PhET Greenhouse Effect Simulation

Note: These materials are take from Carbon TIME (used with permission)

Note: Digital or hard copies of these instructions should be provided to your students for this activity.

Introduction: The PhET Greenhouse Effect Simulation allows you to change the atmospheric greenhouse gas concentration, observe how these changes affect the movement of infrared photons into space, and determine how these interactions ultimately affect the temperature of the Earth's surface. Using the PhET Simulation, you will investigate three questions:

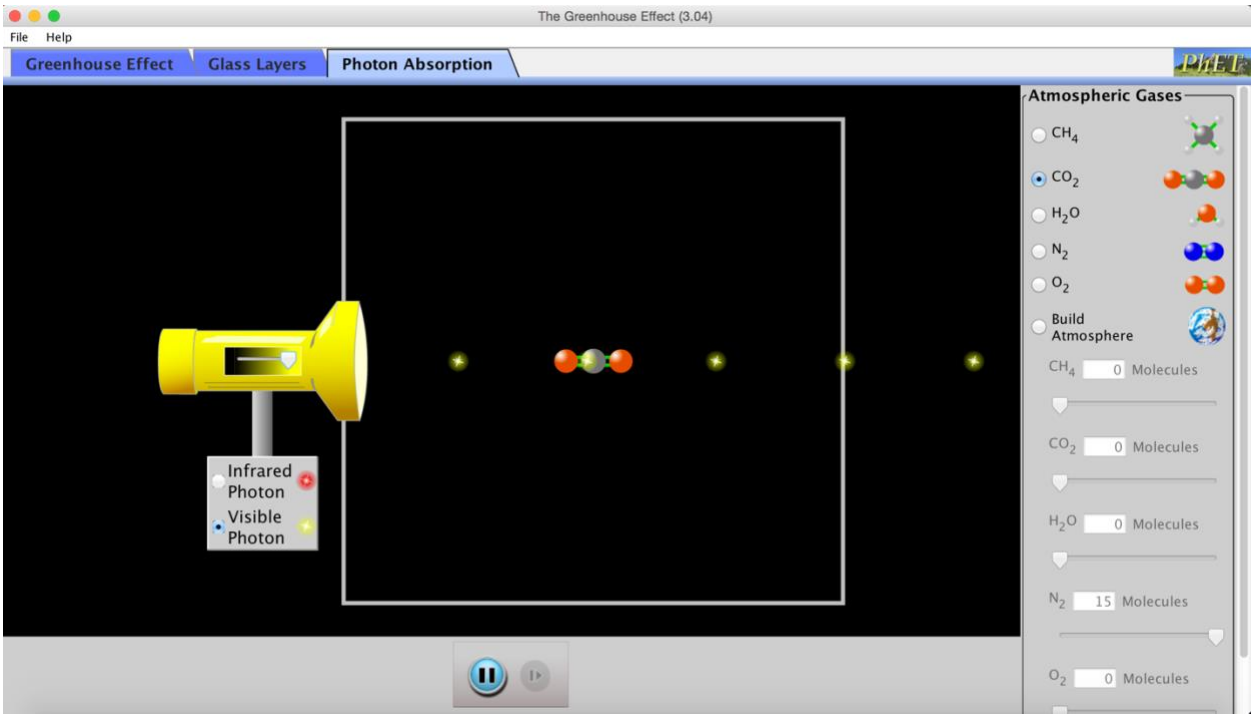
1. How do different gases in the atmosphere interact with light?
2. How do gases in the atmosphere affect the Earth's temperature?
3. Why is the Keeling Curve important?

Ordinarily, it would be impossible to directly observe the interactions of atmospheric gases with light. The PhET simulation serves as a model to make these interactions visible. This can help us explore patterns that are otherwise hard to see.

