

5. Origins of the universe

- I. to understand how the earth became a habitable planet, we need to know how it evolved.
 - A. what made it different than other planets
- II. Origin of the universe
 - A. generally thought to occur with the Big Bang
 - 1. approx. 15 by ago
 - B. the net result of this process appears to be 2 gaseous elements - H_2 and He
 - 1. these are still the dominant elements in the universe - ~99% of all material
 - C. begins by forming giant gas and dust clouds **see photo**
 - 1. clouds then began to break up into a series of megaclouds
 - 2. megaclouds organized into spiral and elliptical shapes **show Fig.**
 - 3. galaxies or nebulae
 - D. some of the gas in these galaxies broke up into smaller clusters to form stars
 - 1. gravitational collapse of the stars produces heat
 - 2. initiates fusion rxns. that make other elements
- III. Elemental synthesis
 - A. red-giant star/nuclear cooking
 - 1. go through a series of fusion rxns. that produce elements up to Fe **Fig. 2-5**
 - 2. fusion reactions convert a small amount of mass to heat
 - a. heats up the star
 - b. increases the stars density
 - B. both combine to increase the core temp. and successively start each of these fusion rxns.
 - C. all the the nuclear fuel is eventually spent in the core
 - 1. the nuclear burning process ends and the star collapses
 - 2. this last collapse leads to an implosion
 - a. implosion of large stars = supernovae
 - D. this process produces free neutrons
 - E. subsequent neutron capture rxns. produce elements with atomic numbers beyond Fe
 - 1. reactions produce stable and radioactive elements
 - 2. radioactive elements important in the evolution of the planet
 - a. internal heat source for the planet that drives plate tectonics
- IV. All of these processes lead to an odd-even preference in the elements
 - A. see it in composition of the sun **Fig. 2-1**
 - B. related to the physics of the processes by which the elements form
- V. Abundance of iron
 - A. Fe is abundant in the cores of stars that explode
 - 1. nuclear physics dictates that this element is the most stable element that can form via these fusion reactions
 - a. formation of other elements requires fission reactions or reactions with free neutrons
 - 2. Fe accumulates in the core before it explodes

- B. other lower weight elements occur in the debris of supernovae since the layer of gas surrounding the core are still burning other elements
- C. leads to the general decrease in elemental abundance up to Fe and the accumulation of the final end-product (Fe) of this nuclear cooking rxns.

VI. Chemical composition of the sun

- A. Fig. 2-1 tells us several things
- B. our sun did not form early on after the big bang
- C. contains elements that only form during the explosive death of a red giant
 - 1. elements beyond Fe
- D. gasses and dust from the explosion of a red giant condensed to form the sun
- E. the same material that formed the sun also lead to the formation of the planets
 - 1. Earth and other terrestrial planets are also predominantly Fe, Mg, Si and O

VII. Formation of the planets

- A. most of the material in the cloud that formed the sun ended up in the sun
 - 1. sun has chemical properties similar to the abundance of the elements in the universe
- B. some of the material ended up in a nebular disk around the newly formed sun
 - 1. formed the planets, moon, asteroids and comets
- C. this material has a different chemical composition than the Sun
 - 1. elements that were contained in dust grains and ice particles were retained in the materials that formed the planets
- D. gasses not retained by the sun were largely lost
 - 1. some did end up in larger outer planets

VIII. Gravitational collapse of this nebular cloud also heated up the inner part of the cloud

- A. allowed the inner region of the cloud to become hot enough to re-initiate thermonuclear fusion rxns
 - 1. re-start nuclear cooking rxns. described above
 - 2. allowed our sun to form
- B. Also led to the chemical fractionation of the planets that formed from the material circling this new sun

Table 3-11 Broecker (w/anim.)
- C. inner region of the ring was hot
 - 1. led to a loss of volatile elements
 - 2. inner planets retained metals and oxides that have low volatilities
 - a. these can condense at high temperatures
- D. outer ring is colder
 - 1. led to the accumulation of ices and gasses
 - 2. gasses also accumulated in the larger outer planets because the core of the planets accreted fairly early
 - a. became sufficiently massive that their gravitational attraction allowed these growing planets to retain these gasses

IX. This explains the chemical composition of the terrestrial planets (Mercury -> Mars)

- A. balance between:
 - 1. nuclear physics - sets the relative abundance of the elements

- 2. inorganic chemistry - controls the chemical forms of the elements
- B. elements that form gasses were apparently largely lost from these planets as compared to chondrites
- C. elements that form oxides were largely retained **Table 3-7 Broecker**
 - 1. some loss of these elements due to volatilization
 - 2. chondrites - material found in meteors thought to “best” represent the original material that formed the planets
- D. oxygen and sulfur are exceptions
 - 1. have gaseous and solid forms
 - 2. oxygen forms solid oxides with metals (eg, Fe)
 - 3. S forms sulfides

X. Age of planets

- A. oldest rocks on earth ~4.1-4.3 bybp (zircons)
- B. material in the solar system appears to be older - ~4.65 bybp
 - 1. based on radiometric dating of chondritic meteorites **see Box Figure 1**
 - a. see text for a discussion of the Pb isochron approach
 - b. this actually tells the time since x’tallization
 - c. radioactive decays “starts” when the time clocks are set by x’tallization
- C. the Earth forms over this time period solar material accumulate into the planet
 - 1. dust, rock, planetessimals
 - 2. may have occurred with ~10-100 my (based on calculations)