5. How does the Greenhouse Effect work?

The Greenhouse Effect, climate change and global warming were not in the curriculum when we were at school. We now all use the term Greenhouse Effect to explain why the planet is getting warmer although it is a bit more complicated than the simple greenhouse analogy. ***The basic physics of the 'Greenhouse Effect', which explains how more CO_2 in the atmosphere leads to warming, has been known since the mid-nineteenth century***

Naturally occurring greenhouse gases, water vapour, carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) normally trap some of the sun's heat, keeping the planet from freezing. Without these naturally occurring greenhouse gases (GHG), the Earth's average temperature would be near to -18°C instead of the much warmer average of 15°C.

The enhanced greenhouse effect is produced by the burning of fossil fuels, deforestation and intensive farming, which are increasing greenhouse gas levels. These prevent the escape of infrared energy (IR) into space leading to an enhanced greenhouse effect resulting in global warming and unprecedented rates of climate change.

Man-made GHGs are the Chlorofluorocarbons (CFCs), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), Sulphur Hexafluoride (SF_6) and Nitrogen Trifluoride.

GHGs differ in the time they remain in the atmosphere and in their global warming potential relative to CO_2.

Key Characteristics of Greenhouse Gases			
Natural Greenhouse Gases	Chemical formula	Global Warming Potential	Atmospheric Lifetime (years)
Carbon Dioxide	CO_2	1	5-200
Methane	CH_4	25	12
Nitrous Oxide	N_2O	298	114
Man-made Greenhouse Gases			
Hydofluorocarbon-23 (HFC-23)	CHF_3	14,800	270
Perfluorocarbon (PFC-14)	CF_4	6000-7400	50,000
Sulphur Hexafluoride	SF_6	22,800	3,200
Nitrogen Trifluoride	NF_3	17,200	740
Chlorofluorocarbon-12 (CFC-12)	CCl_2F_2	10,900	100

These values are from the Fourth IPCC Assessment Report (AR4) released in 2007 and Fifth Assessment Report (AR5) updating them in 2014. CFCs are not controlled under the Kyoto protocol but under the 1987 Montreal agreement.

Greenhouse gas molecules can absorb energy from IR radiation, and it is this ability to absorb and re-emit IR energy which makes them effective heat-trapping gases. Any gases with three or more atoms are potential greenhouse gases. Nitrogen (N_2) and oxygen (O_2), which make up 99% of Earth's atmosphere only contain two atoms and do not absorb IR photons.

A photon of infrared energy causes the GHG molecule to vibrate. After a time, the molecule gives up this extra energy by emitting another IR photon. This can be in any direction and may pass back to Earth up into

space or to another similar GHG molecule. Once the extra energy has been removed by the emitted photon, the molecule stops vibrating. The type of vibration is determined by the wavelength of the photon of IR energy.

Solar radiation reaching the Earth covers the wavelengths of the electromagnetic spectrum from the ultraviolet (UV) through the visible spectrum to the far IR. The heat energy leaving the earth is in the mid and far IR range. Those gases in the atmosphere which have absorption spectra within this range will absorb some of this energy. Ozone absorbs much of the incoming UV radiation, hence the concern when the hole in the ozone layer was discovered in 1985.

Infrared absorption spectra

Ozone absorbs IR emissions leaving the earth at a wavelength between 9 and 10 microns

Carbon dioxide absorbs IR in three narrow bands at 2.7, 4.3 and 15 microns

Methane has two small wavelength regions in which it absorbs strongly at about 3.5 and 8 microns,

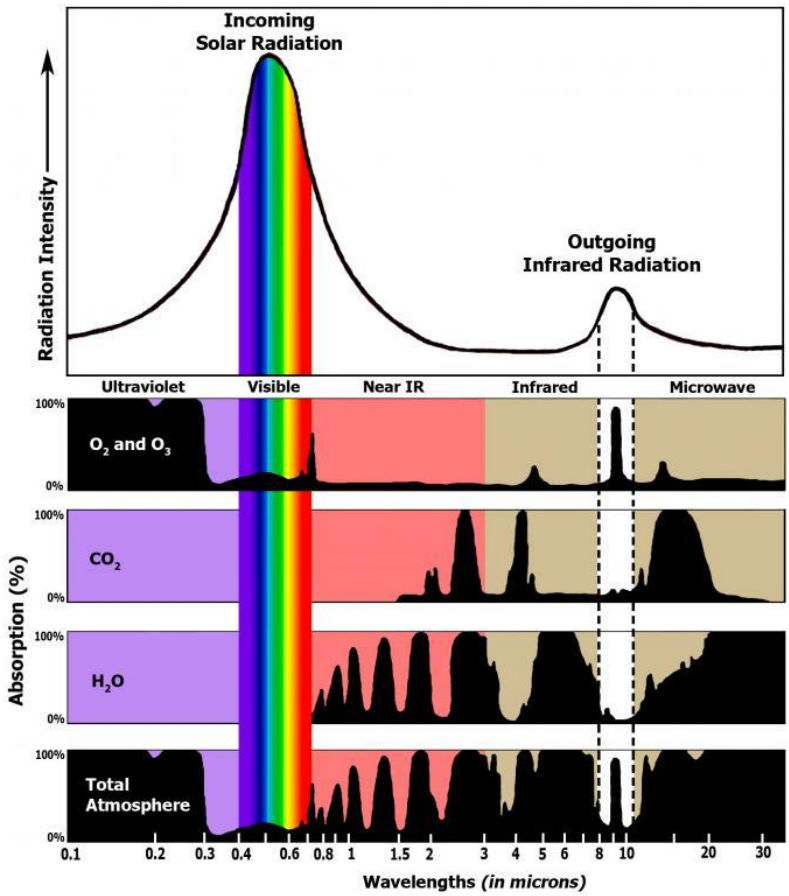
Nitrous oxide, N_2O, has absorption peaks at about 5 and 8 microns,

Water vapour is the strongest greenhouse gas absorbing IR in several regions in the IR spectra. Its concentration is largely controlled by the temperature of the atmosphere.

The atmospheric window is a gap in the spectrum at a wavelength of 10um. It is close to the ozone absorption spectra.

Most IR leaving the earth does so through the atmospheric window at 10um close to the ozone IR absorption spectra.

If you want to get a clearer idea and a bit more detail, the Nasa Climate Science investigations website is a good place to start.



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