Astronomy 82 -- Problem Set 4

due on Top Hat by midnight on Sunday, April 25

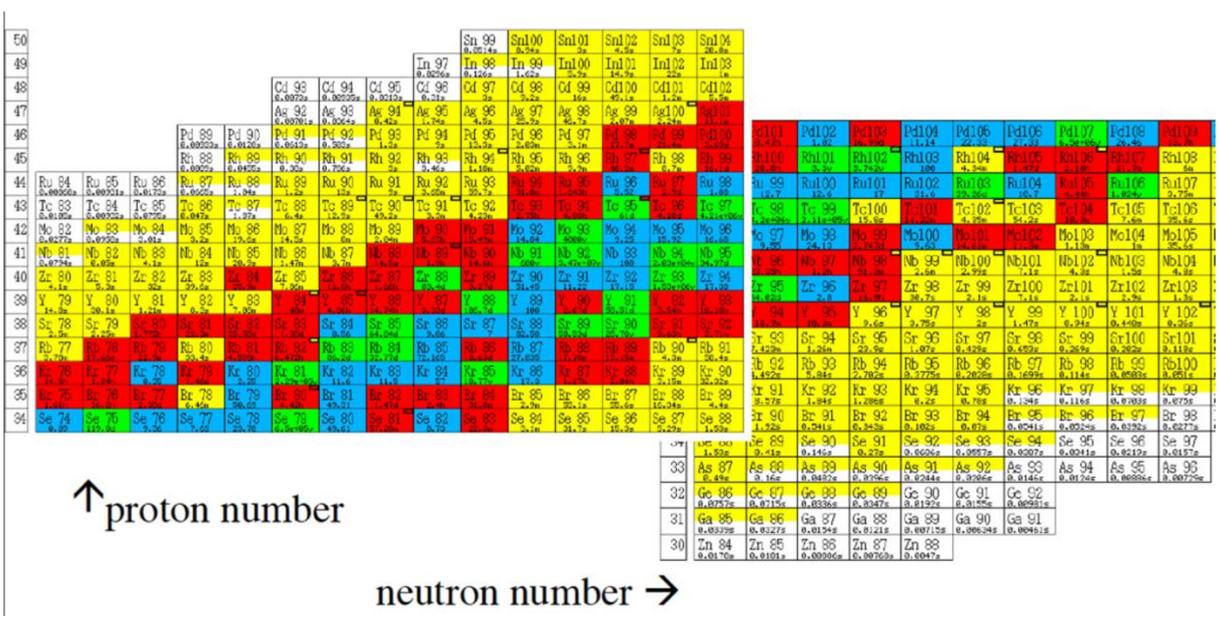
1) *Problem from the textbook (exercise 12.2):* The mass of Vega (spectral class A0 V) is 2 $M_\odot$, radius 3 $R_\odot$, and luminosity 60 $L_\odot$. Find its thermal and nuclear time scales.

2) The horizontal branch is also called the "helium main sequence", and alternatively, the "red clump" because stars spend a lot of time there while they burn helium in their cores and hydrogen in a shell around the core, so they bunch up there in the color-magnitude diagram. When a solar-mass star is on the horizontal branch, it has a luminosity of about 100 $L_\odot$, so it's generating a lot of energy from both helium and hydrogen burning.

a) If helium and hydrogen burning were to contribute equal amounts to the total energy production, how much faster or slower would it be burning hydrogen than helium, or helium than hydrogen, per unit mass of each fuel?
Some pertinent information:
Energy released in the p-p chain by fusion of 4 protons into 1 Helium nucleus: 26.732 MeV
(1 eV of energy equals 1.602 x 10^{-12} ergs)
Energy released in the triple-α reaction by fusion of 3 ^{4}He nuclei into ^{12}C: 7.275 MeV.

b) A solar-mass star on the horizontal branch has a temperature of about 4600 K (that is, cooler than the Sun). How much bigger is it in diameter than the Sun?

3) Elements heavier than iron are synthesized in stars by neutron addition, either by the slow (*s*) process or by the rapid (*r*) process (see chapter 12 of your text). Using a piece of the chart of the nuclides (proton number versus neutron number) below as inspiration, sketch an example of the path taken by both the *s* and *r* processes to produce a stable nuclide (the blue squares), starting from a stable nuclide. Identify a nuclide that can only be produced in stars by the *s* process, and another element that can only be produced by the *r* process.



4) A massive star – 21 $M_\odot$ -- explodes as a supernova in a uniform medium having a density of 100 hydrogen atoms per cubic centimeter. It results in a neutron star with a mass of 1 $M_\odot$. After several thousand years, the supernova remnant enters the snowplow phase, in which it sweeps up interstellar matter, adding it to the expanding spherical shell, but it is no longer being accelerated outward by the pressure of the hot gas in the interior of the shell. At that point, the radius of the shell is 3 parsecs and the shell is expanding at 400 km/s.

a) How big will the shell of the expanding supernova remnant be when it finally slows down to a velocity that is comparable to the average relative velocity of clouds in the interstellar medium, which is about 15 km/s? That can be considered as the point at which the expanding shell fragments and becomes unidentifiable.

b) What will the mass of the shell be at that final stage?