Early Earth (Hadean)

Terms

- Chondrule
- Chondrite
- Hadean
- Big Bang
- Nucleosynthesis
- Fusion
- Supernova

Nucleosynthesis

- The elements H, He, and traces of Li were formed in the original Big Bang.
- Latest age estimates are 13.7±1 GY
- All heavier elements were formed from the primordial H and He by nuclear fusion reactions in stars.
- The fusion reaction proceeds in steps in stars massive enough to undergo the full sequence.
**Nucleosynthesis**

- Large stars undergo successive fusion reactions until Fe is formed by direct fusion.
- Heavier elements are formed by neutron capture.
- The final fusion stage results in a **supernova** explosion.
- Our solar system formed from the remnants of a supernova.

**Condensation and Accretion**

- Each supernova will have a unique distribution of stable isotopes.
- The solar gas collapsed into a disk that heated and then cooled to condense solid particles of minerals called chondrules.
- The chondrules accreted to form planetesimals and the planetesimals accreted to form planets.
**Accretion and Differentiation**

- The accretion process was rapid and the early Earth melted.
- The elements partitioned according to their fluid-phase chemical affinities.
  - Siderophile - Metallic
  - Chalcophile - Covalent
  - Lithophile - Ionic
  - Atmophile - VanderWaals (Inert)

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**The nebular hypothesis and the evolution of the solar system**

*Figure 9.3 (page 192)*
Go to next slide to begin
The inner planets are small and rocky.

The giant outer planets are gaseous, with rocky cores.

Pluto is a snowball of methane, water, and rock.

Hadean Time

Computer simulation of the origin of the Moon

Figure 9.4 (page 193)
Go to next slide to begin
About 4.5 billion years ago, a Mars-sized body impacted the Earth.

The giant impact propelled a shower of debris into space.

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The impact sped up Earth’s rotation and tilted Earth’s orbital plane 23°.

Earth re-formed as a largely molten body... ...and the Moon aggregated from the debris.

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Moon rocks 4.47 billion years old support this impact hypothesis.

The nebular hypothesis and the evolution of the solar system

Figure 9.3 (page 192)
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Inner Planets

<table>
<thead>
<tr>
<th></th>
<th>Mercury</th>
<th>Venus</th>
<th>Earth</th>
<th>Mars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass</td>
<td>3.3</td>
<td>48.6</td>
<td>59.7</td>
<td>6.4×10^{23}</td>
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<tr>
<td>Radius</td>
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<td>6052</td>
<td>6371</td>
<td>3390 km</td>
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<tr>
<td>Density</td>
<td>5.4</td>
<td>5.2</td>
<td>5.5</td>
<td>3.9</td>
</tr>
</tbody>
</table>

Mars

Mars

Mars

Mars
Extra-solar Planets

- More than 1000 planets have been discovered orbiting other stars in our galaxy.
  - Transit Method (Kepler mission)
  - Astrometry Method (Path Wobble)
  - Doppler Method (wavelength shifts)
  - Micro-lensing method
  - Direct observation
**Extra-solar Planets**

- Most exoplanets are gas giants (so far).
- Search is for a terrestrial planet in the ‘habitable zone’ (liquid water stable).
- Water (H₂O) is an abundant molecule.
- Water is stored in the Earth in minerals.
- Oceans are a small component of Earth’s ‘water’.

**Terms**

- Chondrule
- Chondrite
- Hadean
- Big Bang
- Nucleosynthesis
- Fusion
- Supernova
- Nebular Hypothesis
- Accretion

**Assignment**

- Read Chapter 10
- Evolution of the Continents