

Homework problems for Quiz 2: AY5 Spring 2013

1. What element would result from adding 40 neutrons to ${}^{56}_{26}\text{Fe}$ and then having 10 of the neutrons “ β -decay” (that is, eject an electron each)?

${}^{56}_{26}\text{Fe} + 40 \text{ neutrons}$ makes ${}^{96}_{26}\text{Fe}$ (mythical isotope of Fe). The conversion of 10 neutrons to protons gives ${}^{96}_{36}\text{Kr}$

2. The Sun will eventually go through which of the following phases?

☐ planetary nebula

☐ Red Giant Branch

☐ SNII

☐ White dwarf

3. In the fusion of four protons into helium, 4.7×10^{-26} grams of matter is turned into energy. How much energy does this amount of matter produce?

$$E = \Delta mc^2 = (4.7 \times 10^{-26}) \times (3 \times 10^{10})^2 \text{ grams-cm}^2/\text{sec}^2 \text{ (erg)} = 42.3 \times 10^{-6} \text{ ergs}$$

4. How long will a $4M_{\odot}$ star with $L = 5000L_{\odot}$ spend on the main-sequence? (Hint, the main-sequence lifetime of the Sun is 10 billion years).

$$\text{Lifetime} = 4/5000 \times 10^{10} = 8 \times 10^6 \text{ years}$$

5. Label the following True (T) or False (F)

☐ More massive stars have lower temperatures in their cores

☐ The reason main-sequence stars do not collapse due to gravity is the thermal pressure of the gases they are composed of

☐ The fuel that provides the energy source for main-sequence stars is mass

☐ A star that is not in hydrostatic equilibrium will react by changing its radius

6. How much energy is produced by nuclear fusion in the core of the Sun each second?

$$4 \times 10^{33} \text{ ergs}$$

7. For a SN II, list the important events, in chronological order, leading to the explosive ejection of stellar envelope. Start with the fusion of light elements to produce an iron core.

1. Exceed the Chandrasekar limit; 2. photodisintegration of Fe; 3. "neutronization" of core; 4. collapse of outer layers; "bounce" off the neutron core and development of shock wave that blasts off the layers outside the neutron core.

8. Which of the following reactions *release energy*? (Note that not all these reactions actually occur...)

 x $\text{H} + \text{H} \rightarrow \text{He}$

 x $\text{O} + \text{He} \rightarrow \text{Ne}$

 $\text{Cr} + \text{Ca} \rightarrow \text{Ru}$

 x $\text{Th} \rightarrow \text{Rh} + \text{Rh}$

9. The lowest luminosity white dwarfs in the Galaxy have a luminosity of around $10^{-5}L_{\odot}$. Why are there no white dwarfs with lower luminosities than this?

The Galaxy has a finite age. It is not old enough for white dwarfs to have cooled to lower temperatures and associated lower luminosities.

10. What is the average density in kg/cm^3 of a $1M_{\text{Sun}}$ White Dwarf with a radius of 6000km?

Density = mass/volume = $2 \times 10^{33} \text{grams} / \frac{4}{3}\pi 6000^3 \text{km}^3$

convert by using $1\text{kg}/1000\text{grams}$ and $(1\text{km}/100,000\text{cm})^3$

11. Given that hydrogen fusion produces 10^{18} ergs per gram of hydrogen:

A. How much energy can the Sun produce with the 2×10^{32} grams of hydrogen in the core region where it is hot enough for fusion?

$2 \times 10^{32} \text{grams} \times 10^{18} \text{ergs/gram} = 2 \times 10^{50} \text{ergs}$

B. How long could the Sun produce energy via this mechanism at its luminosity of 4×10^{33} ergs/second?

$(2 \times 10^{50} \text{ergs}) / (4 \times 10^{33} \text{ergs/second}) = 0.5 \times 10^{17} \text{seconds}$

12. Which of the following are True (T), which False F?

T The fraction of the Sun composed of helium is larger than it was 1 billion years ago.

T The Sun is losing mass every day

F The fraction of the Sun composed of Fe is larger than it was 1 billion years ago

F The Luminosity of the Sun decreases a small amount every day as it uses up its hydrogen fuel

13. Calculate the spin rate of a neutron star assuming it forms from the collapse of the Fe core of a 25 solar mass star. The original core was spinning at 1 revolution per day and had a radius of 500,000km. The final radius of the neutron star is 10km.

Use conservation of angular momentum.

$$L_{\text{initial}} = L_{\text{final}}$$

$$I_{\text{initial}} \times \omega_{\text{initial}} = I_{\text{final}} \times \omega_{\text{final}}$$

$$\omega_f = \frac{I_i \times \omega_i}{I_f}$$

For a filled sphere the moment of inertia, $I = \frac{2}{5} \times M \times R^2$, so

$$\omega_f = \left(\frac{R_i}{R_f}\right)^2 \times \omega_i = \left(\frac{500,000}{10}\right)^2 \text{ rev/day} = 25 \times 10^8 \text{ rev/day}$$