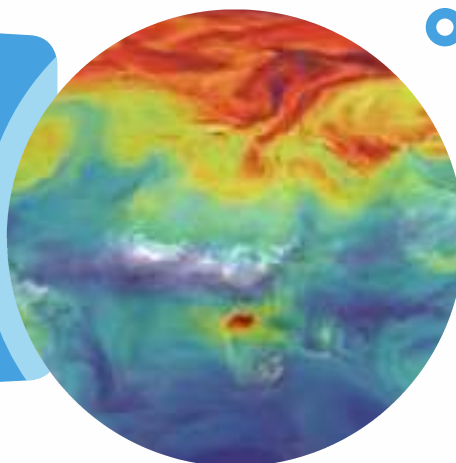


## 10. Absorbing heat

Using carbon dioxide to demonstrate how the greenhouse effect works



### Overview

A temperature difference can be detected when viewing a heat source through air versus carbon dioxide, demonstrating how carbon dioxide can absorb infrared radiation.

### What's happening?

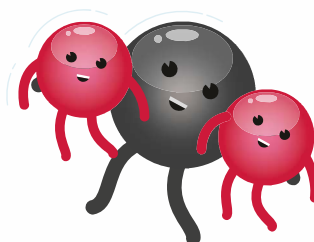
By placing balloons filled with carbon dioxide and air between a heat source and infrared camera, the amount of infrared radiation absorbed can be compared. Carbon dioxide is considered as a 'greenhouse gas' which means it can trap and re-emit infrared radiation (IR, also known as thermal radiation). This is due to the carbon-oxygen bonds and the way in which the molecule can vibrate, absorbing IR radiation at two different wavelengths.

### Why is this important?

The greenhouse effect is often discussed as a negative impact of human activity. It is actually a natural occurrence which is essential for life on earth. Radiation from the sun (ultra-violet, infrared and visible) can be absorbed by the surface of the earth, heating it. The surface

can emit this stored energy in the form of infra-red radiation and can be absorbed by certain molecules in the atmosphere. Some of this energy can be converted into heating the atmosphere by the vibrations of the bonds in these molecules, the rest is re-emitted in all directions with some again being absorbed by the surface of the earth, raising its temperature. Without this continuous process, the average surface temperature of the earth would be around  $-15\text{ }^{\circ}\text{C}$  and life as we know it would not exist.

However, concentrations of carbon dioxide, methane and nitrous oxide are now higher than the highest concentrations recorded in ice cores during the past 800,000 years. Despite water vapour being the largest natural contributor to the greenhouse effect, the rapid increase of anthropogenic greenhouse gases has led to dramatically increasing global temperatures with the largest contributor being the increase in atmospheric carbon dioxide since 1750.



## More stories to tell

### Where is anthropogenic carbon dioxide coming from?

Human activities which contribute most to increasing carbon dioxide concentrations include burning fossil fuels for transportation, for energy production, manufacture of industrial materials such as cement and food production. Deforestation is also a main contributor to greater atmospheric carbon dioxide, responsible for up to 15% of global greenhouse gas emissions. Burning the trees to clear forests releases carbon dioxide and the change in land use reduces the amount of carbon dioxide taken from the atmosphere by photosynthesis alongside changing the way in which carbon can be stored in the soil.

### How does carbon dioxide absorb heat?

Certain bonds in molecules can absorb thermal radiation and different bonds absorb IR at different wavelengths. An oxygen-hydrogen bond (O-H) could absorb IR at 3125 nm and a carbon-oxygen bond (C-O) could absorb IR at 9523 nm. This identifying of bonds and molecules from IR absorptions is known as infrared spectroscopy and is one of chemistry's fundamental analytical techniques.

For something to be able to absorb IR it needs the energy absorbed to change its charge distribution (dipole moment). For the example of a molecule of oxygen (two oxygen atoms double bonded, O<sub>2</sub>) if the atoms move further and closer together along their bond, there is no change in charge distribution, the molecule is still symmetrical. Therefore O<sub>2</sub> cannot absorb IR.

Carbon dioxide (CO<sub>2</sub>) can vibrate in four different ways:

1. Symmetric stretch (O atoms move towards and away from C at an equal amount).
2. Bend in y (the C atom moves up and down the y axis while the O atoms go in the opposite direction).
3. Bend in z (the C atom moves up backwards and forwards in the z axis while the O atoms go in the opposite direction).
4. Asymmetric stretch (the C atom vibrates towards and away from alternating O atoms).

The symmetric stretch does not change the charge distribution of the molecule, but the other three do and so these vibrations are IR absorbing. As the bends in y and z are the same vibration (just in different directions) CO<sub>2</sub> absorbs IR radiation at two different wavelengths and contributes to global warming where O<sub>2</sub> does not.

## The Activity

### Before the show:

1. Set up an IR camera.
2. Turn on the USB cup warmer and ensure it is in a position that can be seen by IR camera.

### During the show:

1. Switch to the IR camera on the projector screen.

**2.** Blow up a balloon of the same material as the one used for CO<sub>2</sub> and capture using a hand pump. Try to make sure they are both the same size.

**3.** Hold the air-filled balloon between the IR camera and USB cup warmer and identify the temperature detected by the camera.

**4.** Repeat with the CO<sub>2</sub> containing balloon captured from the diet coke and mentos activity in 'Capturing carbon dioxide'.

**5.** Demonstrate a small but visible difference in the readings due to IR absorption of the carbon dioxide inside the balloon.

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Try this experiment with different heat sources and different gases if you have access to them. Most common diatomic gases should be IR invisible but gases such as methane will also absorb IR radiation.

## Troubleshooting

**1.** See the IR camera guide section of the handbook if you encounter technical issues.

**2.** Not all IR cameras are sensitive enough to get a meaningful difference in readings. It is therefore recommended that you test this experiment with your equipment to ensure you are comfortable with the optimal set up.

## Health and Safety



Every delivery centre must undertake their own risk assessments for the specific audiences, locations and conditions they are presenting in. Sample assessments are available on The Secret World of Gases website. Below is a guide to the key risks and hazards:

**1.** Care should be taken when inflating balloons to protect eyes from popping balloons.

## SECRET GAS FACT

**On a global scale**, the amount of carbon dioxide in the atmosphere changes depending on the season because of the variation in the amount of land and vegetation cover between the Northern and Southern hemispheres.

