B2 Greenhouse effect in a drinking cup – A model for illustrating climate change

1 Preparation for the subexperiments

1.1 Apparatus and materials

- Aluminum foil, roll
- Artificial light source (optional)
- 1 coaster
- 1 digital thermometer
- 1 nail (steel, “iron”)
- 1 pair of scissors
- Paper, black, DIN A4
- 1 plastic cup (clear), 500 ml
- 1 test tube clamp, wooden

Attention: After you have completed the experiment, return the materials or dispose of them properly as instructed by your teacher.

1.2 Safety information

The materials may be used only as instructed by your teacher or as described in the experimentation instructions.

1.3 Conducting the experiment

Measure the ambient temperature in the sun and in the shade.
For all subsequent experiments, you must make sure that the external conditions are the same:

- Shade, clouds, drafts, temperature of the cup at the start of the experiment (write it down).
- The thermometer should always be in the same position inside the cup and not touch the surface of the cup.
- If the thermometer turns off (battery-saving feature), simply turn it back on by pushing the “on” button again.
- The light must also always be shining through the cup on the same side and at the same intensity.

Note: During all measurements, be sure to avoid touching the thermometer’s probe, since otherwise the measurement will be inaccurate.

You must keep a log on a separate piece of paper for each subexperiment.

- Note the starting and ending temperatures and the resulting temperature difference.
- Briefly describe the experiment setup and execution (sketch, key words) so that an important detail doesn’t get “lost” in the activities. You will need these notes later for the analysis.

You will have approx. 10 minutes for each subexperiment.

2 Conducting the subexperiments

2.1 What influence does it have on the temperature if the cup is closed? – Measurements in an open cup

- Place the cup in the sun or in the cone of light from the light source so that the inside of the cup is illuminated. If you use a lamp, you must keep the angle of incidence and the distance from the lamp to the cup constant for all four subexperiments (you can use the ruler to measure the distance).
- Lay the test tube clamp across the cup and insert the thermometer's probe through it such that it nearly reaches the bottom of the cup. (It must not touch the bottom!)
- Observe the temperature inside the cup as it rises.
- Note the temperature when it basically stops rising (after approx. 5 to 10 minutes).

Fig. 1: Measurement in an open cup.

2.2 What influence does it have on the temperature if the cup is closed? – Measurements in a closed cup

- Remove the cup briefly from the source of light and let it cool down. The cup should be at the same starting temperature for the subsequent measurements as it was at the start of subexperiment 1.
- If nobody has conducted subexperiment 2 yet, take the coaster and make a small (!) hole in the middle using a nail so that the thermometer's probe just fits in the hole without falling through. Then place the coaster on the cup. Push the thermometer's probe through the coaster until it is just above the bottom again. When you place the cup in the light cone, make sure that the coaster does not block the light, in other words, that it does not shade the inside of the cup.
- Repeat the measurements from subexperiment 1. Measure the final temperature after the same amount of time as for subexperiment 1 and record it.

Fig. 2: Measurement in a closed cup.

2.3 What influence does the color of the absorber have? – Measurements in a closed cup with a black absorber

- If nobody has conducted subexperiment 3 yet, cut out a piece of the black paper (absorber) so that it lines half the inside of the cup.
  Also cut out a circle for the bottom of the cup.
- Place the cup in the sun or in the cone of light from the light source so that the black paper is illuminated.
- Then place the coaster with the thermometer on top of the cup.
- Observe the temperature inside the cup as it rises.
- Note the temperature when it basically stops rising (after approx. 5 to 10 minutes).

Fig. 3: Measurement with a black paper absorber.

2.4 What influence does the color of the absorber have? – Measurements in a closed cup with an aluminum foil absorber

- If nobody has conducted subexperiment 3 yet, cut out a piece of the aluminum foil so that it lines half the inside of the cup. Also cut out a circle for the bottom of the cup.
- Place the cup in the sun or in the cone of light from the light source so that the aluminum foil is illuminated.
- Then place the coaster with the thermometer on top of the cup.
- Observe the temperature inside the cup as it rises.
- Note the highest temperature (after approx. 5 to 10 minutes).

Fig. 4: Measurement with an aluminum foil absorber.

3 Observation

Write down a summary of your observations.

4 Analysis

a) Compare the temperature rises observed in the different subexperiments.
   Are you sure that the differences in the temperature rises were not due to different external conditions? Discuss this with your classmates.
b) During each subexperiment, light transports energy into the cup. Describe how the radiant energy is absorbed in the cup and how it is emitted again. When you formulate your response, use the technical terms absorption, reflection, heat transfer, convection, and emission of radiation.

