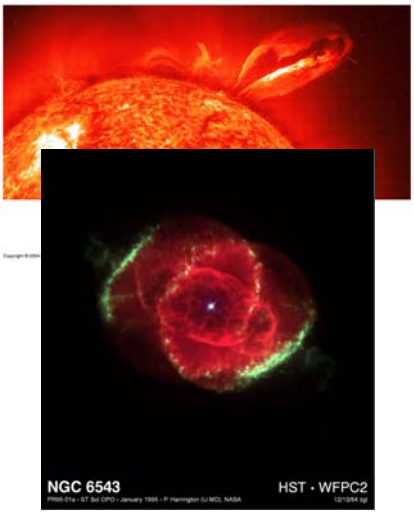
Life of the Sun—14 Oct

- Energy production in the sun ☜
- Sun will use up the hydrogen in the center in 5Byr ☜
- Center of sun must shrink to get hotter to balance gravity ☜
  - Sun will become a red giant. Surface expands.
- Sun will become a planetary nebula
- Sun will become a white dwarf



- Observing
  - Wed & Thurs, Oct 21 & 22, 8:00-10:00pm.
    - Elevator cannot go up after 10:00pm.
  - Attend only if stars are visible. See angel at 6:00pm, if weather is ambiguous.
  - Quiz. You will be asked to locate a star using the Abrams Planetarium star chart. Quiz counts as one clicker assignment.
  - Go to the south end of the building (toward Wilson Rd.) & take the elevator up to the penthouse.
- Test 2 is Wed, Oct 21.
  - One cheat sheet.

Proton-proton chain

- Proton-proton chain (main process in sun)
  - Step 1: Two protons fuse to produce a deuterium nucleus (^{2}H), a positive electron, and a neutrino.

    $p + p \rightarrow {}^2H + e^+ + \upsilon$
    - ^{2}H is deuterium is an isotope of H with one neutron.
    - A neutrino is almost massless, not charged, and interacts very weakly.

1. Did the number of nucleons change? Charge?

- Nucleons are conserved (except in some exotic interactions).
- Charge is absolutely conserved.

1. In the center of the sun, a proton survives collisions without reacting for 10Byr. Besides this involving a weak reaction, what is the other reason for this not occurring often?

   A. Collisions are rare because the gas is tenuous.
   B. Protons repel.

Proton-proton chain

- Step 1: $p + p \rightarrow {}^2H + e^+ + \upsilon$
- In the center of the sun, a proton survives collisions without reacting for 10Byr.
  - Electrical repulsion; Coulomb repulsion; Coulomb barrier
    - Requires fast speed or high temperature to overcome repulsion.
  - Neutrino indicates a "weak" reaction, which is weak.
- Step2: $p+{}^2H \rightarrow {}^3He+\gamma$ (Takes 6s)
  - γ is a photon, a unit of light, which has lots of energy.

1. Did any protons change into neutrons? Is this a weak interaction?

   A. YY. B. YN. C. NY. D. NN.

Proton-proton chain

- Step 1: $p+p \rightarrow {}^2H+e^+ + \upsilon$ (Takes 10Byr)
- Step2: $p+{}^2H \rightarrow {}^3He+\gamma$ (Takes 6s)
  - γ is a photon, a unit of light, which has lots of energy
- Step 3: ${}^3He+{}^3He \rightarrow {}^4He+p+X$ (Takes 1Myr)

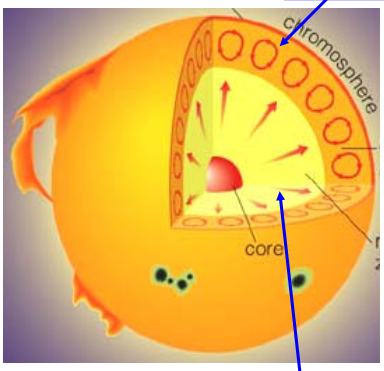
1. What is X?
   A. Neutron.
   B. Electron.
   C. Neutrino.
   D. Proton.
   E. Positron (positive electron).

Proton-proton chain

- Step 1: $p+p \rightarrow {}^2H+e^+ + \upsilon$ (Takes 10Byr)
- Step2: $p+{}^2H \rightarrow {}^3He+\gamma$ (Takes 6s)
  - γ is light with lots of energy
- Step 3: ${}^3He+{}^3He \rightarrow {}^4He+p+p$ (Takes 1Myr)
- Where is the energy?
  - Positrons annihilate
    - $e^+ + e^- \rightarrow 2\gamma$
  - Light interacts with matter to heat it up.
  - Moving reactants heat the matter.
  - Neutrinos escape from the sun carrying away energy.

Interior of the sun

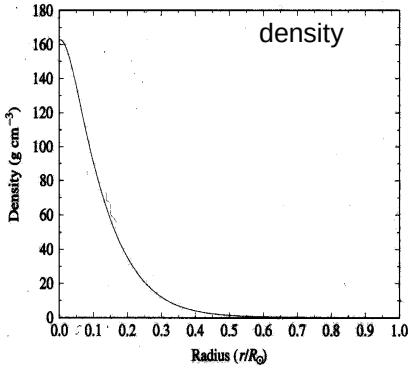
- Use physics to construct models
- Energy is generated by nuclear fusion, which depends on temperature and composition.
- Energy moves from center, where fusion occurs, to outside, where it radiates into space.
- Gas pressure holds the mass of the parts above.

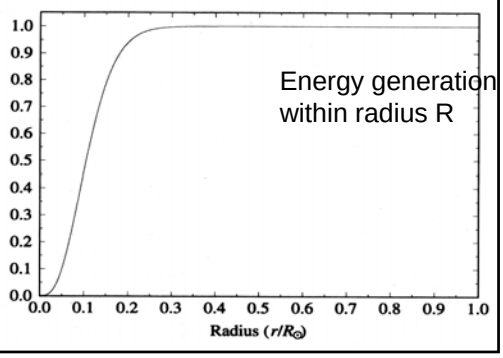


[Fig. 15.2]

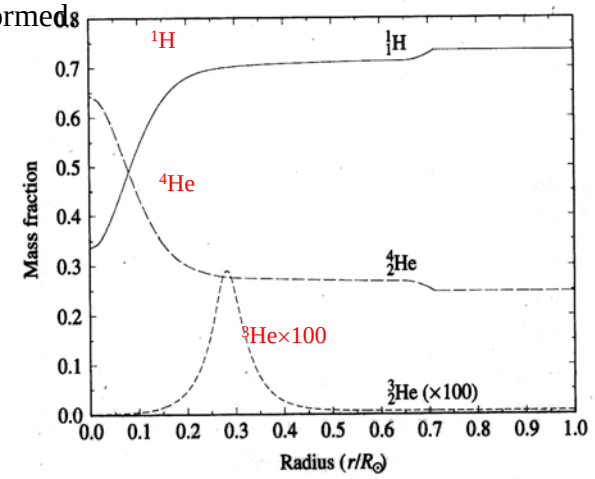
Model of the Sun

1. At what radius is the density of the sun that of water (1gm/cm^3)? 0.5R$_{sun}$. Same for gold (19gm/cm^3) 0.25R$_{sun}$.
2. 90% of the energy is produced within 0.2R$_{sun}$ of





3. Why is there so much helium at the center of the sun?
   A. It used to be hydrogen.
   B. It sunk because it is heavier than hydrogen.
   C. The heavier helium collected in the center when the sun formed.



3. The sun loses 4 million tons of mass every second. Can you capture some of that mass?
   A. Yes. Put up a windmill.
   B. You cannot capture mass that has disappeared.