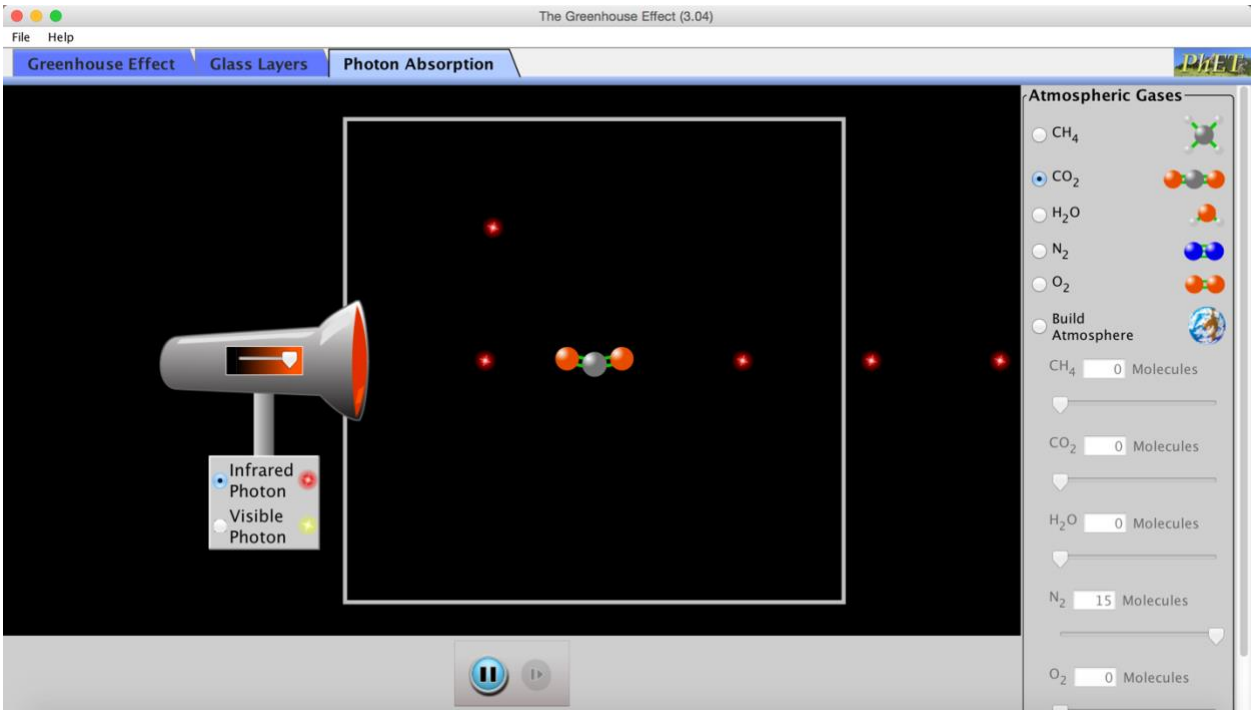
Downloading the PhET Simulation: you will need download it onto the computers or devices that your students will be using. For the file and for instructions on how to download, visit https://phet.colorado.edu/en/simulation/greenhouse .

