20 cm (8 in) from the bottom of the bottle and, using black marker, draw a circle to guide you in cutting off the top of the bottle.

c. Use the sharp point of a knife or scissors to make an initial incision, and then with scissors completely remove the curved portion of the bottle so that you have a cylindrical container about 20 cm (8 in) tall.

d. Prepare two thermometers: Cut out cardboard backing to protect thermometers from the heat effects of the infrared heat lamp. Amount and shape of cardboard will depend on your choice of thermometer.

e. Use transparent tape to attach thermometer to cardboard. *Do not place tape over the bulb of the thermometer*.
Note: Thermometers may have two temperature scales: Celsius (°C) and Fahrenheit (°F). In this case, scientists would use (°C). The expected difference between the control and experimental values is roughly 3°C (or ~6°F). To avoid confusion, you may select one scale and cover the other set of numbers with opaque tape.

f. Final **Atmosphere Model Chambers** will look like the image at bottom right.
Left Chamber: *Control* — open atmosphere allows for heat flow and no condensation.
Right Chamber: *Experiment* — closed atmosphere traps heat, and condensation will occur.
Cadettes will add soil, place thermometers, cover with plastic wrap and attach rubber bands as part of the experimental design.

g. Before Cadettes begin, help them choose a Timekeeper. (see separate "Cooperative Group Responsibilities" pdf document).

h. Optional: assign other jobs from "Cooperative Group Responsibilities" (see separate pdf document).

5. Get Ready

5.1. Read together *Background Exploring Light and the Greenhouse Effect* (see page 8). Direct team members to talk amongst themselves and answer the following:

5.2. Which has ***more*** energy? Underline your answer: VISIBLE or INFRARED light.

Visible

5.3. Which has more energy in the visible spectrum? RED LIGHT or BLUE LIGHT? (This answer is ***different*** than when an artist talks about warm and cool colors of paint!)

Blue light

5.4. Look at the clouds in the image titled "The Greenhouse Gas Effect and Light Energy." How do thin, small clouds reflect outgoing heat differently than thicker clouds?

Thin high clouds reflect less sunlight than low-level puffy big clouds.

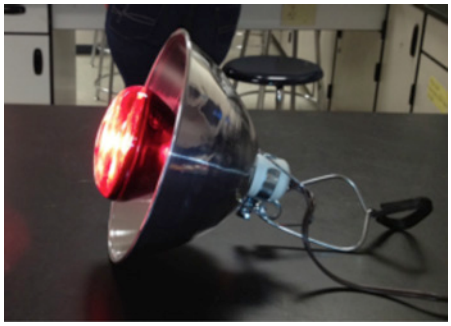
Big low clouds return more heat energy to the Earth's surface.

5.5. Watch this video: *The Electromagnetic Spectrum* (NOVA PBS): http://seti.org/ggtm

6. Explore: Part I

6.1. Equipment Manager: Obtain a piece of ***heat-sensitive film*** and the heat lamp, fixture, and hood. Locate an electrical outlet near a table. Everyone locate your copy of the electromagnetic spectrum (EMS) chart on page 8.

6.2. Get Started



6.2.1. Plug the heat lamp fixture into a nearby electrical outlet and lay the fixture and hood down on the table.

6.2.2. Adjust the fixture so that the lamp is parallel to the table.
CAUTION: Infrared bulb is very HOT! Do not touch!

6.3. Go Directions

6.3.1. Group: Compare the heat lamp to your EMS Spectrum Chart.

6.3.1.1 What color is the heat lamp?

Red

6.3.1.2 Where on the EMS chart would you most closely match the light energy of the lamp?

Infrared to visible red light.

6.3.2. Group: Hold your hand various distances from the heat lamp. Do NOT touch the lamp!!! Feel the difference in heat energy as it relates to distance.

6.3.2.1 As my hand gets closer to the lamp, I feel (MORE/LESS) heat energy.

More

6.3.2.2 As planets get closer to the Sun, they will feel (MORE/LESS) heat energy. (Check your answer with Activity #2 It's All About the Atmosphere Background, page 4.)

More

6.3.2.3 Do your observations (AGREE/DISAGREE) with information from Activity #2?

Agree

6.4. Leader: Very briefly!! hold the film 15 cm (6 in) in front of the heat lamp. **Do not let the film touch the lamp!** The film will translate the energy coming from the lamp into a color and requires only a very short exposure.

