National Aeronautics and Space Administration

Educational Product	
Educators & Students	Grades 5–12

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Educational Brief

CASSINI SCIENCE INVESTIGATION

Venus: A Global Greenhouse

Objective

To take temperature measurements in closed systems over time to demonstrate "greenhouse warming," which is observed in greenhouses and in planetary atmospheres like those of Venus, Saturn's moon Titan, and possibly Earth's.

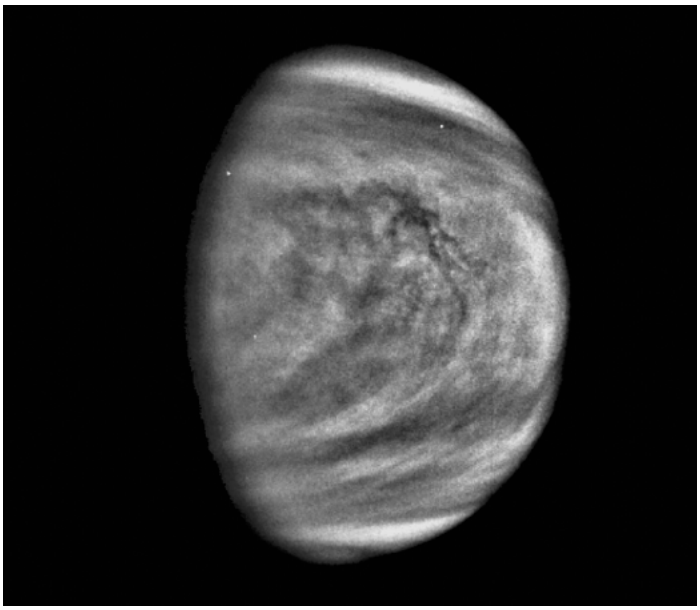
Time Required: 2–3 hours

Saturn System Analogy: Titan

Keywords: Equilibrium, Greenhouse, Titan, Venus

MATERIALS

- Bottles of different colors (similar size and shape) with labels attached. *Glass bottles are recommended to ensure the apparatus remains stable.*
- Bottle caps or corks to seal each bottle
- Thermometers (one per bottle, plus one extra)
- Notepaper for recording data
- Graph paper for plotting data
- Stiff cardboard (small pieces)



Venus as seen by the Galileo spacecraft. A special filter was applied to emphasize the contrasts in the clouds.

Discussion

Nearly everyone has heard about the "greenhouse effect," the natural process by which infrared energy (heat) is trapped in the atmosphere. The primary greenhouse gases are water (H_2O) vapor, carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4). The heat trapped by atmospheric greenhouse gases can raise the average surface temperature of Earth by 35 kelvins (degrees Celsius).

Venus presents an extreme example of the greenhouse effect. The greenhouse gas carbon dioxide is the most abundant chemical (96 percent) in the Venusian atmosphere. The large

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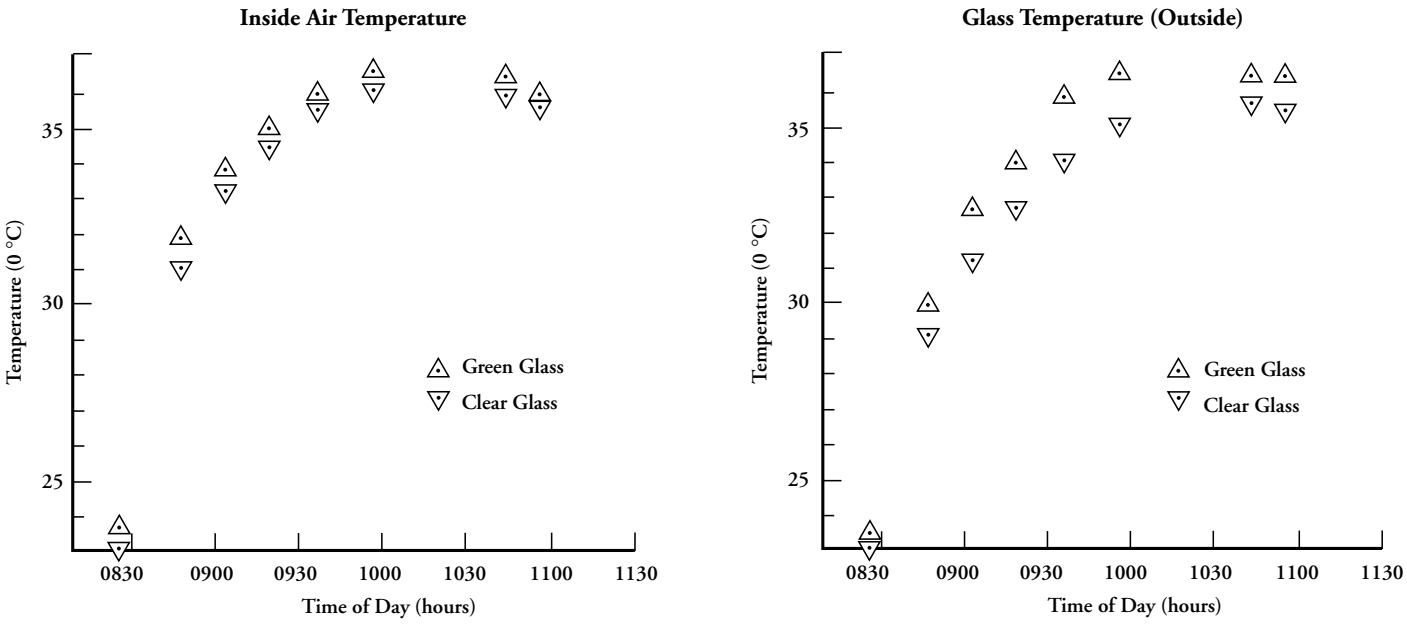

Examples of "greenhouse bottle" plots.

quantity of carbon dioxide helps boost the average surface temperature of Venus to more than 450 ºC (over 900 ºF). In contrast, the atmosphere of Titan, Saturn's largest moon, warms the surface just a few degrees higher than if there were no atmosphere at all.