A. Investigating how different gases in the atmosphere interact with light:

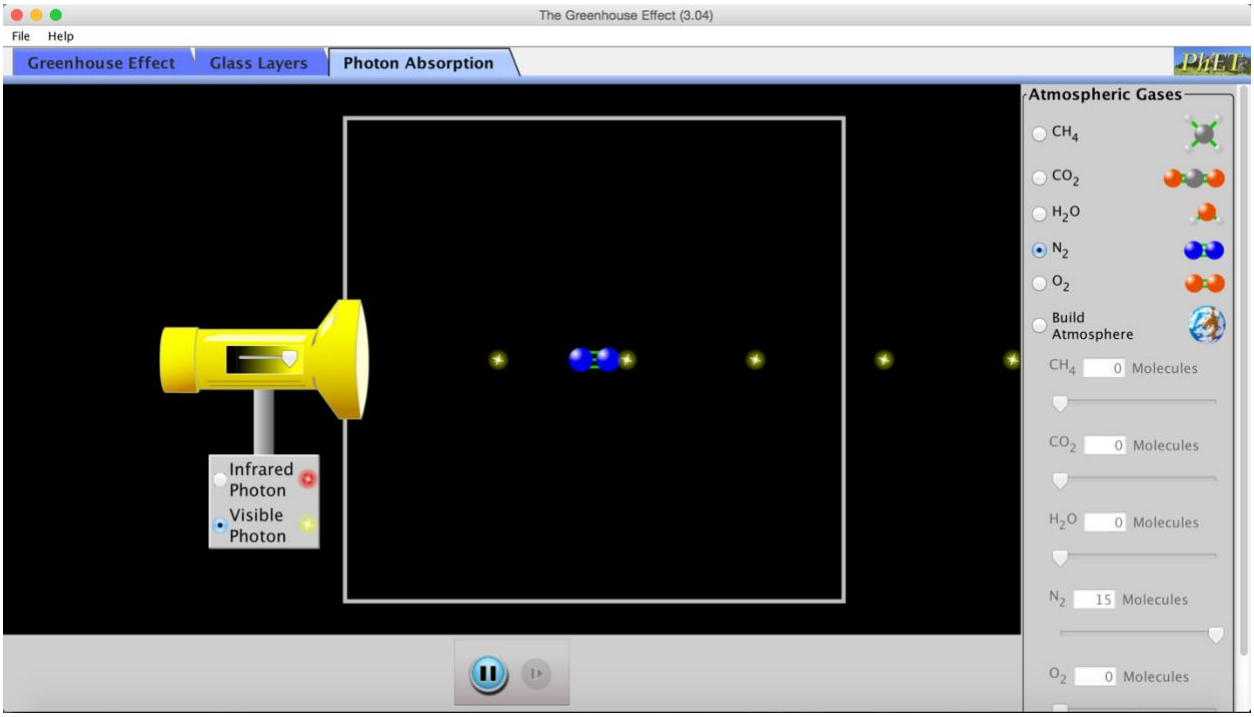
Open the PhET simulation. For the first questions, you will need to open the Photon Absorption Tab (in the upper left). Some gases are unable to interact with visible and/or infrared radiation. It just passes through the gas molecule unaffected. In other cases, a gas molecule may be able to absorb and re-emit a particular form of radiation (causing it to visibly 'wiggle' in this simulation). This component of the PhET simulation helps us to see which gases interact with each kind of radiation. You will be comparing two different gases in this simulation: CO_2 and N_2.



