Activity 5 – The Effect of Greenhouse Gases

What effect do greenhouse gases have on the Earth's temperature?

Klimawandel verstehen und handeln
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Part 1: Can CO2 "intercept" invisible infrared radiation?

Switch on the infrared radiator. As the emitter heats up, read the background text carefully and match the parts of the experiment with their equivalents in reality:

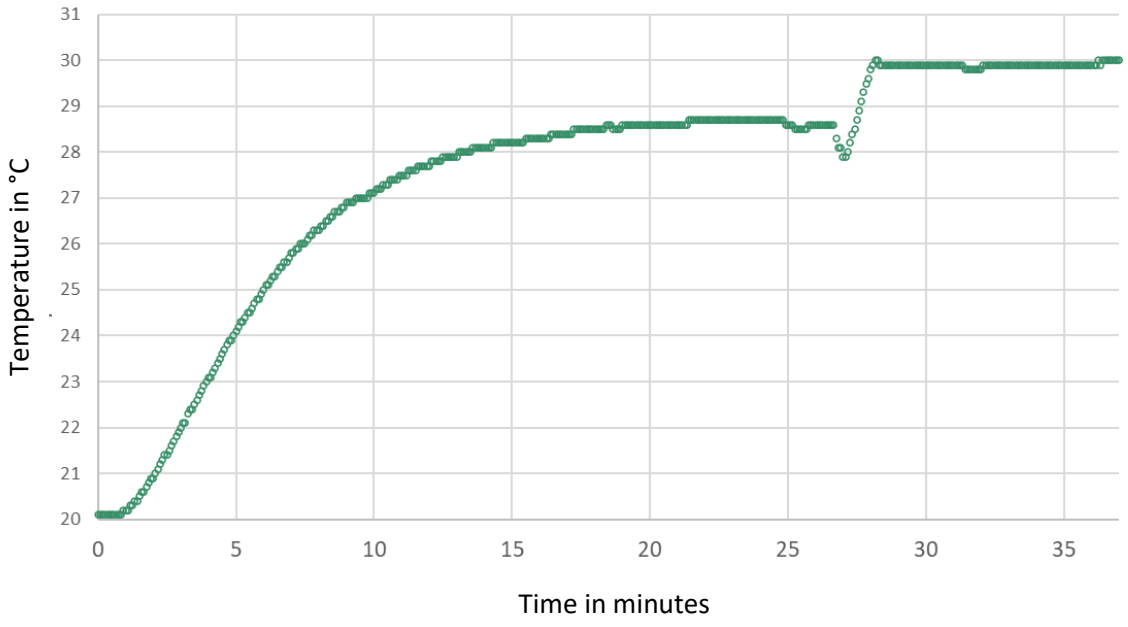
Air in the can	Additional greenhouse gases
Ceramic infrared radiators	*Earth's atmosphere with normal CO_2 concentration*
CO_2 produced in the Erlenmeyer flask	Earth soil

Implementation:

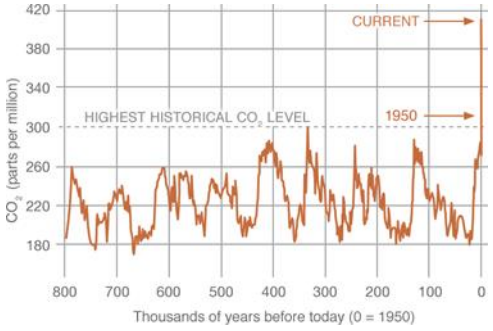
→ Wait until the temperature in the can no longer changes in a time frame of 30 seconds and you can as-sume that the equilibrium temperature has been reached (in the range between 30°C and 40°C). Write this down!

Shown below is a sample measurement with
equilibrium temperature without CO_2: 28,8°C
equilibrium temperature with CO_2: 29,6°C

The temperature rises by 0,8°C!



? The CO2 concentration in the atmosphere is measured in parts per million (ppm). It thus indicates how many molecules of CO2 one million molecules of dry air contain. Search the Internet for "NASA CO2" and search for the current CO2 concentration in the atmosphere. Also compare with the historical values of the last 800,000 years in the figure there.