A simulated greenhouse effect can be demonstrated using common household materials.

Procedure

Prior to the experiment, drill the bottle caps (or corks) to snugly hold the thermometers; there should be some freedom to change the thermometer depth in the bottle. The extra thermometer should be suspended, out of contact with anything but air, and shaded with the cardboard.

Insert the thermometers into the bottle caps (or corks), and then cap each bottle. Place the bottles together in sunlight, either upright or on their sides (prevent them from rolling), and determine that they will not cast shadows on one another over the course of the experiment. Also, ensure the labels will shade the thermometer bulbs for several hours. (If a bulb is exposed to direct sunlight, a false reading may result.) Place the open air thermometer alongside the bottles, also ensuring the bulb remains in the shade. Record the temperatures of each thermometer at regular intervals every 10–15 minutes for at least 2 hours. After collecting the data, plot the temperatures versus the recorded times and interpret the results.

You could do this experiment over a couple of class periods with the first class setting up and starting the experiment and the second class continuing to record the data. After combining the data, both classes can plot the temperature versus the time and interpret these data.

Scientific Note

"Greenhouse effect" is really a misnomer for atmospheric heating by gases. A greenhouse for growing flowers or vegetables on Earth is heated by sunlight falling on the vegetation, which warms up and heats the air trapped in the enclosure. This same process warms the air in the demonstration bottles. A planetary atmosphere is warmed by the absorption of infrared photons by molecules of the atmospheric gases.

Additional Experiments and Questions

1. Why do some bottles warm the air inside faster than other bottles? Do they reach the same equilibrium temperatures?
2. Do the internal temperatures behave differently if the bottles are open to the outside air?
3. What happens if a few drops of water are placed in the bottles?
4. What happens if dry ice sublimates and displaces the air in a bottle? (Don't seal until the dry ice is gone!)

Extension

Several vendors offer temperature sensors and software that allow data to be acquired, recorded, and plotted under computer control. Many spacecraft acquire all their data via computer control, and computerized data acquisition is common in many laboratories on Earth.

Science Standards

A visit to the URL http://www.mcrel.org yielded the following standards and included benchmarks that may be applicable to this activity.

9. Understands the sources and properties of energy.

LEVEL 1 (GRADES K–2)

Knows that the Sun supplies heat and light to Earth.

Knows that heat can be produced in many ways (e.g., burning, rubbing, mixing substances together).

LEVEL 2 (GRADES 3–5)

Knows that heat is often produced as a by-product when one form of energy is converted to another form (e.g., when machines and living organisms convert stored energy to motion).

LEVEL 3 (GRADES 6–8)

Knows that heat energy flows from warmer objects to cooler ones through conduction, convection, and radiation.

Knows how the Sun acts as a major source of energy for changes on Earth's surface (i.e., the Sun loses energy by emitting light; some of this light is transferred to Earth in a range of wavelengths, including visible light, infrared radiation, and ultraviolet radiation).

LEVEL 4 (GRADES 9–12)

Knows how the energy associated with individual atoms and molecules can be used to identify the substances they comprise; each kind of atom or molecule can gain or lose energy only in particular discrete amounts, and thus can absorb and emit light only at wavelengths corresponding to these amounts.

12. Understands the nature of scientific inquiry.

LEVEL 1 (GRADES K–2)

Knows that learning can come from careful observations and simple experiments.

Knows that tools (e.g., thermometers, magnifiers, rulers, balances) can be used to gather information and extend the senses.

LEVEL 2 (GRADES 3–5)

Plans and conducts simple investigations (e.g., formulates a testable question, makes systematic observations, develops logical conclusions).

Uses appropriate tools and simple equipment (e.g., thermometers, magnifiers, microscopes, calculators, graduated cylinders) to gather scientific data and extend the senses.

LEVEL 3 (GRADES 6–8)

Establishes relationships based on evidence and logical argument (e.g., provides causes for effects).

Teachers — Please take a moment to evaluate this product at http://ehb2.gsfc.nasa.gov/edcats/educational_brief.
Your evaluation and suggestions are vital to continually improving NASA educational materials. Thank you.

Student Worksheet — Venus: A Global Greenhouse

Procedure

1. Insert thermometers into bottle caps.
2. Place bottle caps with thermometers on bottles.
3. Place bottles together in sunlight (be sure that no bottles are shaded and that they are spaced far enough apart so that they won't shade each other over a 2-hour period).
4. Be sure that the thermometer bulbs (inside the bottles) are shaded by the bottle labels.
5. Place the open air thermometer in a shaded location (use cardboard) next to the bottles.
6. Record the temperature of each bottle as well as the shaded thermometer every 10–15 minutes for at least 2 hours.
7. After collecting data, plot temperature versus time for your "greenhouse bottles."

Time at start of experiment: _____

Describe your bottles (color and volume):

Bottle #1: _____

Bottle #2: _____

Bottle #3: _____

Time	Temperature – Open Air	Temperature – Bottle #1	Temperature – Bottle #2	Temperature – Bottle #3