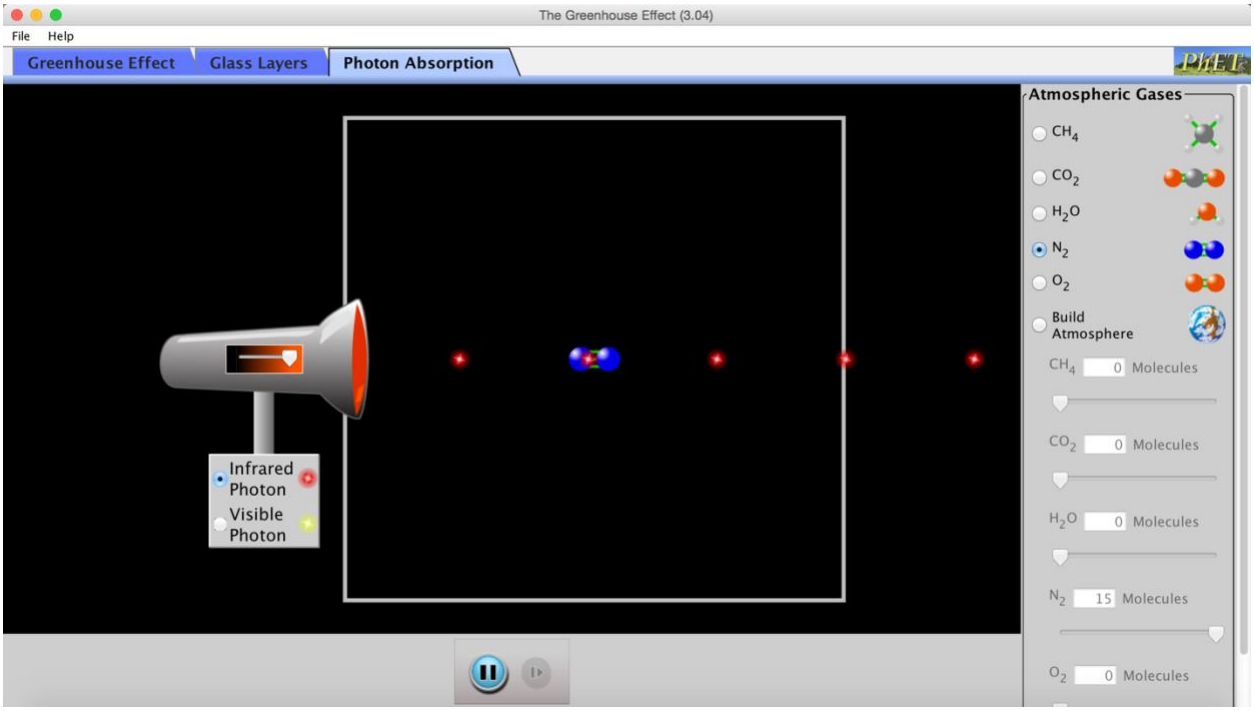
CO_2 and Light Photons: Under the "Atmospheric Gases" panel, select CO_2. On the "radiation gun" on the left-hand side of the screen, make sure that the "Visible Photon" option is selected. Move the slider on the gun all the way to the right and observe how the infrared photons respond when they encounter the CO_2 molecule. Record your data on your worksheet.



CO_2 and Infrared Photons: Under the "Atmospheric Gases" panel, select CO_2. On the "radiation gun" on the left-hand side of the screen, make sure that the "Infrared Photon" option is selected. Move the slider on the gun all the way to the right and observe how the infrared photons respond when they encounter the CO_2 molecule. Record your data on your worksheet.



N_2 and Visible Photons: Under the "Atmospheric Gases" panel, select N_2. On the "radiation gun" on the left-hand side of the screen, make sure that the "Visible Photon" option is selected. Move the slider on the gun all the way to the right and observe how the infrared photons respond when they encounter the N_2 molecule. Record your data on your worksheet.

