Goldilocks and the Three Planets

Middle and High School Grades

Lesson Summary

Students determine what some of Earth, Venus, and Mars' atmosphere is composed of and then mathematically compare the amount of the greenhouse gas, CO_2, on the planets Venus, Earth, and Mars in order to determine which has the most. Students brainstorm to figure out what things, along with greenhouse gases, can affect a planet's temperature.

Prior Knowledge & Skills

- Experience interpreting data
- Visible light represents only a small portion of all light
- General understanding of energy
- Pre-Algebra or Algebra

AAAS Science Benchmarks

The Nature of Science
The Scientific World View
Scientific Inquiry
The Nature of Mathematics
Mathematics, Science, and Technology
Mathematical Inquiry
The Nature of Technology
Technology and Science
The Physical Setting
The Earth
The Mathematical World
Symbolic Relationships

NSES Science Standards

Science as Inquiry: Understandings about Scientific Inquiry

Earth and Space Science: Energy in the Earth System

NCTM Mathematics Standards

- **Algebra:** Represent and analyze mathematical situations and structures using algebraic symbols

Colorado State Standards

- Mathematics Standards 1.4, 2.2, 2.5
- Science Standard 4, 5

Suggested background reading

Light
Greenhouse Effect

Teaching Time: One to Two 50-minute periods

Materials

Each student needs:
Copy of student directions
Calculator

Advanced Planning

Preparation Time: 10 minutes

1. Print copies of the student instructions.

Why Do We Care?

One reason we care is because Earth is the only planet that has life that we know of in our solar system. Some planets are too cold and some are too hot. Understanding the reasons behind the temperature differences in our solar system is the key to understanding the conditions that make a planet habitable.

LASP
LABORATORY FOR ATMOSPHERIC AND SPACE PHYSICS
UNIVERSITY OF COLORADO AT BOULDER

Goldilocks and the Three Planets

Grade Level __ (8-10)

Activity Dependency "Using Spectral Data to Explore Saturn and Titan" activity

Group Size 1-2 students

Expendable Cost per Group $0.30

Engineering Connection

In this activity, students compare data taken from spacecraft instrumentation that was designed by engineers to gather data about the atmospheres of planets.

Pre-Requisite Knowledge

Students should have a basic understanding of mathematical comparisons.
Students should be somewhat familiar with algebraic expressions. Students should have some experience with hypothesis.
Students should be comfortable sharing ideas with peers.

Learning Objectives

After this lesson, students should be able to:

- Explain how a mathematical comparison is done
- Constructively argue why inner planets have different temperatures
- Explain how data is a useful tool when creating a theory
- Explain why engineers create tools to collect data

Introduction / Motivation

You've probably heard about the greenhouse effect and global warming, but did you know that if the Earth had no greenhouse gasses, our planet would be colder? Greenhouse gasses act as a blanket that keep us warm because they trap some warm radiation from the Sun. Too much of a good thing can be really bad, though. If we have too many greenhouse gasses in our atmosphere, we could warm the planet up too much. Some nearby planets, Venus and Mars, also have greenhouse gasses. You've heard the story of the three bears. This is the story of the three planets. Venus is much too hot, Mars is much too cold, and Earth is just right to support life. There is more to the story than you might initially think, though, and your job will be to figure out what other things (or variables) beside greenhouse gasses effect the temperature of the three planets.

Engineers built spectrographs for spacecraft that traveled to the planets Venus and Mars. One of the goals was to find out what gasses make up their atmospheres. These spacecraft sent data back to Earth. The spectrographs found the spectra of Venus and Mars by looking at light from the two atmospheres that originally came from the Sun.

Goldilocks and the Three Planets

When you look at a spectrum taken from a spectrometer, you can figure out what is inside of that atmosphere because the dips and peaks in the graph match up to the known dips and peaks of gasses that scientists and engineers have measured in laboratories. You will be using actual data from spacecraft and data taken in a laboratory today to figure out what is inside the atmospheres of Venus, Mars, and Earth.

Vocabulary / Definitions

Incandescent light bulb	A standard light bulb found in most households
Spectrum (plural: spectra)	The pattern light produces as can be seen through a spectrograph
Spectrograph (also Spectroscope)	A tool that allows the components of light to be seen easily with the eye.
Diffraction	When light bends, as through a prism or diffraction grating.
Diffraction Grating	Usually a piece of film designed to act like a prism.

Procedure:

Background

See also background from the "Graphing the Rainbow" activity.

