Atmosphere of Earth & Venus

- Test 1
- Processes that shape earth
  - Losing gases in atmosphere
  - Gaining gases in atmosphere
- Venus
- Goldilocks Paradox

Test 1

- How am I doing?
  - Good job, if I am in the top quartile (rank <60, score >24)
  - Need improvement, if I am at the bottom (rank >220, score <15)
  - Cuts are on Angel. Test 1 only represents 1/6 of course grade.
- How to do better on the next test. Aim to understand ideas.
  - Purpose of homework & practice test is to check your understanding.
    - Think about key idea for each question.
  - Ideas are important; answers are not. Do not memorize the answers.
  - Models are important; answers are not. Do not memorize the answers.
  - Do not memorize questions: For some questions, the ideas are the same as on homework or practice test, but the wording is different.
**Atmosphere of planets: loss of gases**

- Planets formed from the same material but now have very different atmospheres.
  - Earth has little helium; Jupiter has a lot of helium
  - Mercury has little atmosphere
- Think of gas molecules as baseballs moving and colliding. How do baseballs escape from the earth’s gravity?
- Average kinetic energy of gas molecule
  - KE = \( \frac{3k}{2} \) Temperature
  - KE = \( \frac{1}{2} \) mass \( \text{speed}^2 \)
- Q: Oxygen molecules (m=32) in the air move at an average speed of 300 m/s. Helium (m=4) moves at an average speed of
  - a. 40 m/s
  - b. 300 m/s
  - c. 850 m/s
  - d. 2400 m/s
- Baseball can escape if Kinetic Energy > Potential Energy
  - \( \text{speed}^2 > \frac{2GM_{\text{Earth}}}{R_{\text{Earth}}} \)
  - Escape speed from earth is 11,000 m/s. How can helium escape?

- How can helium escape from earth? By chance, a helium atom gets much more speed than the average and escapes.
  - Average 850 m/s
  - Very rare 12,000 m/s
  - On earth, each molecule get a new try every billionth of a second.
- Q: S1: It is easier to lose a lighter gas. S2: It is easier to lose gas from a hotter planet. S3: It is easier to lose gas from a more massive planet.
  - a. T T T
  - b. F T T
  - c. T F T
  - d. T T F
  - e. Two are false
Gaining atmospheric gases

Three Ways Atmospheres Gain Gas

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Life & the Earth’s Atmosphere

• Life started in CO2 atmosphere, roughly 4 billion yrs ago.
• Life initially only in sea… converted CO2 to oxygen through photosynthesis.
• The released oxygen was swallowed up in interactions with surface material until ~ 2 billion yrs ago.
• After 2 billion yrs ago, oxygen able to build up in atmosphere.
  • + geological activity buried much of the free carbon.
• Atmosphere then converted to today’s mix:
  78% nitrogen, 21% oxygen, 1% everything else.
• Free oxygen ➔ ozone
  ➔ protection from ultraviolet light ➔ land animals

Life converted Earth’s atmosphere from CO2 to N2, O2

Venus is too hot for life. What went wrong?

• Description of Venus
• Atmosphere of Venus
• Why did Venus get too hot, even though Earth, its twin, remained temperate?
Venus
(according to Botticelli)

Venus, our sister planet

<table>
<thead>
<tr>
<th></th>
<th>Venus</th>
<th>Earth</th>
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</thead>
<tbody>
<tr>
<td>Diameter</td>
<td>0.95</td>
<td>1</td>
</tr>
<tr>
<td>Mass</td>
<td>0.81</td>
<td>1</td>
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<tr>
<td>Semi-major axis</td>
<td>0.72</td>
<td>1</td>
</tr>
<tr>
<td>Density</td>
<td>0.96</td>
<td>1</td>
</tr>
<tr>
<td>Rotation (days)</td>
<td>-243</td>
<td>1</td>
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<tr>
<td>Orbit period (days)</td>
<td>224</td>
<td>365</td>
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</table>
Venera Landers (USSR)

Venera 7 (1970)
Venera 10,11 (1975)
Venera 11,12 (1978)
Venera 13,14 (1981)

Venera 13, 14 soil samples: basalts

The view from Venera 14

Radar Map of Venus

Made by Magellan orbiter in 1991-93.

Blue = lower
Brown/red = higher.
The surface of Venus [7.4]

- Impact craters
  - age dating of surface
  - only 15% as many craters as lunar maria.
- Oldest terrain only 800 million yrs old
  - compare to 3.8 billion yrs on Earth
- Constant resurfacing by volcanic action.
  - but appears to have ceased ~ 500 million yrs ago

Rotating Venus

Volcanic Activity on Venus
Radar Imaging: 100 m resolution

Sif Mons, a shield volcano 500 km diameter x 3 km high.

