

I. Origin of the Earth: The Nebular Hypothesis

A. Initial

1. Nebula or Cloud of matter (from supernova of pre-existing star)
2. Containing all 92 elements created during earlier supernovas
3. Heterogeneous distribution (non-random)
4. Spinning

B. Forces acting to form the solar system

1. Gravitational attraction $f=G*(M_1M_2)/r^2$ (Newton's law of gravitational attraction)
2. Internal Pressure (gas in a balloon) acting to support system
3. 'Centrifugal Force' acting away from the center results from spinning around center.
4. Result:
 - a. Resultant vector down to plane and in to center
 - b. Collapse to rotating disc begins

C. Formation of Proto-Sun & Accretion of the Planets

1. Sun

- a. Mater/particles in center of disk collide and slow (lose angular momentum, thus loss of centrifugal vector)
 - b. Condenses to a sphere, compresses and begins to heat-up and radiate
 - c. Continues heating until $> 10^6$ °K, where nuclear reactions or 'hydrogen burning' begin and 'a star is born'.
 - i. Very hot at center (Sun)
 - ii. Is it hot at distant edges?
 - d. Produces thermal gradient.
- #### 2. Accretion of the terrestrial planets simultaneous with sun
- Mercury, Venus, Earth, Mars, (asteroid belt)
- a. Continued collisions create planetesimals -> embryos -> planets

- b. Only refractory elements (i.e. no H for water) were solid at these temperatures (recall thermal gradient), so only they could condense to form the 'rocky' or terrestrial planets.
 - c. solar wind (H and He from sun) 'blows' away light elements
3. Accretion of the Giant planets (Jupiter, Saturn, Uranus, Neptune)
- a. Larger: Giant planets are larger & can retain light elements (H, He etc.)
 - b. Cooler: The region the giants formed in is further from the sun and thus cooler. Therefore, gasses didn't move as fast and could be retained.
 - Cool enough for H₂O and CH₄ to form solids and condense easier.
 - c. 'light' solar wind, so light elements not 'blown' away
 - d. Result: large, gas-rich (low density) planets

III. Origin of Earth-Moon System

A. Early stage of Earth: Planetesimals condense to Form Earth.

- 1. Bulk composition:
 - a. Recall: solar wind blew light elements away from terrestrial planetesimals
 - b. Thus, heavier elements form Earth (and terrestrial planets)
 - Fe – 35%, O – 30%, Si – 15%, Mg – 10%, remaining 10% all 88 other elements.
- 2. Collisions between Embryos & Planetesimals
 - a. Collisions release heat (kinetic energy liberated as heat = $1/2mV^2$).
 - ENOUGH HEAT TO MELT!
 - c. Additional heat from condensation of the planetesimal (compression heating) and decay of short-lived radioactive elements.
- 3. Magma Ocean
 - a. Earth is partly molten from heat due to 2 above
 - b. Chilled crust due to heat loss at surface.
 - e. Stratified Earth results
 - i. Fe-core from drips of immiscible liquid Fe
 - ii. Si-Fe, Mg Mantle immiscible liquid
 - iii. Si-oxygen crust.

B. Formation of the Moon

1. Characteristics of the Moon.

- $r = 1738\text{km}$, mass $\sim 1.2\%$ of Earth, age = 4.4 b.y.

2. Formation Hypotheses: Giant impact origin

- a. Initially a segregated planetesimal with magma ocean, like earth but smaller.
- b. Glancing impact with earth.
- c. Core sucked back into earth, splashed moon and earth mantle condenses to moon.

III. Earth's structure results from this segregation:

A. Crust:

1. Continental

- a. 35km, under mountains <75 km,
- b. felsic (Si-rich) to mafic (Fe-Mg rich)

2. Oceanic

- a. < 10 km
- b. Mafic to Ultramafic (very rich in Mg-Fe)

B. Mantle = most of earth's volume

1. ~3000 km thick

2. Ultramafic

C. Core Fe-Ni-S

1. ~3,370 km thick

2. Inner solid (6370 - ~5000)

3. outer liquid (~5000 to 2,900) – circulation here produces Earth's magnetic field!

D. Earth's Rheologic or mechanical Layers: defined by mechanical behavior (Strength)

1. Lithosphere – brittle (flexural rigidity)

- a. contains crust and upper part of mantle
- b. 0-100 km (oceans) 0-150 km under continents

2. Asthenosphere

- a. plastic at about 1280°C
- b. Base (arbitrarily) set at base of transition zone (700 km)

3. Mesosphere extends to outer core

4. Outer Core and inner core