Note: *This lesson can be done as an online flash interactive instead of the paper and pencil version included here. If the appropriate computing speed and version of Flash is not available, an accompanying PowerPoint presentation as well as separate images and movies can be used to augment instruction. For the interactive and associated lesson material, visit the website:* http://lasp.colorado.edu/education/spectra

The greenhouse effect is actually not a bad thing. Greenhouse gasses on Earth, such as H_2O, methane, and CO_2, trap infrared radiation from the Sun that warm the Earth. This acts like a blanket, and Earth would be colder without it. Global warming is a concern in today's society because, as we pump man-made greenhouse gasses into the atmosphere, we trap more and more solar radiation and heat up the Earth.

There are greenhouse gasses on other planets and solar system bodies, too. In this lesson, the students will be looking at the amount of CO2 on Venus, Earth, and Mars. What they will discover is that Venus has the most CO2, Mars has the second greatest amount, and Earth has the least. What should be surprising is that Mars has more CO2 than Earth. Why, then, is Mars so much colder than Earth? Instead of looking at the planets as individual bodies to be studied and analyzed, the solar system must be looked at as a whole. Venus is much closer to the Sun than Earth, has a much thicker atmosphere and more greenhouse gas. CO2 is the most plentiful greenhouse gas in Venus' atmosphere, but it has others as well. Mars, on the other hand, has more CO2 than Earth, but is much farther away and has a very thin atmosphere all together. CO2 is the most plentiful greenhouse gas, but Mars has very little in its atmosphere and only small amounts of other greenhouse gasses. Mars is also much farther from the Sun than Earth. Earth has other greenhouse gasses aside from CO2, and the greenhouse gas that is most plentiful is H2O, water!

Goldilocks and the Three Planets

There is more going on in the solar system than is immediately apparent… Venus is too hot; it is close to the Sun and contains far more greenhouse gas. Mars is too cold; it is far from the Sun and has more CO2 than Earth, but far less of other gasses. Earth is just right; it not only has the perfect amount of greenhouse gas, but it is also just the right distance from the Sun to make life very happy.

Troubleshooting Tips

Students may need assistance with algebraic expressions.

Assessment

Pre-Lesson Assessment

Class Discussion: What kinds of data do spacecraft collect when they travel to other planets? What do engineers need to do to make sure data arrives on Earth? (ans. antenna, computer systems, computer chips, storage devices)

Post-Introduction Assessment

Think-Pair-Share: What are greenhouse gasses good for?

Post-Activity

Writing and illustration:
With a peer, have students create a travel guide explaining:

1. How far Venus or Mars is from the Sun
2. What the surface conditions are like
3. What equipment is needed for the journey and visit
4. Why a person might want to go to that planet

Activity Extensions

Complete the activity "Building a Fancy Spectrograph"

References

Pater, Imke. Lissauer, Jack. Planetary Sciences. New York, NY: Cambridge University Press, 2001.

Owner

Integrated Teaching and Learning Program and Laboratory, University of Colorado at Boulder

