

What makes a gas, a greenhouse gas?

A laboratory experiment from the Little Shop of Physics at Colorado State University



Overview

Greenhouse gases and their role in climate change has become a heated topic of discussions, news reports, magazine articles and books. There are many different types of gas molecules in the atmosphere. Why are some greenhouse gases and others not?

Theory

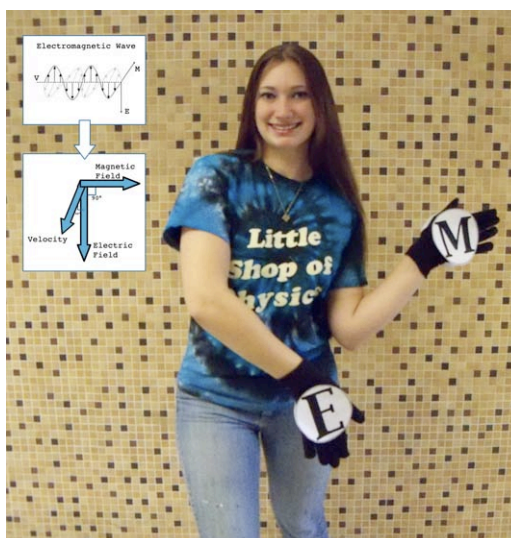
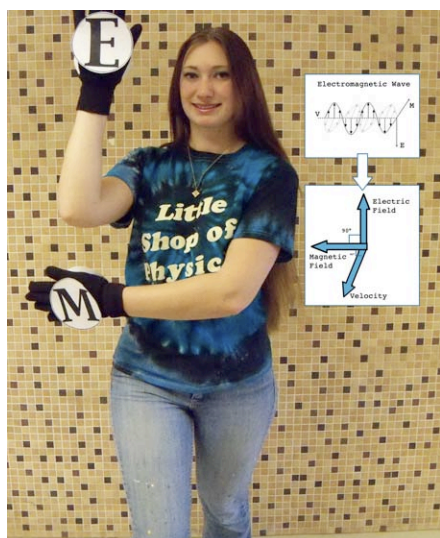
The earth's atmosphere is composed of a variety of gases—in fact, 99% of the Earth's atmosphere consists of two gases: nitrogen (N_2), which makes up 78%, and oxygen (O_2) which accounts for 21%. The other 1% is a mix of argon, neon, ozone, carbon dioxide, water vapor, methane and other trace gases.

Necessary materials:

- A large open area for your students to move about freely in groups of 2 and then 3
- 2 gloves—one marked E on both sides and one marked M on both sides
- Stickers, hats, wigs, or other ways to designate what type of atom each student is portraying.

Check out Scott Denning, Professor of Atmospheric Science at Colorado State University, and education director of CMMAP demonstrating the “dances” of atmospheric molecules at

http://changingclimates.colostate.edu/movies/scott_denning_796kbits.

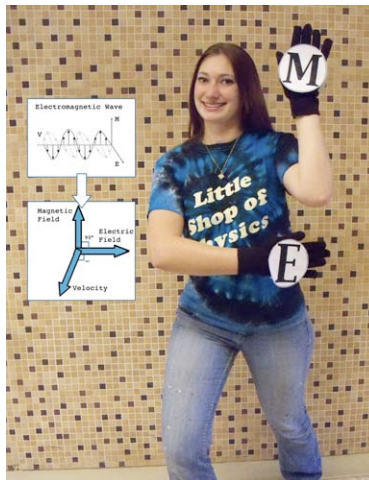
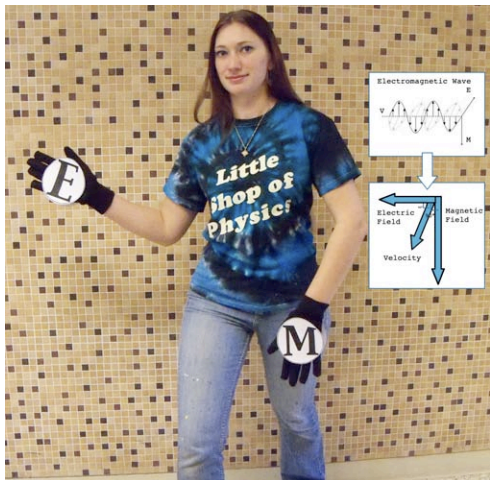


In this simulation of an electromagnetic wave, the wave is traveling out of the page toward you. The electric field is oriented up and down, as the magnetic field moves from side to side.