6.4.1. The color of the warmest spot on the film is:

Purple-blue

6.4.2. As the film cools, list the order of colors as the colors change:

Purple, blue, green, yellow, orange, red

6.4.3. Do the colors change in the same order of visible colors on your chart?

Yes

6.4.4. UNPLUG THE LAMP when you have completed step 6.4. CAUTION: Infrared bulb is very HOT! Do not touch!

6.5. Group: Turn this page over and lay your hand flat with your fingers spread out. Trace the outline of your hand. Turn the paper back over and finish reading the directions:

6.5.1. Let the film cool to room temperature, warm your hands briefly with the lamp, then make a handprint on the film by **pressing the film firmly between your two hands** for a few seconds. Remove **one hand** and quickly observe the *fading* order of the colors.

6.5.2. Turn this page *back to your hand outline* and using the appropriate colored pencils, sketch the color patterns as your handprint cools. Repeat making a "film" handprint if you need to see the *fading* color pattern more than one time to check the colors.

6.5.3. Use your EMS chart to help answer the questions below:

6.5.3.1 Are the color changes on the handprint in the same order as the visible colors on your chart?

Yes. Red or orange on the edges toward blue in the middle.

6.5.3.2 What part of your hand in the sketch has a color associated with the MOST energy? Why?

The warmest part of the hand that touches the film. The fleshy part of the fingertips and the palm generate more heat.

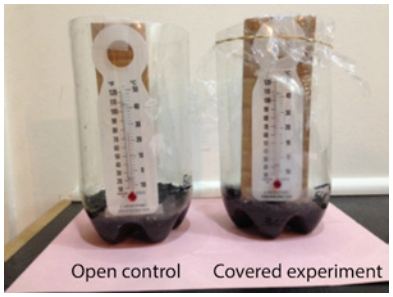
7. Explore: Part II

Complete the set-up for your Atmosphere Model Chambers:

7.1. Equipment Manager: Check your **Atmosphere Model Chambers**. One chamber will serve as a ***Control*** and the other, an ***Experiment***.

7.2. Leader: Read the activity directions and determine where the test bottles will be set up relative to the infrared fixture.

7.3. Group: Set up both **Atmosphere Model Chambers**:



7.3.1. Add 250 ml (1 cup) of moist soil to each chamber.

7.3.2. Check the temperatures on both thermometers. Keep thermometers in the shade and wait until both are the same temperature.

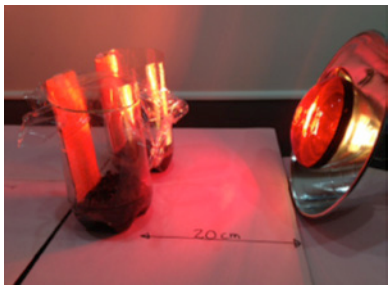
7.3.3. Tape the top of thermometers to the inside of the chambers at the top of the chamber, keeping the cardboard out of the moist soil.

7.3.4. Cover the **experiment** chamber with plastic wrap and secure the plastic with a rubber band. Your final set up should look like the above right image.

7.4. Equipment Manager: Place the chambers about 20 cm (8 in) from the light source. The bottles should be separated by 2 cm so as not to touch each other.

7.5. Make sure the test bottles are lined up so that the thermometer faces ***away*** from the lamp and the cardboard protects the thermometer from the direct heat of the lamp.

7.6. Recorder: Immediately record the **time** and **temperature** for each thermometer on your Data Sheet in the spot for "T=0." Ideally, the temperature values should be the same at the beginning. *Fill in the "Actual Temperature Read Times" on the DATA TABLE before starting.*



7.7. Timekeeper: Be prepared to record temperatures every 5 minutes for a maximum of 20 minutes during the Explore Part II activities.

7.8. Leader and Group: Check to see that your set-up looks like the image on the right, then ***turn on the heat lamp***. Caution: HOT!!

7.9. Every 5 minutes, record the time and two temperature values in your Data Sheet.
Timekeeper and Recorder: Share data with other members of the team. Do you see any differences in the appearance of the two chambers? Write that in the observation column on your Data Sheet. Make sure each team member has completed the Data Table.

7.10. Equipment Manager: Turn off the infrared lamp at the end of 20 minutes of observation and recording time.

8. Data Sheet

Complete in small groups.