Contributors

Laboratory for Atmospheric and Space Physics, University of Colorado at Boulder

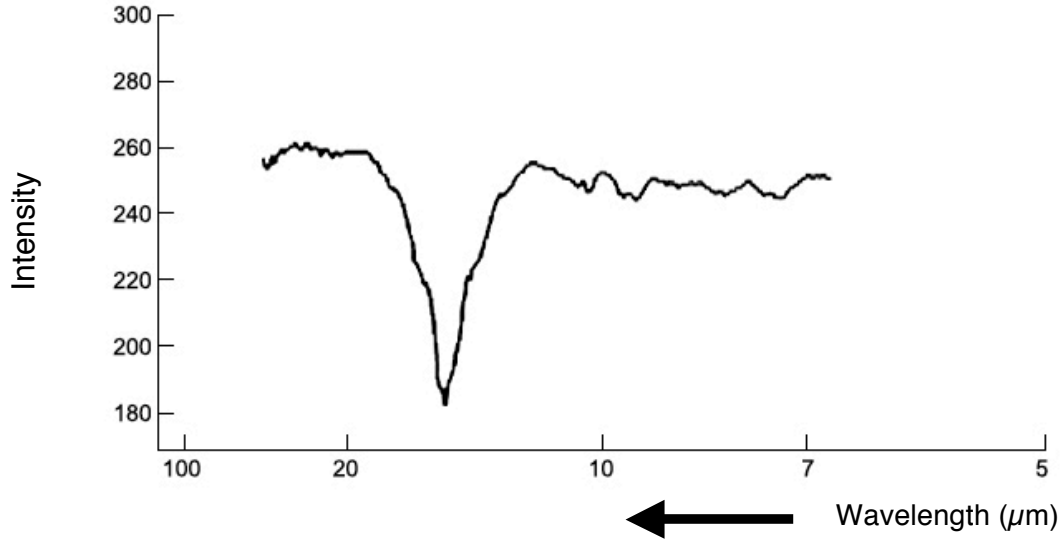
Goldilocks and the Three Planets

Student directions

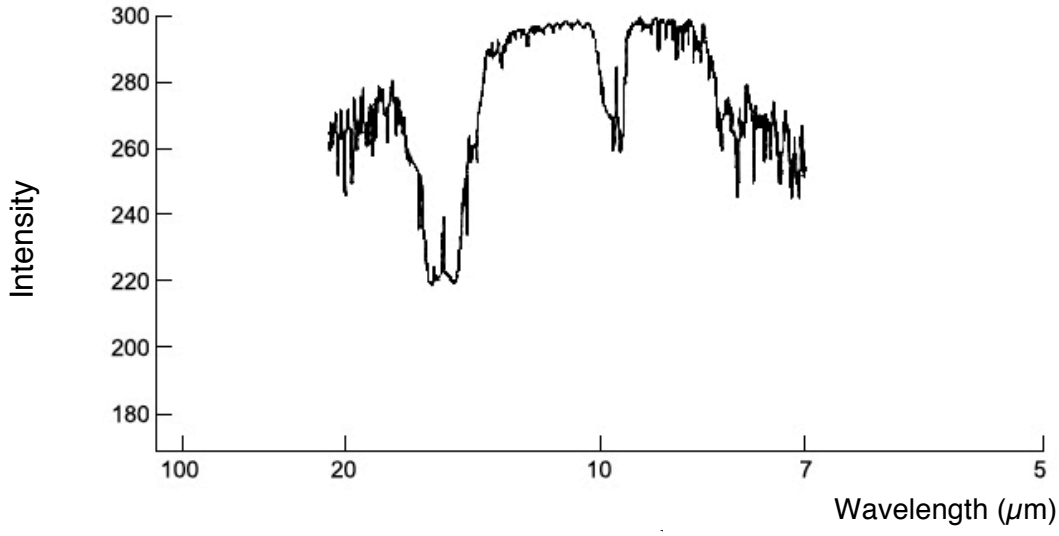
Part 1

First, let's compare the spectra of Venus and Earth. The spectrum of Venus was taken from the Venera 15 spacecraft with an instrument called the Infrared Fourier Spectrometer in the 1980s. The spectrum of Earth was taken by the Nimbus 4 spacecraft which orbited Earth in the 1970s. Compare the dips in the spectra with known elements on the following page. Be sure to look at the scale very carefully.

