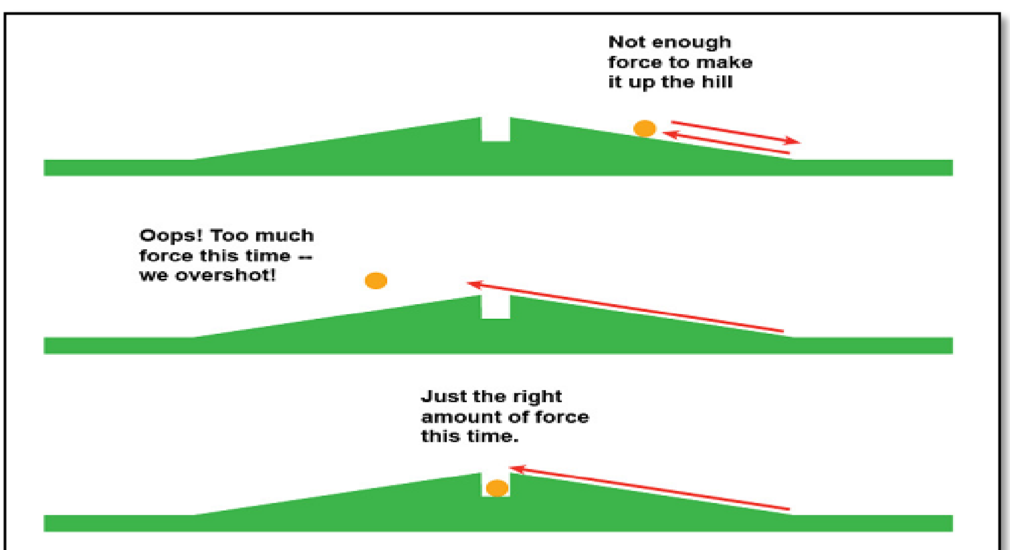
Student Sheet 1

LAB ACTIVITY: WHY IS CO_2 SO SPECIAL?

Why do climate scientists place so much importance on the role of carbon dioxide (CO_2) in human-caused climate change? Isn't CO_2 just a trace gas? After all, CO_2 molecules are only about 400 out of every million molecules of air (400 parts per million, or ppm). How can a gas in such small concentration cause Earth's temperatures to rise and bring about all the disasters the alarmists are warning about?

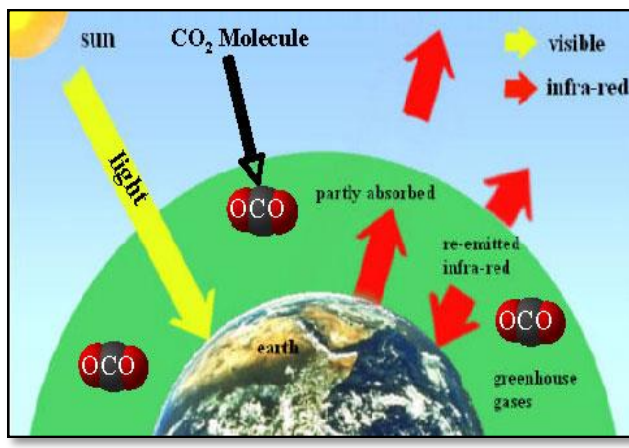
Carbon dioxide is only one of the ***greenhouse gases***, along with water vapor, methane, nitrous oxide, ozone, and CFCs 11 and 12. However, CO_2 stays in the atmosphere for centuries, much longer than the others. For example, water vapor is the most abundant greenhouse gas, but it condenses and only stays in the atmosphere for a few days, so it doesn't build up in the atmosphere as CO_2 does. Carbon dioxide acts as a sort of gatekeeper: it allows visible light to pass right by but will absorb ***infrared (heat) energy***. The key to understanding how it does this is a concept called ***resonance.***

Imagine that you are playing miniature golf, and you come to one of those nasty holes where the cup is right at the top of a hill. If you putt the ball too softly, it will roll back down the hill and everyone will laugh at you. If you putt the ball too hard, it will skip over the hole, resulting in more hysterics. But if you putt the ball with just the right force, it will drop neatly into the cup at the top of the hill, and everyone will be in awe of you.

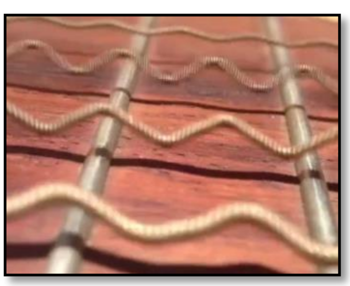


Student Sheet 2

All light is made of ***photons***, tiny little packets of energy, far too small to see individually. Photons behave in some ways like particles, little bits of stuff, and in other ways like waves. It's not just visible sunlight that is made of photons, but a lot of other kinds of waves like radio waves, television broadcasts, x-rays, and the ultraviolet rays. The difference between light and these other kinds of waves depends on the size of the wave - the ***wavelength***. Very short waves are x-rays and ultraviolet rays, that cause sunburn. Visible light like sunlight is made of medium-length waves. Radio and television waves are very long waves. But all of these rays are made of photons.