The energy from the sun travels to the earth in the form of electromagnetic waves and warms it up. The earth in turn cools itself off by radiating long wavelengths of thermal radiation back to space.

Certain gases in the atmosphere absorb these outgoing electromagnetic waves.

This is very important; with no such greenhouse gases, the planet



Now the magnetic field is oriented up and down, and the electric field moves from side to side.

would be a giant ice ball with an average temperature of -18° Celsius, or 0° Fahrenheit. Life as we know it would not exist! The greenhouse gases are able to absorb the thermal radiation and send some of the energy back down to earth. But why are some gases able to do this and others not? It turns out that a molecule that has the capability of vibrating in different ways can absorb different wavelengths. It then can emit heat back to warm the earth.

Doing the Experiment

Before doing this experiment, label one glove or sign with an E on both sides, and then label another one with an M on both sides. Put on the gloves or hold the signs and practice portraying an electromagnetic wave—having one letter go from side to side while the other letter is going up and down. This is a bit trickier than it looks.

Gather your students in a large open area so they can spread out as needed. Explain to them that they are going to act out 4 different molecules that are part of the Earth's atmosphere and discover which ones are greenhouse gases and which ones are not.

N_2 & O_2

Have your students break into pairs and lock arms together to simulate the chemical bonds between them. Each molecule pair can be facing in any direction, but they are to stand still. Tell one half of the class that



N_2 is a molecule with equal charge sharing. Neither atom has a net charge. There is little interaction with electromagnetic waves.



O_2 is also a molecule with equal charge sharing. Neither atom has a net charge. There is little interaction with electromagnetic waves.

they represent nitrogen molecules and the other half that they are oxygen molecules. Explain that these two types of molecules are like two balls on a stick, and that they don't have a net positive or negative charge.

Put on the two gloves that are labeled E and M and tell them that you are portraying an electromagnetic wave. The wave is traveling straight ahead of you. If the individual atoms in the molecule have a net positive charge, they will be pulled in the direction of the electric field (the E on the glove). If they have a net negative charge they will be pulled in the opposite direction.

Use the gloves and have the E and M move back and forth vertically and horizontally as seen in the pictures above. What happens to the N_2 and O_2 molecules? Not much! The individual atoms don't have a net positive or negative charge, so they don't interact with the electric field, and neither do the molecules. Net result: *Electromagnetic waves don't interact with the major components of the atmosphere, so the atmosphere is transparent.*

CO₂

Now have the students break into groups of 3. Explain that they are going to portray carbon dioxide molecules. The carbon atom is in the middle with a slight positive charge and there is an oxygen atom on each side with a slight negative charge. Each group of 3 students should lock arms and stand in a line. Simulate an electromagnetic wave and demonstrate with one of your groups of 3 before having your whole group join in the simulation. Here are suggested EM wave movements to try.



H₂O

Have your students stay in their groups of 3 and tell them that they are now going to act out H. Oxygen is in the center and has a slight negative charge. Each hydrogen atom locks an arm with the oxygen and positions him/herself at a 45° angle to the oxygen atom, but 90 degrees from the other hydrogen atom. The hydrogen atoms have a slight positive charge. Demonstrate with one of your groups of 3 how H₂O has many ways to vibrate due to its shape. If the electric field points down, the O can go up as the two H drop down. If the electric field points up, the two H can go up as the O drops down.



The H₂O molecule can spin, twist & more.

Explain to your class that different vibrations allow a molecule to absorb different wavelengths. The molecule then emits these wavelengths in all directions, with the result that some are sent back down to earth warming the planet. Greenhouse gases have this quality. Discuss which of the four molecules were greenhouse gases. Explain that even though H₂O is a more powerful greenhouse gas than CO₂, water vapor only exists in the lower layers of the atmosphere, where CO₂ exists throughout.

of your students act as N₂, 21% as O₂, and then have several in the mix depicting a CO₂ or water vapor molecule as you wield the electric field glove. It might give your students a sense of how powerful greenhouse gas molecules are—even though they make up less than 1% of the atmosphere.

An interesting activity to try is to have 78%

Summing Up

In this kinesthetic activity, students will have an opportunity to act as different molecules in the earth's atmosphere. They will experience why certain molecules are so good at absorbing and emitting thermal radiation and others are not.

For More Information

CMMAP, the Center for Multi-Scale Modeling of Atmospheric Processes: <http://cmmmap.colostate.edu>

Little Shop of Physics: <http://littleshop.physics.colostate.edu>