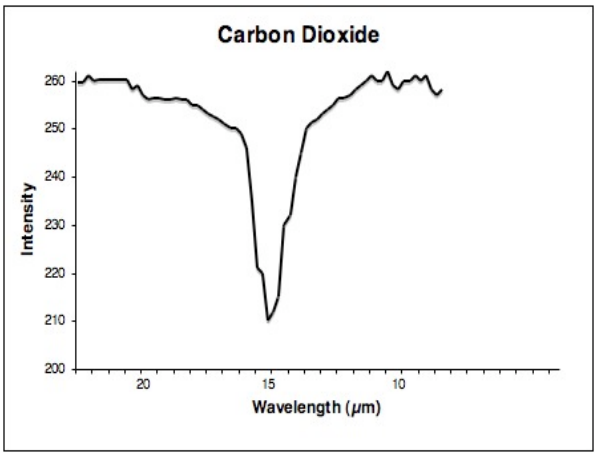
Venus

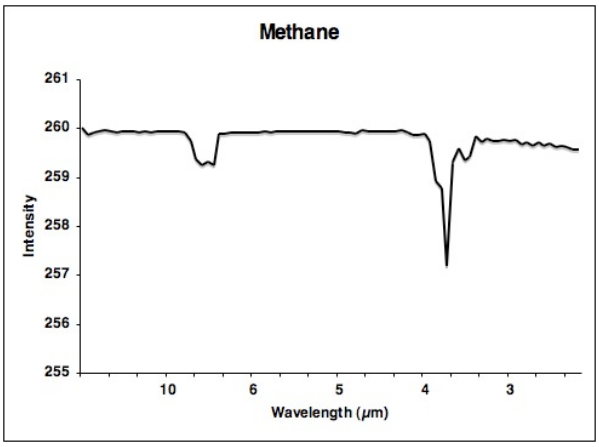


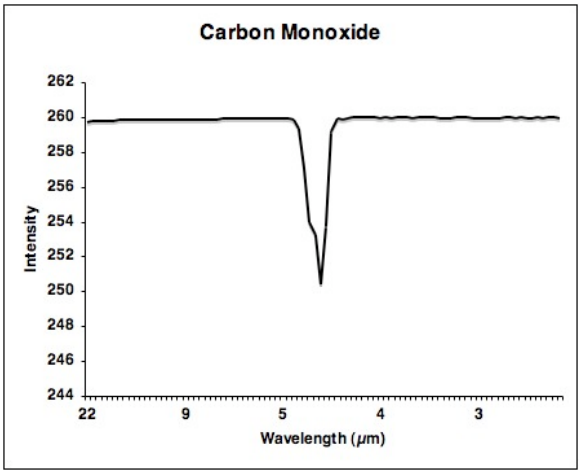
Earth

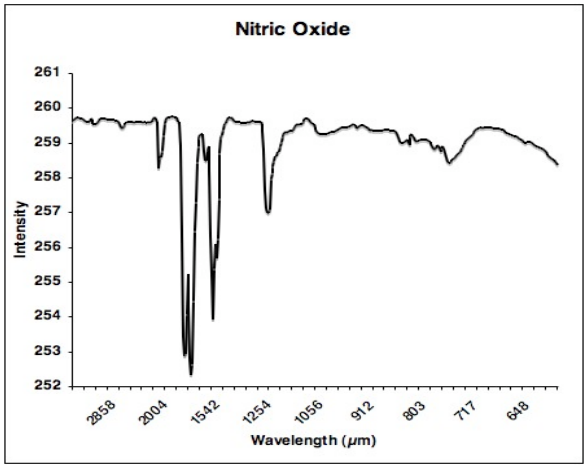


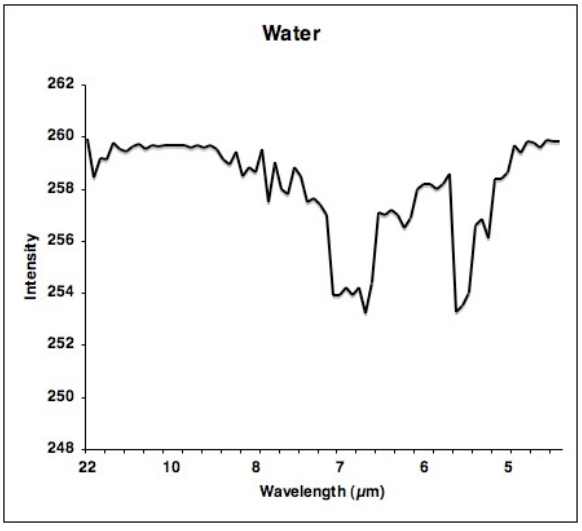
Goldilocks and the Three Planets

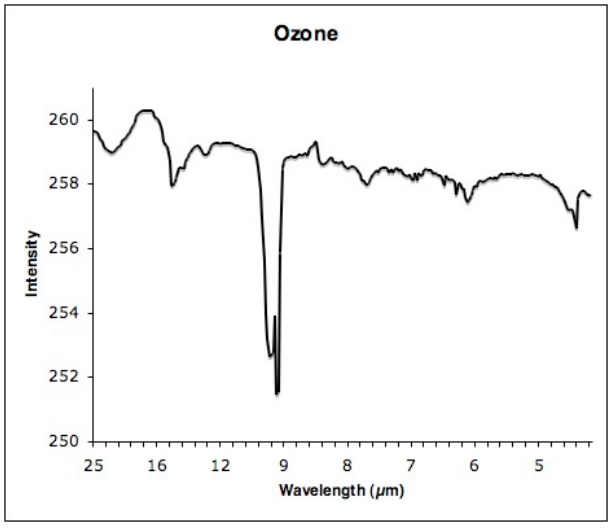












Goldilocks and the Three Planets

1. Which substances are definitely present in both Earth and Venus' spectra?

2. Which substances are definitely present in only Earth's spectrum?

3. Which substances could be present in Earth's spectrum, but it is difficult to say that they are definitely present? Why?

4. Carbon Dioxide, water, and methane are a few greenhouse gasses. Describe whether or not you see these gasses in the spectra of Venus and Earth.

Goldilocks and the Three Planets

5. Now, let's do some math! Venus has 90 times more atmosphere than Earth does. About 97% of the total mass of Venus' atmosphere is Carbon Dioxide, but only 0.04% of the total mass of Earth's atmosphere is Carbon Dioxide.
    a. Write an expression for the amount of Carbon Dioxide in the Earth's atmosphere using 'm_e' for the mass of Earth's atmosphere.

    b. Write an expression for the mass of Venus' atmosphere using 'm_e.'

    c. Write an expression for the amount of Carbon Dioxide in Venus' atmosphere using the expression from part b.

    d. Compare the amount of Carbon Dioxide in Venus' atmosphere to the amount in Earth's atmosphere by dividing the expression from part c by the expression from part a. Round your answer.