Explore Part II DATA Table

Directions: Record the time on your watch or a clock and then add 5 minutes to each column on the left so you will know ahead of time when to read and record the next temperature values.

(A) is the time you begin your experiment. (A) + 5 minutes = (B) which is the time you make your next temperature reading. Your final read time at (E) should be 20 minutes after you started the experiment.

We have completed the table below with *SAMPLE data* (in *italics*).

Actual Temperature Read Times	Experiment Time "T" (minutes)	CONTROL Temperature and Observations °F or °C	EXPERIMENT Temperature and Observations °F or °C
(A) Your watch/clock start time =	T = 0	*70*	*70*
(A) + 5 minutes = (B)	T = 5	*81*	*81*
(B) + 5 minutes = (C)	T = 10	*84*	*condensation is observed* *86*
(C) + 5 minutes = (D)	T = 15	*87*	*more condensation* *89*
(D) + 5 minutes = (E)	T = 20	*88*	*water dripping on sides* *94**

* Temperature difference between control and experiment is roughly 4–6 °F. Appearance of condensation in the covered chamber depends on how moist the soil is at the beginning of the experiment.

Questions:

8.1. Which bottle had the higher temperature at the end?

Experiment

8.2. What difference did you observe in the appearance of the two bottles over time that might explain why one bottle had a higher temperature? Explain:

Experiment bottle reached a higher temperature and condensation is observed on sides. Water vapor is trapped inside the experiment bottle by the plastic top.

Elaborate — Thinking about the Greenhouse Effect and Global Warming

Watch the video: *Global Warming* (NASA): http://seti.org/ggtm

8.3. Discuss how science uses models to understand complex issues:

8.3.1. How well did our Atmosphere Model Chamber bottles function as a test for the greenhouse effect?

Our atmosphere is a large and complex system, so experiments and measurements concerning it are difficult. For instance, measuring average temperatures is tricky and temperature is important to the water cycle and cloud formation.

8.3.2. What was the greenhouse gas we studied?

We studied water vapor.

8.3.3. In our model, what did the plastic wrap represent?

The plastic wrap represented a closed system like a planet's atmosphere that traps heat.

8.3.4. In our model, what did the lamp represent?

It represented the Sun's energy.

8.3.5. Was this a good model for an atmosphere?

One way to study the greenhouse effect and global warming is to build models and test theories and ideas about climate change by experimenting with the model. However, this model has limitations.

Scientists think something is trapping heat in the Earth's atmosphere, causing the temperature to go up. However, it is not a SOLID barrier like plastic.

8.4. We can study one greenhouse gas and learn about other greenhouse gases:

8.4.1. This experiment studied water vapor, a greenhouse gas. Other greenhouse gases such as carbon dioxide and methane will be discussed in the next activity with respect to human control. How does water vapor differ from other greenhouse gases?

Greenhouse gases trap heat in one way or another, increasing the temperature of Earth's surface. However, greenhouse gases are not equal in their effects, because the gases cycle through the Earth's system in different ways than water.

Background Information

What are the percentages of gases contributing to the greenhouse gas effect?

Water vapor	50%
Clouds	25% (Clouds are water droplets — condensed water vapor. View *Unscramble the Clouds* activity: http://tinyurl.com/m79kedp)
CO_2	20%
Other gases	Remainder.

So why are scientists not more concerned about water vapor, since it is the most predominant greenhouse gas? That is related to how long the greenhouse gas remains in the atmosphere. For water, the average is just a few days. The rapid turnover of water means that if human activity WERE directly adding or removing lots of water vapor, there would be no slow build-up of water vapor, unlike what is happening with carbon dioxide. Reference article: http://tinyurl.com/lz98zoc

9. Connection to the Leadership Journey *Breathe. It's Your Planet — Love It!*

Now that you better understand greenhouse gases and the greenhouse effect, think about real atmospheric issues that are relevant to you on earth. In Activity #6, you will learn about global warming and you will develop your Air Care Team Action plan.

