Inner Planets (Part II)

Sept. 18, 2002

1) Atmospheres
2) Greenhouse Effect
3) Mercury
4) Venus
5) Mars
6) Moon
Announcements

- Due to technical difficulties, Monday's quiz doesn't count.
- An extra credit problem is available on the course web site.
  - It is due Thurs. Sep 19 at 5pm
Review

- Fact vs Theory
- Inner Planets
  - Planet interiors
  - Magnetic fields
- Four Main Processes
  - Tectonics
  - Volcanism
  - Impact Cratering
  - Gradation
Gases – Some Basics

- Lighter gases rise
  - This is really because heavier gases sink and push the lighter gases upward

- Temperature of a gas is really the speed of the molecules
  - Faster gases are hotter

- Sunlight and heat from a planet’s interior provide energy to heat atmospheres
  - Sunlight can also break up molecules

- Fast atoms/molecules in the outer atmosphere can escape the planet’s gravitational pull

- Planets have a hard time hanging onto hydrogen and helium
Primary Atmospheres

- A planet’s original atmosphere comes from the gas of the accretion disk
  - It is composed mainly of hydrogen and helium
    - same stuff the Sun is made of
- If a planet’s gravity isn’t strong enough, it can’t hold onto these light gases
  - They escape and leave the planet without an atmosphere
  - Heating and solar wind help these processes
- This happened to the inner planets
  - We will see later it did not happen to the gas giants
Secondary Atmospheres

- The rocks and planetesimals which combined to form each planet had gases trapped within them.
- During various phases of planetary formation, gases were released:
  - Differentiation caused them to "rise" to the outer surface of the planet.
  - Primarily carbon dioxide.
- Also, comets and meteors which contain water and gas hit the planet.
- These gases formed the secondary atmosphere.
Solar Heating

- Sunlight warms the atmosphere and surface of planets
  - this heat is radiated back in the infrared
  - wavelength (color) of light depends upon temperature
- Many gases in the atmosphere absorb infrared light
  - these gases let visible light through
  - “greenhouse gases”
  - these gases include carbon dioxide and water vapor
  - also include methane and chlorofluorocarbons (CFCs)
Atmospheric Greenhouse Effect

- The greenhouse gases re-radiate the infrared light
  - much of it goes back towards the planet
  - this adds additional heat to the planet
  - Earth would be much colder it not for this

- Planets exist in an equilibrium between solar heating, greenhouse heating and radiation
Runaway Atmospheres

- **Greenhouse Effect**
  - greenhouse heating boils off surface water, increases greenhouse gases and clouds
  - additional water vapor increases planet temperature
  - boils off more water...
  - also, intense sunlight breaks apart water molecules and hydrogen escapes
  - probably happened on Venus - closer to the Sun

- **Atmospheric leakage**
  - lighter (outer) gases lost to space
  - less pressure from above, easier for heavier gases to escape
  - probably happened on Mars - low gravity
## Comparative Atmospheres

<table>
<thead>
<tr>
<th></th>
<th>Venus</th>
<th>Earth</th>
<th>Mars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure (bars)</td>
<td>92</td>
<td>1.0</td>
<td>0.007</td>
</tr>
<tr>
<td>Surface Temperature (K)</td>
<td>737</td>
<td>288</td>
<td>210</td>
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<tr>
<td>Carbon dioxide (%)</td>
<td>96.5</td>
<td>0.033</td>
<td>95.3</td>
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<tr>
<td>Nitrogen (%)</td>
<td>3.5</td>
<td>78.1</td>
<td>2.7</td>
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<tr>
<td>Oxygen (%)</td>
<td>0.00</td>
<td>20.9</td>
<td>0.13</td>
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<tr>
<td>Water (%)</td>
<td>0.02</td>
<td>0.1 to 3</td>
<td>0.03</td>
</tr>
<tr>
<td>Argon (%)</td>
<td>0.007</td>
<td>0.93</td>
<td>1.6</td>
</tr>
<tr>
<td>Sulfur dioxide (%)</td>
<td>0.015</td>
<td>0.02</td>
<td>0.00</td>
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</tbody>
</table>
Earth – Just Right

- Massive enough to hold onto atmosphere
- Far enough from the Sun so water was able to remain in solid and liquid form
- Carbon-dioxide
  - erosion exposed fresh materials which absorbs CO₂ to form limestone
  - tiny sea creatures used carbonates to form protective shells which eventually became part of limestone sea beds
  - if all this CO₂ was released, we would have an atmosphere composition similar to Mars and Venus
Layers of Atmosphere

The Earth’s atmosphere has layers

- layers defined by temperature behavior
- troposphere
- tropopause
- stratosphere
- mesosphere
- thermosphere

Other planets have layered atmospheres

We’ll see more of this in stars and gas giants
Mercury

- Closest to the Sun – 0.39 AU
- Small – 2,440 km radius
- Little atmosphere
- Fast revolution – year is 88 days long
- Slow spin – day is 59 Earth days
- Dense – 61% iron
- Used to be volcanically active, but not now
- No moon
- Only visited by Mariner 10 flyby
Venus

- Orbit similar to Earth’s - 0.72 AU radius
- Size similar to Earth - 6,051 km radius
- Mass slightly less than Earth
  - gravitational pull about the same
- Slow rotation - a day is 243 Earth days long
- Faster revolution - a year is 225 Earth days long
- Evidence of volcanic and tectonic activity
Venus (cont)

- Venus has an intense atmosphere
  - more than 90 times the pressure
  - intense surface temperature - 737 K
  - sulfuric acid in the clouds
  - limited water vapor

- No moon

- Mapped by radar (Magellan) and Soviet landers survived a short time

- Many physical characteristics to Earth, but environment is VERY different
Mars

- 4th planet from the Sun – 1.52 AU orbital radius
- Half the size of Earth – 3,397 km radius
- About 1/10th the mass of Earth
- Light atmosphere – 0.7% of Earth’s
- Martian day is slightly longer than an Earth day
- Tilt similar to Earth’s
- Year is 1.9 times Earth’s
- Has seasonal variations
Mars (cont.)

- Signs of past tectonic, volcanic and gravitational processes
  - still going on?
- Has 2 moons, Phobos and Deimos
- Numerous unmanned missions to Mars in 1970s and current
- Planet most likely to be visited next by humans
  - need to bring our own oxygen, food and fuel to get back
- Small compared to planets (1/100 the mass of the Earth), but large compared to other moons
- Orbit and spin are matched (once a lunar month)
- Composed of similar materials to Earth’s mantle
- Volcanic activity long ago (formed maria)
- Essentially no atmosphere
- Surface dominated by cratering
- Only body other than Earth that humans have visited
  - 12 U.S. astronauts from 1969-1972 - Apollo 11-17
Earth

Pretty!
Intro to Outer Planets

- Planets beyond the asteroid belt
- Gas giants
  - Jupiter
  - Saturn
- Ice giants
  - Uranus
  - Neptune
- Other
  - Pluto

- Outer planets are much further from the Sun than the inner planets
Big, Bigger, Biggest

- **Uranus and Neptune**
  - about 15 Earth masses
  - radii about 4 times Earth’s

- **Saturn**
  - about 95 Earth masses
  - radius about 9.5 times Earth’s

- **Jupiter**
  - about 318 Earth masses
  - radius about 11 times Earth’s