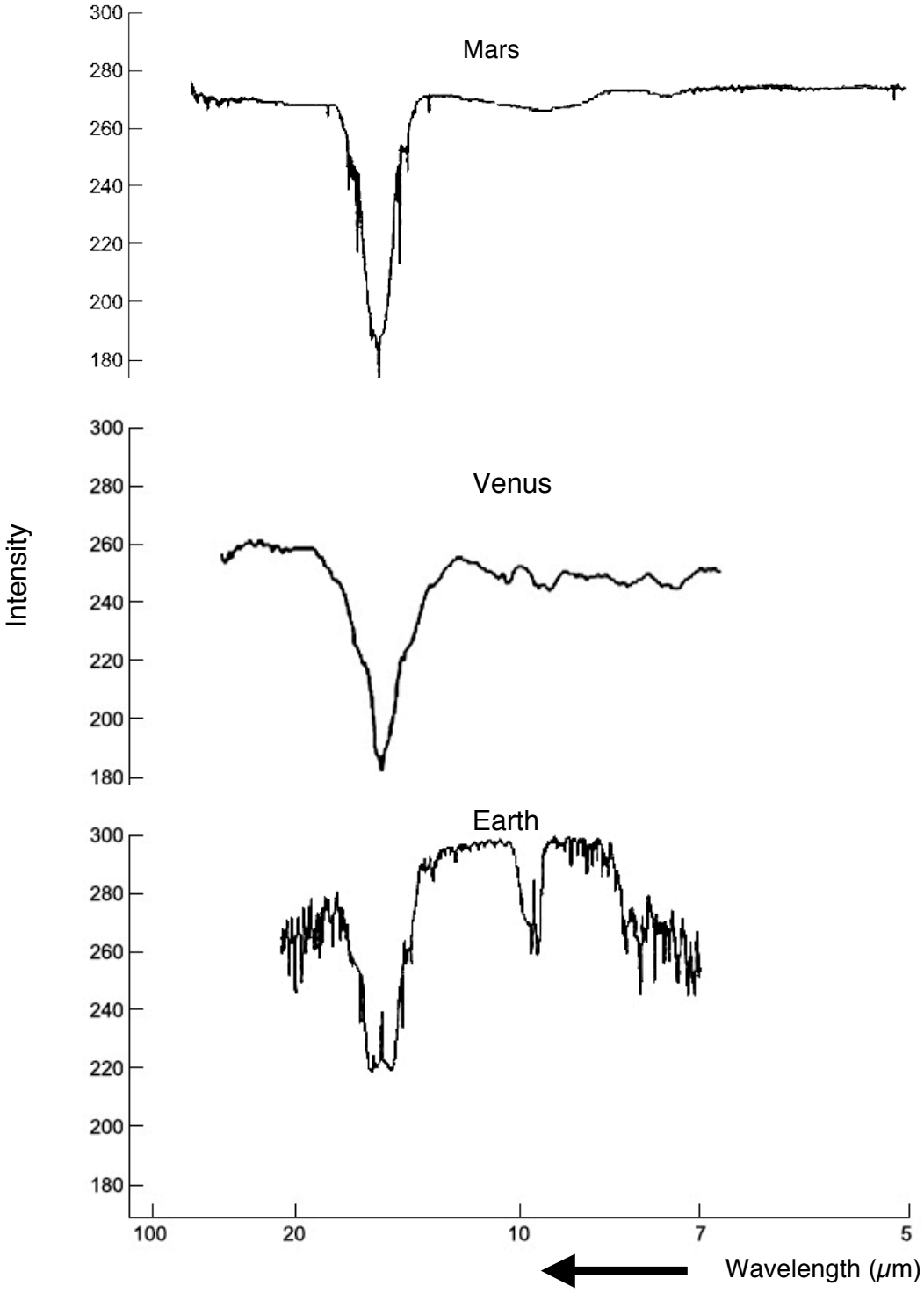
6. Using the value from part d above, fill in this blank: Venus has_____ times more Carbon Dioxide than Earth.

7. Venus is very very hot! It can get up to 900 ^{0}F at the surface, hot enough to melt lead!! What conjectures can you make about the cause of Venus' hot temperature?

Goldilocks and the Three Planets

Part 2

Now, let's look at the spectrum of Mars compared to Earth and Venus. The spectrum of Mars was taken by the Mariner 9 spacecraft in the 1970s.



