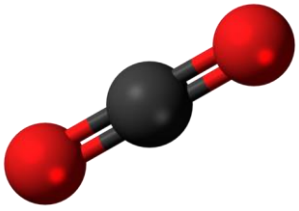
WHY IS CARBON DIOXIDE A GREENHOUSE GAS?

A greenhouse gas is a substance that contributes to the warming of the atmosphere by absorbing infrared radiation. There are several such substances, including methane (CH_4) and water vapour (H_2O) but carbon dioxide (CO_2) is particularly important because it persists in the atmosphere for hundreds of years.

CO_2 molecules strongly absorb infrared radiation[1] at a wavelength of 4260 nanometres[2]. But why do they do this?

When molecules that consist of two or more atoms absorb energy, one thing they do is vibrate more rapidly. The laws governing atomic physics (quantum mechanics) prescribe that when a molecule vibrates faster, it must jump from one energy level to a higher energy level. It cannot absorb any arbitrary amount of energy - it has to absorb energy of a particular wavelength.

Now the CO_2 molecule comprises three atoms joined together like this:



When it absorbs energy, this molecule can respond in different ways, including *stretching* or *bending* with more energy. It can stretch *symmetrically* (both bonds getting slightly longer at the same time, followed by getting shorter at the same time) or *asymmetrically*, (one bond getting longer while the other gets shorter, and then reversing).

As it happens, it's this asymmetric stretch[3] which absorbs energy at a wavelength of 4260 nanometres and thus creates the greenhouse properties of CO_2.

Another term for infrared energy is radiant heat. Thus, CO_2 is an absorber of radiant heat. The more of it there is, the more radiant heat is absorbed or trapped after it is reflected back from the earth. This additional absorbed energy is shared with the neighbouring molecules through molecular collisions. These molecules become more energetic and faster moving. This is another way of saying that they get hotter.

To sum up: it's the asymmetric stretch of CO_2 that is a key source of atmospheric warming, and the more CO_2 there is, the more pronounced that effect becomes. Since about 1800 (and much more rapidly since about 1970) the atmospheric concentration of CO_2 has been rising because of the burning of fossil fuels, to meet the rapidly expanding energy needs of a rapidly expanding human population. Result: global warming and climate change.

[This discussion was prepared by Warwick Cathro of 350 Canberra, who is responsible for any errors or omissions].

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[1] Infrared energy ranges in wavelength from 700 to one million nanometres

[2] A nanometre is a billionth of a metre

[3] This is due to fluctuations in the “dipole moment” of the molecule as it vibrates. Think of the “dipole moment” as an arrow pointing from the negatively charged end of the molecule towards the positively charged end. Because the stretch is asymmetric, the dipole moment changes as the bonds expand and contract, causing the molecule to interact with infrared radiation.