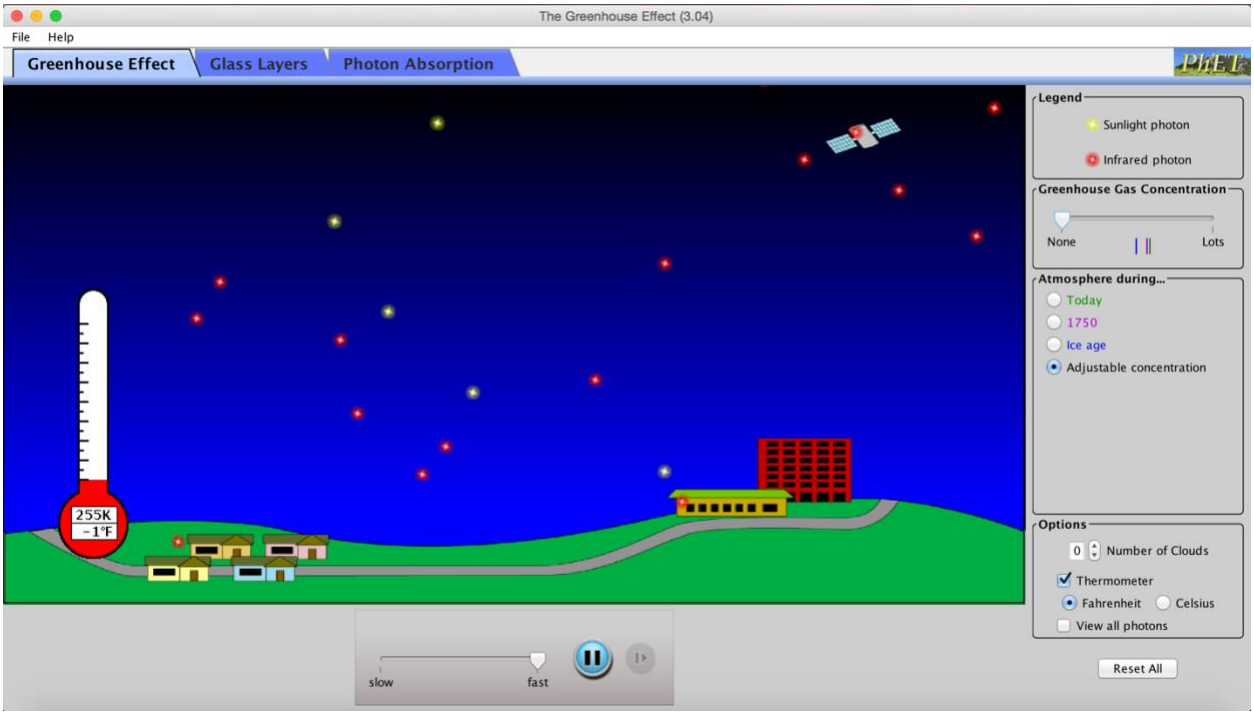


N_2 and Infrared Photons: Under the "Atmospheric Gases" panel, select N_2. On the "radiation gun" on the left-hand side of the screen, make sure that the "Visible Photon" option is selected. Move the slider on the gun all the way to the right and observe how the infrared photons respond when they encounter the N_2 molecule. Record your data on your worksheet.

Conclusions: Complete this section of your worksheet by answering the remaining questions. What differences did you notice between how different kinds of energy and different kinds of molecules interact in different ways?

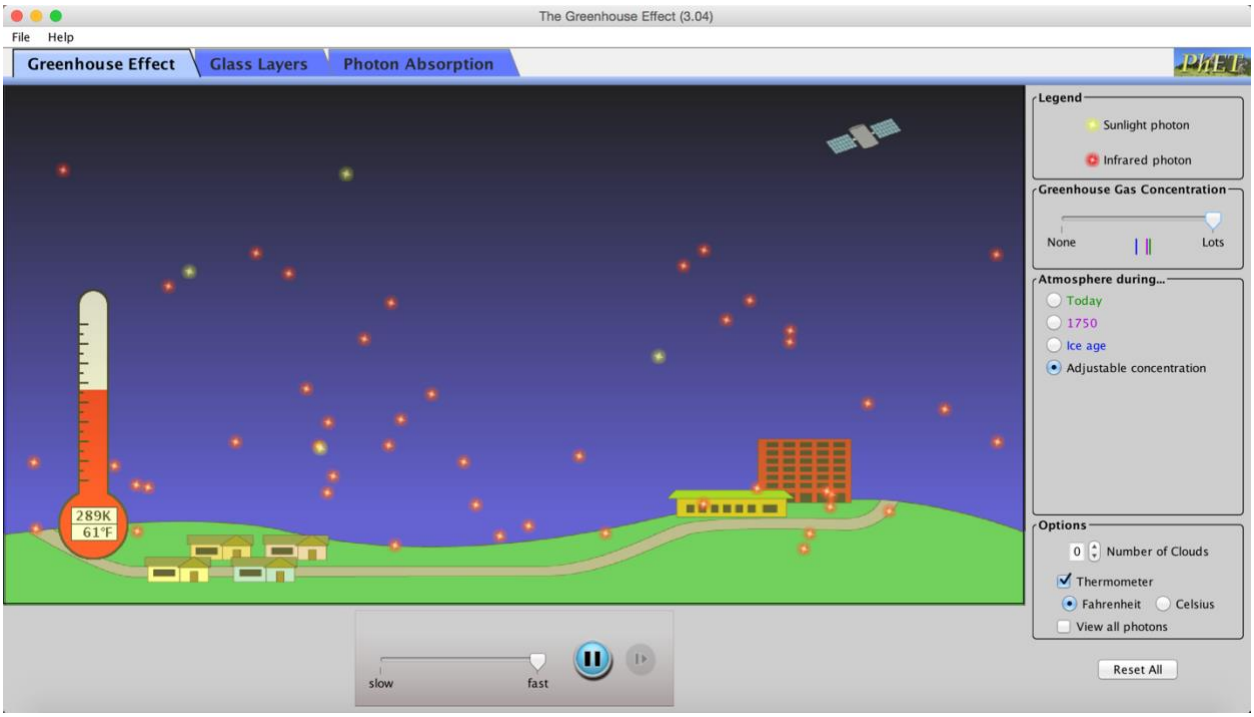
B. Investigating how different gases in the atmosphere affect the Earth's temperature:

For the next questions, you will need to open the Greenhouse Effect Tab (in the upper left). The earth's atmosphere is comprised of a variety of gases. We will now look at a more complex model of how different kinds of radiation interact under different atmospheric conditions. For this section, you will be adjusting the concentration of greenhouse gases (gases like CO_2 which can absorb and re-emit infrared radiation) and you will observe the resulting differences in the patterns in the movement of light and infrared photons. You will also observe the impact that these changes have on the Earth's temperature.



Low CO_2 Levels & Temperature: In the "Greenhouse Gas Concentration" panel, move the slider to "None". Watch the yellow sunlight photons as they move from outer space to the surface of the earth. Then watch the red infrared photons as they move from the surface of the earth to outer space. What observations can you make about their movement? Record your data on your worksheet.

Next look at the thermometer on the left-hand side of the screen. Record the temperature that occurs under these conditions. Record your data on your worksheet.



High CO_2 Levels & Temperature: In the "Greenhouse Gas Concentration" panel, move the slider to "Lots". Once again, observe the movement of both the yellow sunlight photons and the red infrared photons. What observations can you make about their movement? Record your data on your worksheet.

Again, look at the thermometer on the left-hand side of the screen. Record the temperature that occurs under these conditions. Record your data on your worksheet.

Conclusions: Complete this section of your worksheet by answering the remaining questions. How did the changes to the concentration of greenhouse gases affect temperature? How does this relate to your observations from Part A?

C. Investigating why the Keeling Curve is important:

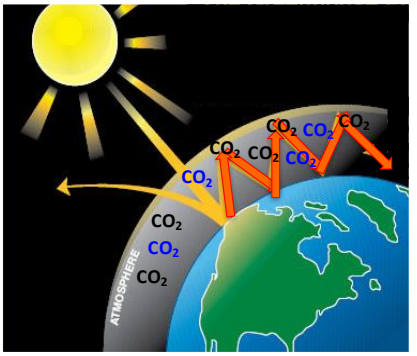
For the next questions, you will remain on the Greenhouse Effect Tab (in the upper left). Now you will be connecting the relationships between changing greenhouse gas concentrations and temperature to past, present, and future conditions.

Conclusions: Complete this section of your worksheet by answering the remaining questions. How does what you observed in Part C relate to the Keeling Curve? How does this relate to your observations from Part A? What can this tell us about future implications?