Lava flow

“Pancake” volcanoes, due to very thick lava.

Corona: a collapsed dome over a magma chamber.
Interior Structure
- Similar to Earth
- Iron core 3000 km in radius
- Molten mantle
- Crust

Tectonics
- No plates as on earth
- But much shearing, compression and stretching of crust by convection currents in mantle.
- Has pushed up “continents”
  - Aphrodite and Ishtar
- Rift valleys and cracks

The Atmosphere of Venus
- Surface Pressure = 92 x Earth’s
- Surface Temperature = 482° C
  - melting point of lead: 327°
- Sulfuric acid cloud layer at 30-60 km

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<thead>
<tr>
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<th>Earth</th>
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<tbody>
<tr>
<td>CO₂</td>
<td>96%</td>
<td>0.03%</td>
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<tr>
<td>N₂</td>
<td>3.5</td>
<td>78.1</td>
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<tr>
<td>Ar</td>
<td>0.006</td>
<td>0.93</td>
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<tr>
<td>O₂</td>
<td>0.003</td>
<td>21.0</td>
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</table>
Some Surface Temperatures in °F

- Mercury (Mariner 10) 800°F
- Venus (Mariner 2; Venera landers) 900°F
- Hell (Revelations 21:8) 832°F
  - “But the fearful and unbelieving shall have their part in the lake which burneth with fire and brimstone”
  - boiling point of brimstone (sulfur); 832°F

Goldilocks #1

- Venus is too hot; Mars is too cold. Why is the earth just right, not too cold and not too hot?
- Venus is too close to the sun, and Mars is too far.
  - This is part of the answer.
  - Reflected light is 2nd ingredient.
  - Greenhouse effect is 3rd ingredient.
  - History is 4th.

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<tr>
<th>Planet</th>
<th>Pressure</th>
<th>Sunlight relative to Earth</th>
<th>Reflected</th>
<th>Temp w/o GH</th>
<th>Actual Temp</th>
<th>Greenhouse warming</th>
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<tbody>
<tr>
<td>Venus</td>
<td>90 atm</td>
<td>1.92</td>
<td>76%</td>
<td>-44 C</td>
<td>477 C</td>
<td>521 C</td>
</tr>
<tr>
<td>Earth</td>
<td>1 atm</td>
<td>1.00</td>
<td>30%</td>
<td>-18 C (0F)</td>
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<tr>
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<td>0.006 atm</td>
<td>0.43</td>
<td>25%</td>
<td>-63 C</td>
<td>-55 C</td>
<td>8 C</td>
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Greenhouse effect

- Greenhouse effect
  - Sunlight is absorbed by the planet’s surface
  - Surface emits infrared radiation
  - Infrared radiation is absorbed by CO₂ & H₂O and reradiated many times before it escapes into space. CO₂ & H₂O acts like a blanket.
  - Without the greenhouse effect, earth would be frozen.
  - Mars has a small greenhouse effect
  - Why did Venus evolve to have such a large greenhouse effect?

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Why did greenhouse run amok on Venus?

- When the sun becomes brighter, the earth becomes warmer.
  - More evaporation ⇒ more rain
  - More rain ⇒ loss of more CO₂, sequestered in rock
  - Less CO₂ ⇒ less greenhouse effect
  - Less greenhouse ⇒ Earth cools, lessening effect of sun brightening

1. Which is not a possible reason why greenhouse ran amok on Venus?
   a. Too hot to rain
   b. Type of rocks cannot sequester CO₂
   c. There is no plate tectonics
   d. Venus was born without water.
Why did greenhouse run amok on Venus?

- Deuterium
  - Normal H has 1 proton in nucleus
  - Deuterium D has 1 proton & 1 neutron. Mass of n & p same.
- Q1 Suppose I had a pound of normal hydrogen. I trade a deuterium for every hydrogen atom. How much would I have?
  - A: 1lb, B: 2lb, C: ½ lb, D: 4 lb.
- Q2 At the same temperature, which gas moves fastest and is more likely to escape?
  - A: normal H; B: deuterium; C: H2O, D: DHO
- Key observation of water: Earth’s ocean has 100,000 X more than Venus’ atmosphere.
- Key observation on deuterium abundance
  - On earth, H/D=5000
  - On Venus, H/D=50.
- Q3 Which hypothesis is wrong?
  a. Venus formed without much water.
  b. Venus lost its water.

- Venus lost its water
  - Venus is hotter because it is closer to sun.
  - Water was in atmosphere.
  - Ultraviolet light broke water into oxygen and hydrogen. Hydrogen escaped.
  - No rain ⇒ no way to get rid of CO2.
  - Models show Earth will suffer same fate if sunlight increases by 40%. CO2 cycle will not be sufficient to keep Earth temperate.
Why did Mars become so cold?

• Read & think.