Planet Designer: Martian Makeover!

Middle School Grades

Lesson Summary

Students learn about Mars past and present before exploring the pressure and greenhouse strength needed for Mars to have a watery surface as it had in the past.

Prior Knowledge & Skills

- Introductory understanding of the greenhouse effect
- Experience with variables
- Ability to use data tables
- Experience interpreting data to form arguments

AAAS Science Benchmarks

The Physical Setting

The Earth

NSES Science Standards

- **Science as Inquiry:** Abilities necessary to do scientific inquiry

Suggested background reading

MAVEN website:
http://lasp.colorado.edu/maven/

Teaching Time: One-to-two 50-minute periods

Materials

Each student will need:

- Copy of "The MAVEN Mission" article
- Copy of Student Directions
- Access to a computer with Flash
- Poster paper
- Markers or colored pencils
- Glue (optional)
- Scissors (optional)

Advanced Planning

Preparation Time: 30 minutes

- Before the activity, the following demonstration is recommended for explaining the pressure-temperature relationship of water: Exploratorium, Imagine Yourself on Mars, The Cold Boiling Water http://www.exploratorium.edu/mars/teachers/onmars.html
- Make copies of the student hand outs and instructions
- For homework, have students read the article, "The MAVEN Mission"
- For reference, pass back student work from, "Planet Designer: What's Trending Hot?"
- Prepare a computer room to run the Flash interactive (if Flash is supported) or download the executable file on each computer if Flash is not available. The interactive can be found here: http://lasp.colorado.edu/home/education/k-12/project-spectra/

Why Do We Care?

The Mars Atmospheric and Volatile EvolutioN (MAVEN) mission will collect data to help scientists understand Mars' atmospheric history to determine what happened to the flowing water.

Mars once had liquid water, maybe even oceans. How much water did it have? When in history did it have it? Was Mars ever habitable? These are hotly debated topics. If we can figure out when Mars had flowing water, and for how long it had it, we can establish whether Mars was once a habitable world. The MAVEN mission will fill in critical details in this planetary puzzle.

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Activity Dependency It is recommended for students to have completed the activity “Goldilocks and the Three Planets,” and “Planet Designer: What’s Trending Hot?”

Group Size 1-2
Expendable Cost per Group US$0.30

Engineering Connection (Adapted from Retro Planet Red For High School Grades)
Mars has evidence of liquid water flowing on the surface throughout its history. There are areas that look like dried up riverbeds, lakes, and even areas where it looked like oceans existed. At some point, around 3.8 billion years ago, a large part of Mars’ atmosphere went away, along with the flowing liquid water. The flowing liquid water is now either found frozen in the polar caps and below the surface, or it escaped as water vapor along with the rest of the atmosphere into space. The Imaging Ultraviolet Spectrometer (IUVS) instrument onboard the MAVEN mission is designed to measure the hydrogen escape rate in the atmosphere. Since the hydrogen that is escaping comes from water (H_2O) in the atmosphere, knowing how much hydrogen is escaping today will help us determine how much escaped throughout time and how much liquid water Mars had flowing on the surface in the past.

Learning Objectives
After this activity, students should be able to:

- Explain, in general terms, what atmospheric conditions (greenhouse strength, atmospheric thickness) Mars needs to maintain surface water.
- Explain, in general terms, how Mars is different today than it was in the past.
- Compare Mars past and present to Earth today.

Introduction / Motivation (Adapted from Martian Makeover! For High School Grades)
(See also Introduction / Motivation from “Planet Designer: What’s Trending Hot?”)

There is evidence water once flowed on the surface of Mars, and even more evidence that reservoirs of frozen water exist below the surface of the planet, but no direct evidence exists that water currently flows on the surface. And, how could it? The average surface temperature is roughly -50°C. The temperature can get up to 25 °C (depending on the season and latitude), (depending on the season and latitude), but the atmospheric (air) pressure (on the surface) of Mars is only 1/100 of Earth’s. Since the air pressure is so low, and temperatures so cold, if you dumped a glass of water onto the Martian surface it would either freeze or evaporate (See also: *Before the Activity* listed on title page). Mars wasn’t always this way, though. It’s thought to have once had a thick greenhouse atmosphere that kept the pressure and temperature of the planet much higher. Water probably flowed on the surface for millions of years, but at some point, around 3.6 to 3.8 billion years ago, Mars lost its atmosphere and liquid surface water. Lakes and rivers either froze solidly or evaporated to become water vapor in the atmosphere. Water that froze to the ground became covered in thick Martian dust and is now buried. A lot of the water vapor in the atmosphere escaped into space. The MAVEN mission will help us pin down exactly what happened to the atmosphere over time since we are missing some crucial pieces in the puzzle. We don't know exactly how much atmosphere Mars had in the past, how much of the atmosphere was greenhouse gas, or even how much water Mars once had. Although MAVEN will answer the question of where the water and greenhouse gas went, a single mission can only do so much, and MAVEN won't be able to tell exactly what the greenhouse gases on Mars were in the past. For that, we'll need more missions to the red planet for information about its atmosphere, and even possibly a mission to dig deep below the surface to give us an idea of what Mars was really like in the past.

Today, using a computer game, you will try to make Mars a watery world and find out what kind of atmosphere Mars would have needed to make that possible.