Goldilocks and the Three Planets

Put an X in the table below with the substances you know are definitely present.

	Carbon Monoxide	Nitric Oxide	Methane	Water	Ozone	Carbon Dioxide
Venus						
Earth						
Mars						

1. Let's compare Mars and Earth. Mars' atmosphere is much thinner than Earth's, about 0.95% of Earth's atmosphere. About 95% of Mars' atmosphere is Carbon Dioxide. Remember, only 0.04% of the Earth's atmosphere is Carbon dioxide.

    a. Write an expression for the mass of Mars' atmosphere using 'm_e.'

    b. Write an expression for the amount of Carbon Dioxide in Mars' atmosphere using the expression from part a.

    c. Compare the amount of Carbon Dioxide in Mars' atmosphere to the amount in Earth's atmosphere by dividing the expression from part b by the expression from part a from part 1.

2. Using the value from part c above, fill in this blank: Mars has _____ times more Carbon Dioxide than Earth.

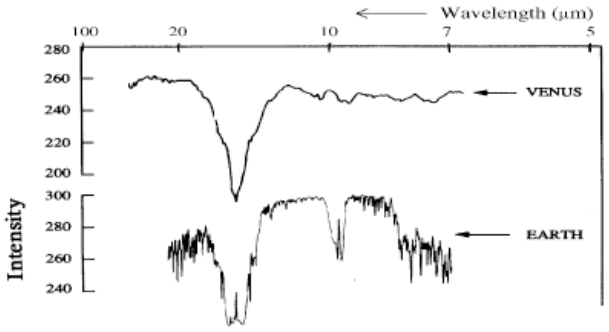
3. Even though Mars has more Carbon Dioxide than Earth, it has a much colder average surface temperature of about -70 ^{0}F. Clearly, Mars has more Carbon Dioxide than Earth, but much less than Venus. Why do you think Mars' temperature is so much lower than Earth's? What factors can affect a planet's temperature? Brainstorm with a peer.

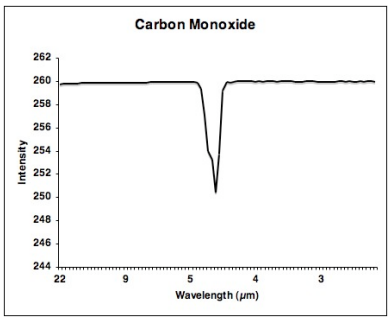
Goldilocks and the Three Planets

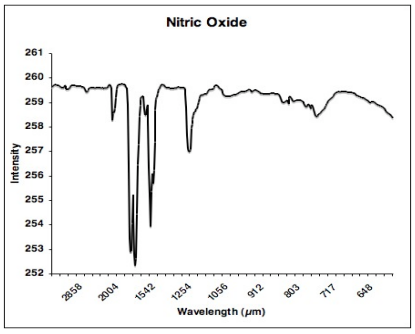
Teacher's Key: Goldilocks and the Three Planets

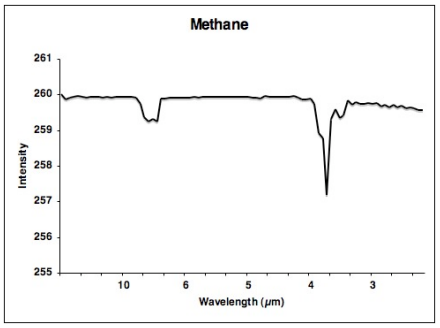
Part 1

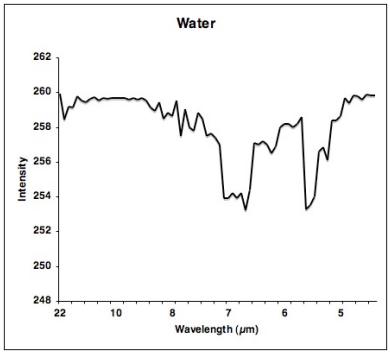
First, let's compare the spectra of Venus and Earth. The spectrum of Venus was taken from the Venera 15 spacecraft with an instrument called the Infrared Fourier Spectrometer in the 1980s. The spectrum of Earth was taken by the Nimbus 4 spacecraft which orbited Earth in the 1970s. Compare the dips in the spectra with known elements on the following page. Be sure to look at the scale very carefully.

