Carbon Dioxide—The Gatekeeper

Ideas about matter and energy come together as we return to the question, "What's so special about carbon dioxide?"

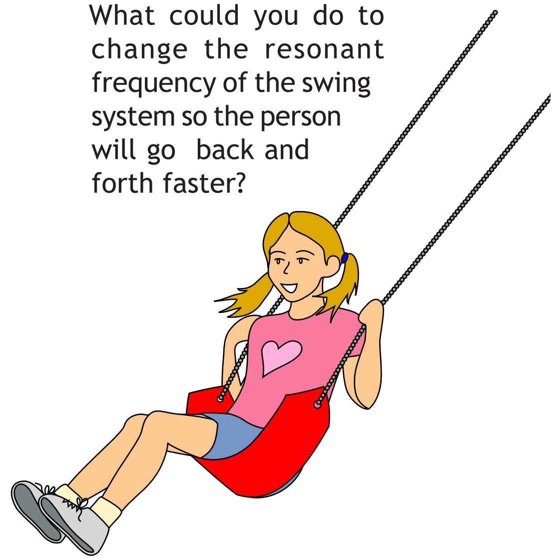
Carbon dioxide acts as a sort of gatekeeper. As we said at the beginning of this chapter, carbon dioxide allows visible light to pass right by but will absorb infrared energy. The key to understanding how it does this is a concept called *resonance*.

Imagine you are pushing your friend on a swing. If you want to get your friend to swing as high as possible, you need to time your pushes just right. If the swing goes back and forth once every second, you must push at a frequency of once per second. You must also give the push at just the right instant, when the swing is just about to go forward.

The right pushing speed required to transfer energy from one system (you) to another (the swinger) is called the *resonant frequency*. The following activity illustrates how resonant frequency is important when light energy interacts with molecules in the atmosphere.

QUESTION 4.1.

What could you do to change the resonant frequency of the swing system so the person will go back and forth faster?



Investigation

Why Do Some Molecules Absorb Infrared Energy?

A fascinating aspect of resonant frequency is that you can feel it. When you're pushing someone on a swing, you know when you have found the resonant frequency because you can feel your energy being transferred to the swing and the person on it. Each time you push, you can see the swing go higher and higher and higher.

Gas molecules in the atmosphere resonate when they are struck by a vibrating photon of light, but the molecules are so small, it is impossible for us to feel their resonant frequencies. In this investigation you will experiment with models of molecules that are millions of times larger than the real ones. You will use these models to see what happens when they are energized with different frequencies of vibration.

The models represent four different kinds of molecules found in the atmosphere: nitrogen, oxygen, carbon dioxide, and methane. The vibrations you will produce with your hands represent different frequencies of light.

Molecules are systems composed of different kinds of atoms connected by bonds. Many different kinds of materials can be used to create models of molecules, but not all of them will allow you to experiment with resonance.

Materials

- Strips of springy plastic, thin flexible rods, or long stiff springs to represent flexible molecular bonds. (Wooden materials such as Tinker toys or toothpicks are not flexible enough, so don't use them.)
- Styrofoam balls, rubber balls, or nuts and bolts to represent the atoms.
- Clock or watch with a second hand.

Experimental Procedure

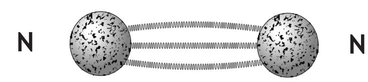
Using the materials make a model of nitrogen, oxygen, carbon dioxide, and methane (see next page). Test each model to determine its resonant frequency. For example, hold the carbon dioxide molecule by the central carbon atom and shake it up and down a few inches. Try a range of shaking speeds, or *frequencies*, from very slow (one shake per second) to very fast (seven or eight shakes per second).

See if you can find a frequency at which it is much easier to keep the model vibrating. It may dance around in a rhythmic way. If it does, it has absorbed the particular frequency of energy that you put into it. This frequency is called the *resonant frequency*.

Use the clock to time your shaking. Measure the resonant frequency by counting the number of vibrations in a five-second interval while your model is "dancing." Divide by five. Do as many trials as you need until you are convinced you have measured the resonant frequency of each model or until you are convinced you cannot find one.

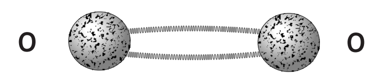
Nitrogen

Nitrogen makes up 78% of the atmosphere. Molecules of nitrogen gas are composed of two atoms of nitrogen (N) connected by a strong (short) triple bond.



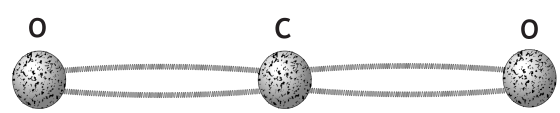
Oxygen

Oxygen makes up about 20% of the atmosphere. Molecules of oxygen gas are composed of two atoms of oxygen (O) connected by a strong (short) double bond.



Carbon Dioxide

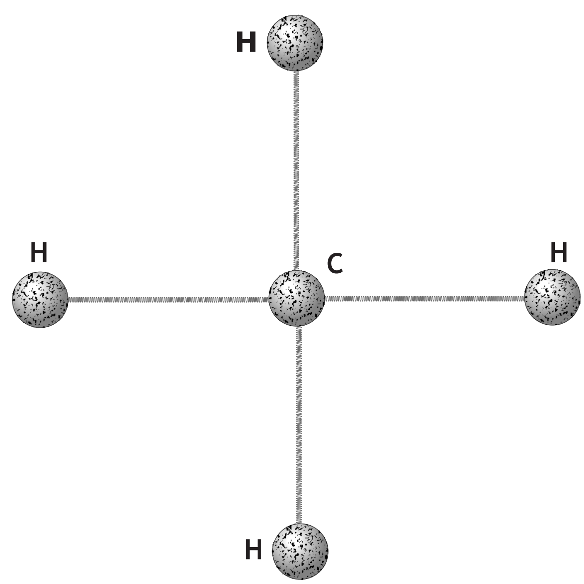
Carbon dioxide accounts for less than one percent of the atmosphere, but it makes a very important contribution to the greenhouse effect. Carbon dioxide molecules are composed of an atom of carbon (C) in the center, connected to two atoms of oxygen (O) with a weak (long) double bond.



Methane

For this experiment, all the atoms can be placed in a flat plane, as though they are lying on a table.

There is even less methane in the atmosphere than carbon dioxide, but it also makes a very important contribution to the greenhouse effect. Methane molecules are composed of a single carbon atom (C) in the middle, surrounded by four atoms of hydrogen (H), at equal distances, connected by weak (long) single bonds.



QUESTIONS

4.2 Which of the four molecules has the fastest resonant frequency?

Which has the slowest?

Which seem to have no resonant frequency?

4.3 If there are differences in resonant frequencies, why do you think they are different?

4.4 The behavior of these models are analogies to the behavior of real molecules of carbon dioxide, methane, oxygen, and nitrogen. From the observations of your models and their interactions with different frequencies of vibration, why do some gases in the atmosphere absorb infrared radiation while others don't?