Optional: Greenhouse Effect Reading

Note: These materials are take from Carbon TIME (used with permission). Written by C. Kohn

The Greenhouse Effect

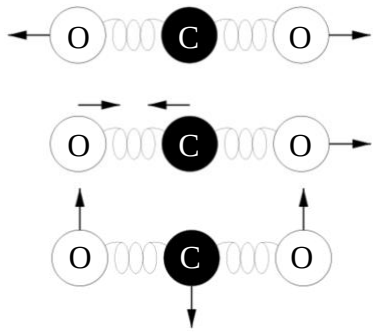


Just as the composition of your clothing affects the movement of heat energy away from your body into the surrounding air, the composition of the atmosphere affects how the temperature of the earth is regulated. The temperature of our air depends on the balance between solar radiation (mostly visible light) that warms the Earth up and invisible infrared (IR) radiation that cools the Earth down if it leaves the Earth and goes into outer space. The gases in the atmosphere mostly let solar radiation pass right through, but the story about how they interact with infrared radiation is more complicated—and that's a story we need to tell.

Greenhouse Gases

Most of the atmosphere is comprised of nitrogen gas (N_2) and oxygen gas (O_2), but these gases do not change the rate at which energy moves from the surface of the earth into space. On the other hand, some gases like carbon dioxide (CO_2) affect how energy (in the form of infrared radiation) is able to move from the earth's surface into space. These kinds of gases are called *greenhouse gases* because like a greenhouse or a car on a hot summer day, they allow visible light radiation to enter, but slow the loss of leaving infrared radiation.

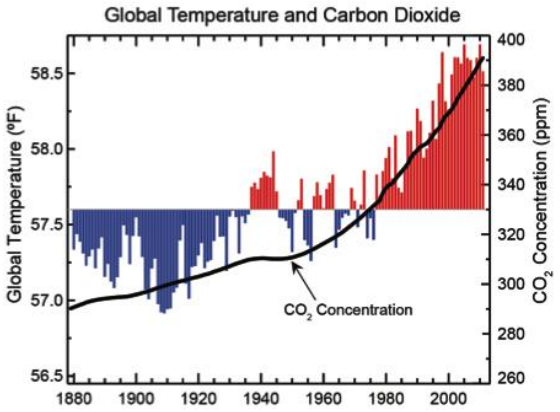
So why do some gases slow the loss of heat in the atmosphere while others don't? Some molecules absorb infrared light by converting the light energy into the energy of vibration. Molecules with more than two atoms, and those with different kinds of atoms can vibrate in multiple kinds of ways, allowing them to absorb and re-emit infrared radiation. Whether or not a molecule can interact with infrared radiation leaving the Earth depends on these vibrations. The atoms on N_2 and O_2 molecules are identical and can only move closer or further apart. This is not complex enough to enable interaction with infrared radiation. On the other hand, there are multiple kinds of atoms on a CO_2 molecule, and they have complex vibrational modes. This allows CO_2 to absorb infrared light and emit it in any direction. This slows the loss of this energy from the earth's atmosphere. Increasing the levels of greenhouse gases that exist in the atmosphere makes it more difficult for infrared radiation to leave the earth (similar to the effect of slowly closing car windows on a sunny day).



The atoms on a CO2 molecule have more complex vibration modes that allow them to absorb infrared light and emit it in any direction. (*Source: scied.ucar.edu*)

Connecting the Keeling Curve to the Greenhouse Effect

This naturally-occurring phenomenon is called the *greenhouse effect* and is necessary for life on Earth. Without greenhouse gases, the Earth would be freezing cold! However, if the concentration of greenhouse gases in the atmosphere increases *too much*, it will cause the planet to reach temperatures that damage our ecosystems. Just like leaving a car's windows closed on a hot summer day can cause the temperature inside the car to rise, increasing the concentration of CO_2 and other greenhouse gases in the atmosphere can cause the temperature of the planet to increase.



Source: 2013 Draft National Climate Assessment

Dr. Charles Keeling was the first person in the world to accurately determine the rate at which carbon dioxide in the air was gradually increasing each year. Greater concentrations of CO_2 result in greater absorption of infrared radiation. As a result, the average temperature of the Earth is increasing. There are still hot places and cold places, and there are still hot days and cold days, but as the graphs shows, the Earth's overall average temperature has been increasing for more than 100 years.