5 Questions

a) What influence do the so-called greenhouse gases (e.g., water vapor as humidity or the fine droplets of water in the clouds, CO_2, methane, and nitrous oxides) have on the emission of the solar energy absorbed by the Earth back into space in the form of long-wave infrared radiation?
b) What are the differences between natural influences and influences caused by humans (anthropogenic influences)?

To answer the questions, in addition to the results of your measurements you can also use Fig. 5 and the explanation below:

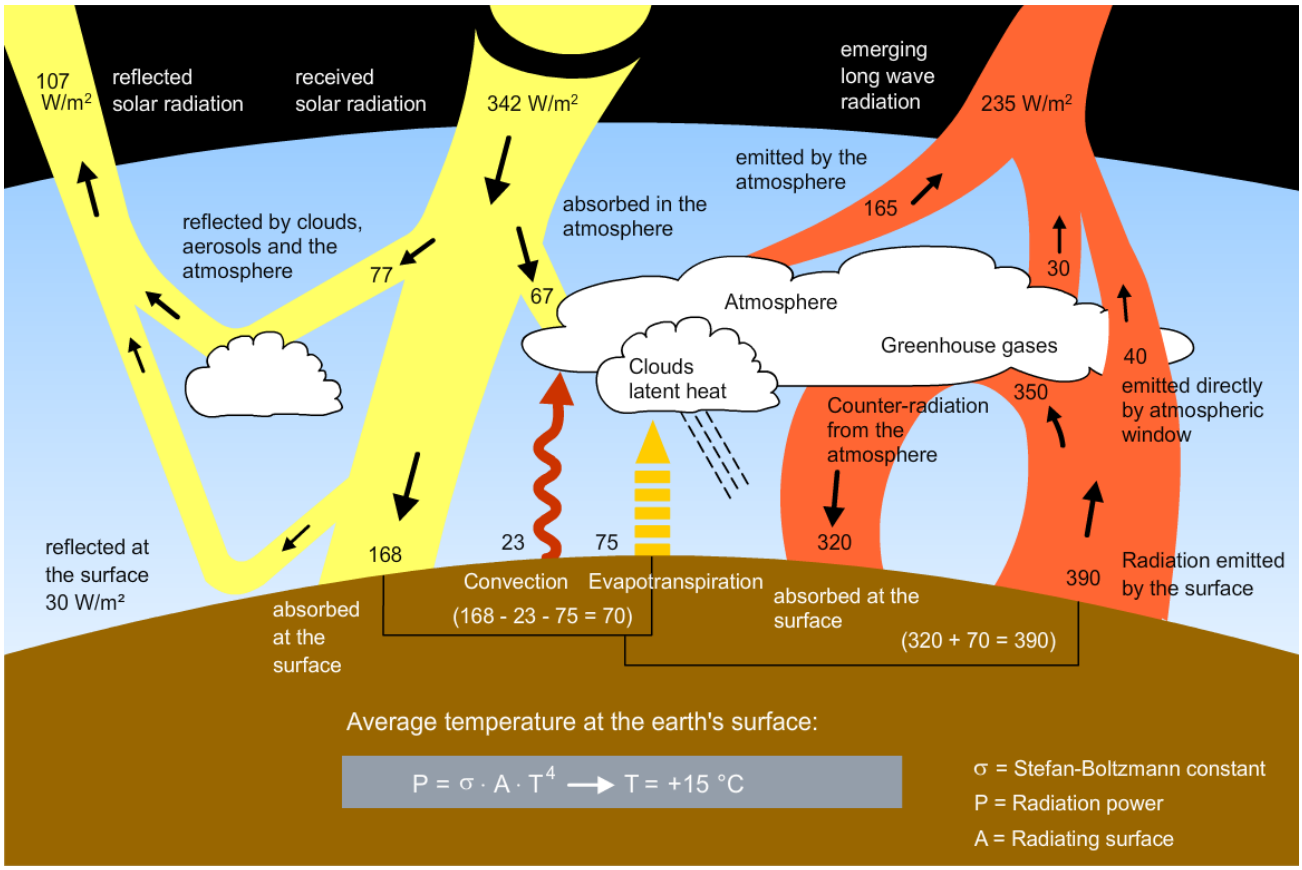

Fig. 5: The natural greenhouse effect.

Explanation: The Earth's surface is warmed by solar radiation and emits the absorbed energy primarily as heat radiation. This is because air has very low thermal conductivity and the distance from the Earth's surface to the surface where the atmosphere meets space is very long (approx. 100 km). The stratification of the atmosphere also prevents heat dissipation beyond the cloud cover through convection.