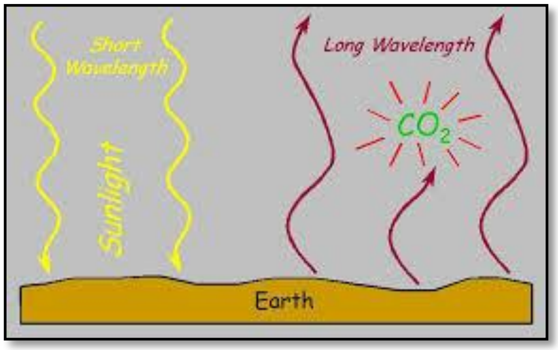


In the same way as the golf ball scenario played out, only photons with specific energy characteristics can be absorbed by a molecule of carbon dioxide or any other greenhouse gas. The greenhouse gases are constantly bombarded by infrared radiation emitted from the earth. When photons bump into other atoms, some of their energy can get the electrons in those atoms ***resonating*** or moving faster than they were before - that's what we call ***heat***. The properties of these molecules and their bonds determine if a gas in the atmosphere will absorb infrared radiation or not.

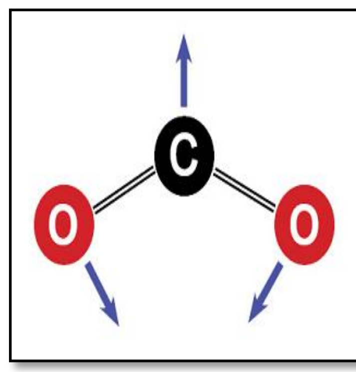


Gases are the simplest type of molecule, and they only vibrate in very particular ways. Vibrations in a gas molecule are like vibrations of a guitar string in that they are fussy about ***frequency (rate).*** This is because, like a guitar string, a gas molecule will only vibrate at its "ringing" or ***resonance frequency***.

Student Sheet 3



Incoming solar radiation is ***visible and ultraviolet (UV) radiation*** that reaches the lower atmosphere and the surface of Earth. This energy is reflected, scattered or absorbed when it interacts with the gases in the atmosphere. Because Earth cannot keep all this absorbed energy forever, it reradiates or ***emits*** it at longer wavelengths (with less energy) than the one at which it was absorbed. The incoming, absorbed energy is ***short-wave radiation*** and the emitted energy is ***long-wave radiation***.



When a photon hits a gas molecule, it causes it to vibrate, take on the photon's energy and absorbs it. CO_2 vibrates by bending in the direction of the arrows shown in the image. Not just any old photon can get absorbed by a CO_2 molecule; it has to be a photon within certain wavelengths. Any photon that is not within those relatively narrow wavelengths will just pass by the CO_2 molecule and go look for a friendlier greenhouse gas to take up with, or maybe just go on up into space.

Climate scientists are concerned that CO_2 concentrations in the atmosphere have risen from 280 ppm in pre-industrial times to 400 ppm today. That increased concentration has caused an imbalance in the natural greenhouse effect, so that the atmosphere is capturing extra energy each year, raising global surface temperatures. The upshot is that even a relatively small concentration of a substance can have a large impact, especially at large scales and over longer time periods. Atmospheric carbon dioxide therefore, qualifies as the principal control knob that governs the temperature of Earth.

Student Sheet 4

I.PROCEDURE:

1. Construct the molecule assigned to your team following the directions given to you by your teacher.

2. Start with the molecule constructed by your team:
   - If the molecule is carbon dioxide or methane, hold it by the center atom and shake it.
   - If it is nitrogen or oxygen, hold it by either end and shake it.
   - Keep the shaking movement within a range of 6 inches.
   - Try a range of shaking speeds, or frequencies, from very slow (1 shake per second) to very fast (7-8 shakes per minute).
   - Use the clock /watch to time the shaking.

3. Try to find the frequency at which it is much easier to keep the model vibrating. This is the "resonance frequency" of the molecule.
   - Count the number of vibrations at 5 second intervals.
   - Write this information in the DATA TABLE in the appropriate column.
   - Divide the number of vibrations by 5.

     EX: No. of vibrations ÷ 5 = resonance frequency
   - Write the answer in the correct space on the **DATA TABLE.**

4. Do at least 3 trials until you are convinced that you have found the resonance frequency of your molecule.

5. Exchange models with other groups and try to determine the resonance frequency of each model.

6. Answer the questions in the **CONCLUSIONS** section.

Student Sheet 5

DATA TABLE: RESONANCE FREQUENCY OF MOLECULES

Molecule name	Number of vibrations	Resonance frequency
1		
2		
3		
4		

II.CONCLUSIONS:

1. What hypothesis can you formulate to explain your observations?
2. Which of the 4 models had the fastest resonance frequency?
3. Which had the slowest?
4. Which seemed to have no resonant frequency?
5. If there are differences in resonance frequency, why do you think they are different?
6. The behavior of the molecules built from Styrofoam balls are useful similarities to the behavior of real molecules in the atmosphere. From the observations you made of the models and the interaction with the different frequencies of vibration, why do you think that some of the gases in the atmosphere absorb radiation and others do not?
7. Why do GHGs absorb infrared radiation and do not absorb visible light?

*8.The range of infrared radiation from Earth is 6 to 22 microns. Each greenhouse gas and water vapor absorbs radiation from different areas of the electromagnetic spectrum. Carbon dioxide and water absorb long wave radiation from 12 to 19 microns. Methane absorbs wavelengths 6 to 8 microns. Water blocks radiation below 7 microns from being reflected out to space. What is the window of possible infrared radiation back out to space and how do these gases contribute to closing the window?

9. Find out the principal range of infrared radiation absorption for CFCs.