Study Questions for Lectures of March 13 and 15

1) In the helium burning stage in stars, how many helium 4 (^{4}He) nuclei need to combine to make carbon? Describe how these nuclei combine in a two-step process. (You do not have to remember about "excited states" of carbon.) What is the unstable product of the first step? How does the fact that it's unstable affect the production of elements heavier than helium in Big Bang nucleosynthesis?

2) In most stars (those lighter than 8 times the mass of the sun), what happens when the helium burning stage ends? Why?

3) What is the relation between energy, frequency, and wavelength for particles like protons, neutrons, and electrons? Is the relation different for particles of light, namely, photons?

4) In a white dwarf, is it pressure from protons, from neutrons, or from electrons that holds the star up against gravity? How and why are the relative masses of protons, neutrons, and electrons related to your answer about what holds a white dwarf up?

5) From where does a white dwarf get its energy to shine? What will be the ultimate fate of white dwarfs?

6) If a star's mass is greater than 8 times the mass of the sun, but less than 11 times the mass of the sun, what new stages of burning does it go through after helium burning? Explain why each new stage of burning requires a higher temperature to start. Describe the processes that take place in the core if a star when a stage of burning ends, and explain how these processes make it possible for the next stage to start.

7) Suppose a star's mass is greater than 11 times the mass of the sun. What stage of burning is possible after those described in question 6?

8) What is the importance of nuclear processes (in massive stars) that produce free neutrons?

9) If you look at bigger and bigger nuclei, why is there a limit in size, after which the nuclei become *less*, rather than more stable? (Be sure your answer talks about the competition between the Strong Force and the electromagnetic force, and how the "battle" between these two forces changes in character as the size of the nucleus increases.) Which nucleus is the most stable? Draw an "energy profile" curve for the combining of two nuclei to make a new nucleus that is *smaller* than the most stable nucleus. Draw a second "energy profile" curve for the combining of two nuclei to make a new nucleus that is *larger* than the most stable nucleus.

(Examples of “energy profile curves” are Figures 2 and 3 in the lecture of March 15.)

10) Using your answers to question 9 as a starting point, explain why really big nuclei, such as uranium, are “radioactive.” Why are elements with nuclei bigger than that of uranium not found naturally on Earth now? Where does the energy for the Earth’s current “slow boil” come from?

11) Explain why the stage of burning in your answer to question 7 is the last possible stage of burning in a star.

12) What happens after the last stage of burning in a star more than 11 times the mass of the sun?

13) What happens to the electrons when a big star collapses to make a neutron star? Using the idea of the wavelength of a particle, explain why a neutron star is so much denser than a white dwarf.

14) Which of the four fundamental forces do neutrinos experience? Explain why this fact allows neutrinos to carry away much of the energy of star collapsing into a neutron star.

15) Explain the origins of the two blast waves in a supernova explosion. Explain the importance of supernova explosions for the creation of the solar system, the Earth, and life.

16) In February 1987, a supernova explosion in a nearby galaxy was observed on Earth. Name at least two ways in which scientists on Earth detected the explosion.