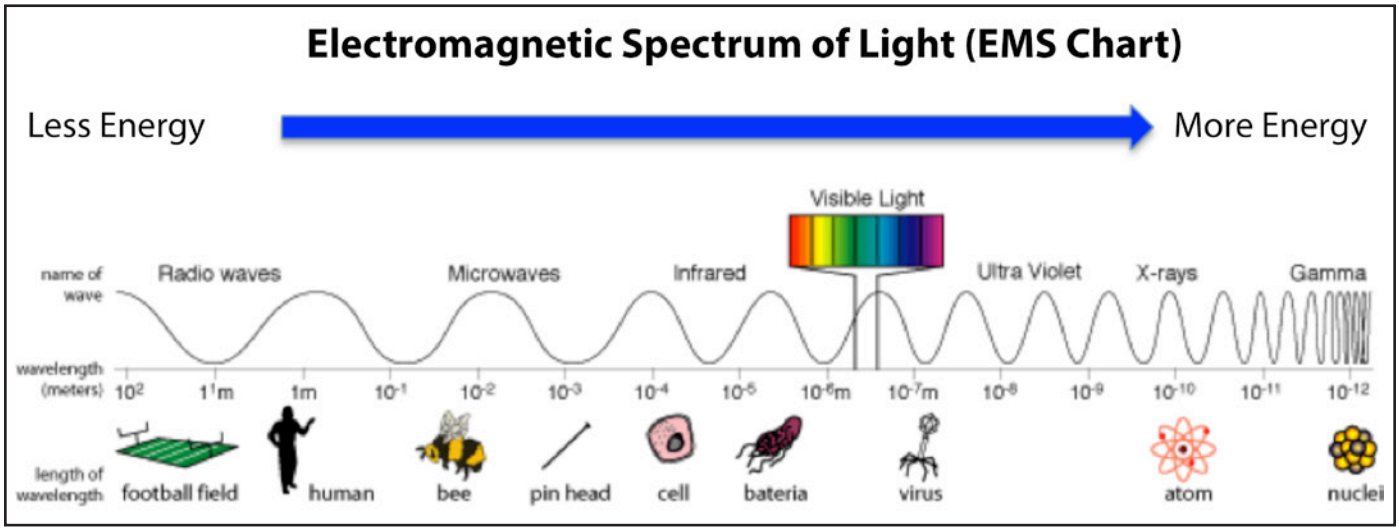


Image credit: NASA

The Greenhouse Gas Effect and Light Energy

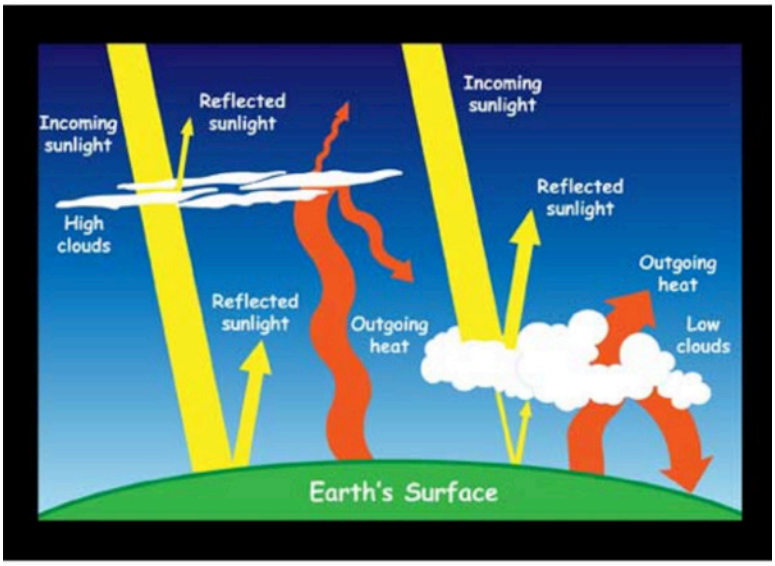


Image credit: NASA

Water in the atmosphere acts as a greenhouse gas. The atmosphere contains a lot of water. This water can be in the form of a gas — water vapor — or in the form of a liquid in clouds. Clouds are water vapor that has cooled and condensed back into tiny droplets of liquid water.

Earth's atmosphere acts like a greenhouse. During the day, the Sun shines through the atmosphere and the surface warms up in the sunlight. At night, Earth's surface cools and releases heat back into the air.

Some of the Sun's heat is trapped by the greenhouse gases such as carbon dioxide, water vapor, and other gases in the atmosphere. That's what keeps our Earth warm and cozy.

Note that two common gases making up Earth's atmosphere — nitrogen and oxygen — are NOT greenhouse gases.

Look at your Electromagnetic Spectrum (EMS chart) above to review infrared and visible light. A greenhouse gas is any gas which *transmits visible light but absorbs infrared light*.