350 CANBERRA AND THE AUSTRALIAN ASSOCIATION FOR ENVIRONMENTAL EDUCATION

GREENHOUSE GAS DEMONSTRATION, 2019

Background

The effect of carbon dioxide on the atmosphere has been studied experimentally since 1856, when Eunice Foote compared the warming of two flasks, one filled with "carbonic acid gas", when they were simply placed in direct sunlight.[1]

In recent years a number of "greenhouse gas demonstrations" have been featured on YouTube[2]. Each involves the warming of two flasks (sometimes partly filled with water) using a heat lamp, and the measurement of their temperatures using digital thermometers. Carbon dioxide is first introduced into one flask, for example by using a substance containing sodium bicarbonate. The presence of CO_2 causes that flask to warm noticeably more than the control flask, due to the absorption of infrared radiation by the CO_2 molecules.

Experiment design

During 2019 our group (Canberra citizens with affiliations to 350 Canberra and the Australian Association for Environmental Education) sought to reproduce these experiments. After several trial runs we settled on the following apparatus and conditions.

- We purchased two "DeltaTrak" digital thermometers from Instrument Choice, calibrated them using the recommended ice bath method, and checked them in warm water (at about 50 C) to ensure that they agreed within 0.1 C
- To avoid any bias caused by the absorption of energy when sodium bicarbonate is added to water, we omitted these chemicals and instead used a few pellets of dry ice in the active flask and waited for the pellets to vaporise and for the two flasks to reach the same temperature
- To avoid any bias caused by a pressure difference between the two flasks, a small hole was drilled in the stopper of each flask (in addition to the hole that accommodates the thermometer). This allows the carbon dioxide in the active flask to escape slowly, but it ensures that both flasks remain at atmospheric pressure
- To avoid any bias caused by the positioning or angle of the heat lamp, with the potential for different amounts of infrared radiation to impact on each flask, we placed the two flasks at opposite ends of a clear storage container mounted on a music turntable, and rotated the turntable while the 275 watt heat lamp was switched on.

The photos below show the basic apparatus:

[1] Eunice Foote. Circumstances affecting the heat of the sun's rays. The American Journal of Science and Arts, November 1856, page 383. https://archive.org/stream/mobot31753002152491#page/383/mode/2up

[2] Including the Alka Seltzer experiment [https://www.youtube.com/watch?v=kwtt51gvaJQ] , the Dry ice experiment [https://www.youtube.com/watch?v=gxyPh5XoVJo] and the Bicarb with vinegar experiment [https://www.youtube.com/watch?v=f2qAd1sEsBA].

Public demonstration and results

The experiment was featured at Science Week 2019, and was run several times at the “Shine Dome”, Australian Academy of Science, on 10 August 2019. Members of the public were engaged in discussion about the experiment, and were also recruited to assist by (for example) calling out the stopwatch times. The thermometer readings were keyed into a spreadsheet which built a graph of the temperature difference between the flasks over time. Typical run times were 20 to 30 minutes.

An accompanying spreadsheet shows a typical result. While the active flask (the one containing carbon dioxide) usually warmed less than the control flask in the first couple of minutes, it consistently overtook the control flask and remained warmer by 1.0 to 1.5 degrees Celsius for more than 20 minutes. The initial slower warming is ascribed to partial lack of equilibrium in the flask after the vaporisation of the dry ice pellets appeared to be complete.

Further demonstrations

It is planned to conduct some more experimental runs in outdoor locations during the Australian summer months in early 2020. These experiments will dispense with the heat lamp and the turntable and will rely simply on the infrared radiation from the sun, as in the original Eunice Foote experiments.