Procedure

Background (Adapted from: Retro Planet Red for High School Grades)

Using the basic model the students explored in the activity, "Planet Designer: What's Trending Hot?," students will estimate what temperature, atmospheric thickness, and greenhouse strength Mars would require in order to maintain liquid water on the surface.

All of Mars' problems began around 4.1 billion years ago when it lost its magnetic field. Mars cooled down in its early history, and convection of the molten metal in the interior stopped. Convection in the interior of a planet creates a dynamo effect as moving charges circulate. Without a convecting molten core, Mars was no longer able to generate a magnetic field. The solar wind emanates from the Sun and carries particles as well as the solar magnetic field with it. Without a magnetic field, charged particles in the upper atmosphere of Mars can be efficiently carried away by the solar wind, and still are today.

A key element in this process is Mars' low gravity. The amount of gravity a planet or body has is dependent on its mass, and Mars is only about a tenth of Earth's mass. Escape velocity, the velocity needed to leave the comfort of a planet, is dependent on mass. The escape velocity of Earth is 11 kilometers/second (~7 miles/second), while the escape velocity of Mars is 5 kilometers/second (~3 miles/second). Any particle near the top of the atmosphere that exceeds this velocity in an upward direction will simply fly away. It's also part of the reason the solar wind could easily carry off particles—the gravity of Mars was just not large enough to hang on to them while the pied piper, the solar wind, swept past the planet. It would also be fairly easy for a comet or asteroid that impacted Mars to make a big enough splash to send portions of the atmosphere into space.

As Mars got colder over millions of years, water on the surface froze solidly and was buried over time. Once atmospheric pressures became low enough from the atmospheric loss, ground water also evaporated or sublimated forming atmospheric water vapor. When water vapor reached Mars' upper atmosphere it photo dissociated, which is when a photon from the Sun breaks the molecule apart. It's easy for hydrogen in the upper atmosphere to escape a planet. A little extra energy from atmospheric heating or from a stray particle traveling through space could give it a little boost, and away it goes! Missions like the Phoenix Lander and Mars Odyssey have helped us better understand how much frozen water is underground by either digging into the soil (Phoenix) or by using gamma ray spectroscopy to map below the surface (Odyssey). The Imaging Ultraviolet Spectrometer (IUVS) onboard the MAVEN mission, will profile hydrogen in the atmosphere and determine its escape rate to space. Once we determine the loss rate, we can calculate how much hydrogen would have been in the atmosphere 4 billion years ago, and how much water vapor would have been needed in the atmosphere to make that much hydrogen. Then, we can make an educated guess about how much water existed on Mars back in time.

If Mars had a warmer and wetter climate, it must have had a thicker atmosphere and stronger greenhouse effect at one time. The loss of hydrogen and of other gases that accompanied it caused the climate to change. How long did that take and what was the atmosphere really like before that? The MAVEN mission is the first mission to thoroughly examine Mars' upper atmosphere and its current loss rate to space to begin to answer these questions. On top of measuring the hydrogen escape rate, various instruments measure the rate of atmospheric escape due to the solar wind. MAVEN scientists want to get a lock on how long it took for Mars to become the dry, dusty world we find today, and finding the atmospheric escape rate is the key!

With the Students

1. Follow the discussion topics in the Pre-Activity Assessment
2. Take students to the computer room
3. Assist students as they add atmosphere to Mars and explore the effects on Mars' surface temperature

Assessment

Pre-Activity Assessment

Example Discussion Questions

Q: From the previous activity, "What's Trending Hot?" what things did you need to change in order for liquid water to exist on the surface of your planet?

A: Distance to the Sun, albedo, atmospheric thickness (increased pressure), and greenhouse strength.

Q: What do you know about Mars?

Accept a variety of responses. Mars is dry, it has a thin atmosphere, it has polar caps, it's further from the Sun than Earth, it has less gravity than Earth etc.

Q: Could people live on Mars? What would they need to bring with them?

Accept a variety of responses. People could live on Mars if they created sealed shelters (that also protected people from radiation). They would need to bring food and water, and would probably need to grow their own food and purify any "waste water" to drink later on. They *would have to bring oxygen tanks. They couldn't go outside the shelter without a specially designed suit that kept them pressurized, provided oxygen, and maintained a comfortable temperature.*

Q: Mars used to have flowing water on the surface. What do you think was different about Mars in the past?
A: Mars probably had a thicker atmosphere and a stronger greenhouse effect. It would have had more atmosphere.

Q: How did the Sun contribute to Mars' atmospheric loss?
A: The Sun has a solar wind, which can carry away some of the atmosphere. Mars' magnetic field protected the atmosphere from the solar wind, but around 4.1 billion years ago, the magnetic field shut off.

Q: What does gravity have to do with Mars' atmospheric loss?
A: Mars has low gravity, so it's easier for things like the solar wind or a big meteorite impact to remove some of the atmosphere.

Post-Activity Assessment
Gallery Walk: Students can make a labeled poster about: 1) Mars' atmospheric loss, 2) watery Mars v. Earth today" or 3) Mars 3.8 billion years ago v. Mars today. Once students are done with the poster, hang student work around the room and have students observe and question each other's work (respectfully). One way to do this is to provide sticky notes for students to make comments. Have an open discussion about student work with the class.

References

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