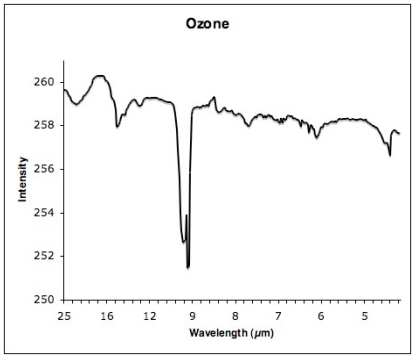


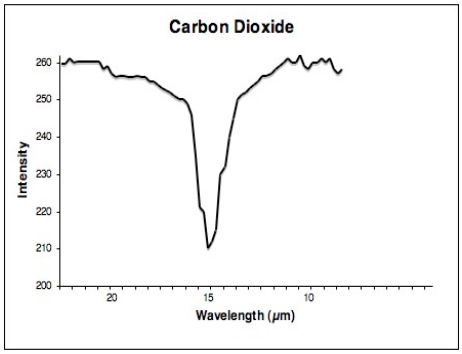












Goldilocks and the Three Planets

1. Which substances are definitely present in both Earth and Venus' spectra? *Ans: Carbon Dioxide is the only definite substance.*
2. Which substances are definitely present in only Earth's spectrum? *Ans: ozone and water are both present in Earth's spectrum. It is easier to see the ozone, so students may overlook the water (see next question).*
3. Which substances could be present in Earth's spectrum, but it is difficult to say that they are definitely present? Why? *Ans: Water may be present but it is difficult to tell because the wavelength range given for water is partially off of the plot for Earth. We cannot answer whether carbon monoxide or nitric oxide are present because we have not been given enough information. The scale given for these substances do not appear on the plot for Earth. Also, it is difficult to say for sure whether Methane appears in Earth's spectrum because the wavelength range given for methane is partially off of the plot for Earth, and the area where methane could be has quite a few dips and is very close to the end of the plot on the right side. Accept a variety of sensible answers.*
4. Carbon Dioxide, water, and methane are a few greenhouse gasses. Describe whether or not you see these gasses in the spectra of Venus and Earth. *Ans: We see carbon dioxide in both plots. We see water in Earth's spectrum.*
5. Now, let's do some math! Venus has 90 times more atmosphere than Earth does. About 97% of the total mass of Venus' atmosphere is Carbon Dioxide, but only about 0.04% of the total mass of Earth's atmosphere is Carbon Dioxide.
   a. Write an expression for the amount of Carbon Dioxide in the Earth's atmosphere using 'm_e' for the mass of Earth's atmosphere. *Ans: $0.0004m_e$*
   b. Write an expression for the mass of Venus' atmosphere using 'm_e.' *Ans: $90m_e$*
   c. Write an expression for the amount of Carbon Dioxide in Venus' atmosphere using the expression from part b. *Ans: $0.97 \times 90m_e$ simplified $87.3\ m_e$*
   d. Compare the amount of Carbon Dioxide in Venus' atmosphere to the amount in Earth's atmosphere by dividing the expression from part c by the expression from part a. Round your answer. Ans:

      $$\frac{87.3m_e}{0.0004m_e} = 218249.\overline{9}$$

      or 218,250

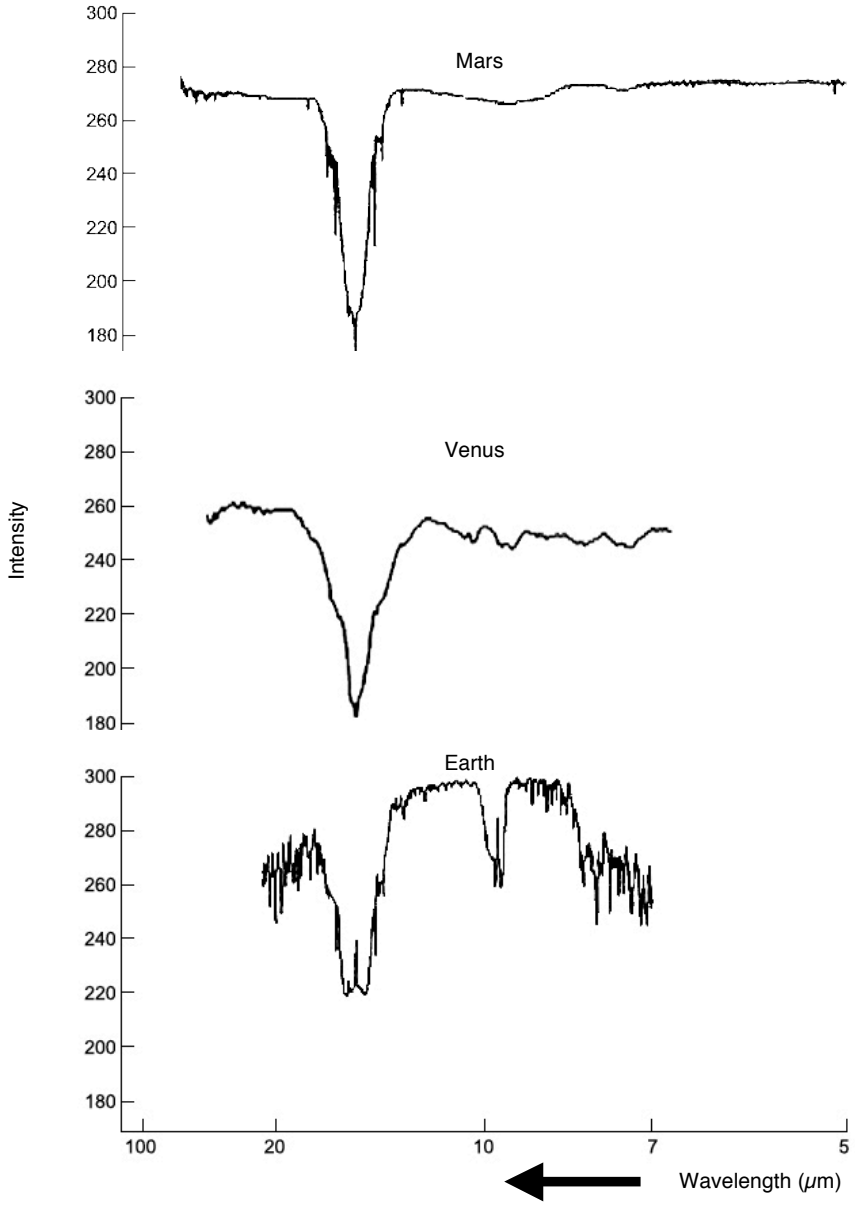
      Also acceptable (rounded): 220,000

6. Using the value from part d above, fill in this blank: Venus has_____ times more Carbon Dioxide than Earth. *Ans: 218,250 or about 220,000 times more Carbon Dioxide than Earth.*

7. Venus is very very hot! It can get up to 900 ^{0}F at the surface, hot enough to melt lead!! What conjectures can you make about the cause of Venus' hot temperature? *Ans: From the calculation, one speculation about Venus' temperature is that it has a very large amount of greenhouse gas that keeps it very hot.*

Part 2

Now, let's look at the spectrum of Mars compared to Earth and Venus. The spectrum of Mars was taken by the Mariner 9 spacecraft in the 1970s.



Goldilocks and the Three Planets

Put an X in the table below with the substances you know are definitely present.

	Carbon Monoxide	Nitric Oxide	Methane	Water	Ozone	Carbon Dioxide
Venus						x
Earth				x	x	x
Mars						x

1. Let's compare Mars and Earth. Mars' atmosphere is much thinner than Earth's, about 0.95% of Earth's atmosphere. About 95% of Mars' atmosphere is Carbon Dioxide. Remember, only 0.04% of the Earth's atmosphere is Carbon dioxide.
   a. Write an expression for the mass of Mars' atmosphere using 'm_e.' *Ans: 0.0095me*
   b. Write an expression for the amount of Carbon Dioxide in Mars' atmosphere using the expression from part a. Ans:

      0.95 x 0.0095me or 0.009025me
   c. Compare the amount of Carbon Dioxide in Mars' atmosphere to the amount in Earth's atmosphere by dividing the expression from part b by the expression from part a from part 1. Ans:

      $$\frac{0.009025m_e}{0.0004m_e} = 22.5625$$

      or

      23

2. Using the value from part c above, fill in this blank: Mars has _____ times more Carbon Dioxide than Earth. *Ans: 23*
3. Even though Mars has more Carbon Dioxide than Earth, it has a much colder average surface temperature of about -70 ^{0}F. Clearly, Mars has more Carbon Dioxide than Earth, but much less than Venus. Why do you think Mars' temperature is so much lower than Earth's? What factors can affect a planet's temperature? Brainstorm with a peer. *Ans: There are many factors that can affect a planet's temperature. Clearly, the amount of greenhouse gas is an important factor because Venus is so much warmer than Earth… but the distance from the Sun is also very important. Venus not only has more greenhouse gas, but it is also closer to the Sun than Earth. Mars has some more carbon dioxide, but is farther from the Sun than Earth. Mars also has much less atmosphere, and no water, which is also a greenhouse gas. Earth has water, so that contributes to Earth's greenhouse gasses. Since Earth is closer to the Sun and has other greenhouse gasses aside from carbon dioxide, it is warmer than Mars. Accept a variety of answers. Further research can be done on greenhouse gasses on the three planets and planetary temperature.*