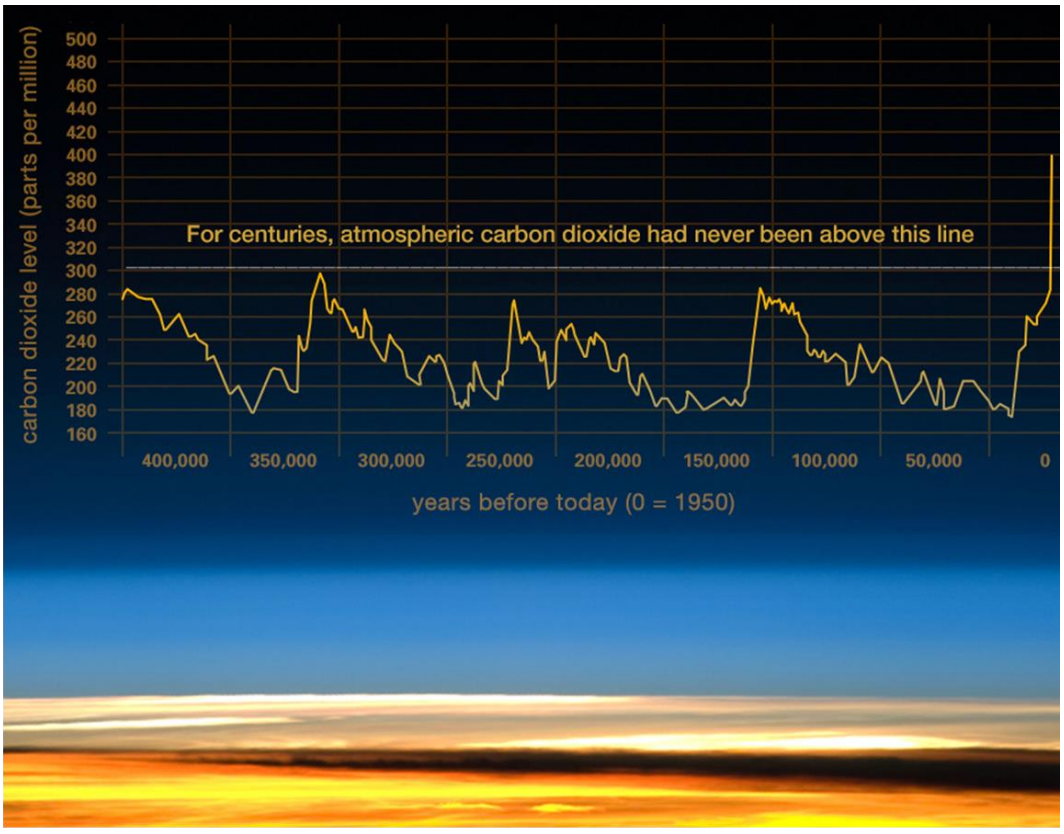
Quelle: NASA

The CO2 concentration in the atmosphere has increased by almost 50% in the last 200 years - from about 0.0280% to 0.0416% today.

(NASA, February 2021).

Periodic fluctuations can be seen in the historical values, with periods of higher CO2 concentration alternating with periods of lower CO2 concentration.

However, the trend in CO2 concentration over the last century is highly abnormal and not comparable to the fluctuations of the last 800,000 years! We have had an extremely strong and rapid increase of CO2 in the atmosphere since the 19th century. The current concentration is as high as never before!



Quelle: climate.nasa.gov/evidence/

? What has led to the observed greenhouse gas concentration since the 19th century? How is the exper-iment related to these data? Summarise your findings in two sentences.

Since the 19th century or with the beginning of the industrial revolution, humanity emits enormous amounts of CO2 through machines like cars! Many technologies that humans have developed are based, among other things, on fossil fuels or coal, with one product being CO2, which is emitted so that we can use electricity, for example.

Since CO2 in the atmosphere increases the greenhouse effect and thus causes the temperature of the planet to rise (reminder: radiative equilibrium), it is very easy to see that humans are directly responsible for global warming or climate change.

„The Fastest Time on Record“, Foto von 1893, Quelle: Wikimedia

Karl Eduard Biermann 1847
Quelle: Preußen Kunst und Architektur, Wikimedia (11.02.2020)

Part 2: Infrared radiation is intercepted

In addition to measuring the temperature in the can, the radiation that passes through the can can be measured (transmission).

Implementation:

→ Wait until the temperature remains constant (as above) and then observe the temperature reading (and visible image, if applicable) of the thermal imaging camera as CO2 is poured into the cardboard tube.

After filling with CO2, the image on the thermal imaging camera changes, the observed zone becomes somewhat darker or the temperature to be read off decreases somewhat after approximately 5 min. Approx. 0.6°C lower.

The same process is shown more spectacularly in the following video:

https://www.youtube.com/watch?v=SeYfl45X1wo

Task:

→ Interpret the result! Note that a thermal imaging camera calculates the temperature of an object using the emitted thermal radiation (see Activity 4 - Stefan-Boltzmann law).

The heat radiation now no longer reaches the thermal imaging camera unhindered. The CO2 absorbs the energy from the heat radiation and releases it evenly in both directions (to the lamp and to the camera). Thus, not all of the heat radiation from the lamp reaches the camera, the image becomes darker and the temperature is lower (Stefan-Boltzmann: lower radiation → lower temperature).

Basically an aspect of the greenhouse effect on earth was simulated here:
The lamp emits heat radiation (representing the earth); towards the thermal imager (representing space). The tube with the CO2 (representing the atmosphere) absorbs this however and radiates again. a part back.

Part 3: Why do greenhouse gases in the atmosphere heat up the Earth's surface?

Implementation:

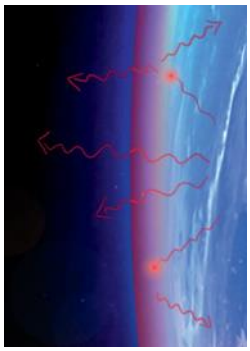
→ The Petri dish out of glass in the following experiment acts like a very dense greenhouse gas atmosphere that absorbs almost all the infrared radiation from the Earth's surface (infrared radiator). Observe the infrared radiator from the front with the thermal imaging camera, first without the glass plate and then push the glass plate in between with the help of wooden clip (left picture). Observe for about one minute and then write down your observations.

Without the glass plate, a bright red to white image is seen on the camera where the emitter is. With the glass plate in between, this changes rapidly, the image becomes darker and the temperature is also sharply reduced where the emitter is. After some time, however, the temperature increases again somewhat.

The glass plate absorbs the heat radiation of the radiator and radiates heat radiation again. Over time, it absorbs more energy from the radiator.

→ Now look (directly afterwards) at the glass plate from the surface of the Earth (right picture). The effect observed here in the model experiment is a further crucial element in understanding the greenhouse effect. Explain it by putting the sentence blocks in the right order:

1. *The greenhouse gas CO2 absorbs the heat radiation emitted from the Earth.*
2. *It is heated up by absorbing radiant energy.*
3. *The heated gas itself now radiates infrared radiation in all directions, including towards the Earth.*
4. *This additional source of radiation heats up the Earth's surface.*



Rückstrahlung von IR-Strahlung durch die Atmosphäre