ASTR 1120 Section 1 (3 credit hours): Spring 2006

SUMMARY OF KEY CONCEPTS: WEEK #2

Lecture #3 – textbook 4.3 / 5.3 (4th edition) or 4.2 / 4.3 (3rd edition)

We discussed the concept of *forces* – a force being something that *changes the velocity* of an object. The four fundamental forces are gravity, electromagnetism, the weak nuclear force, and the strong nuclear force. We noted that gravity is intrinsically the weakest – it dominates over large scales in the Universe because (a) electric charges come in positive and negative flavors, which tend to cancel out, and (b) because the nuclear forces are very short range.

We then reviewed the structure of matter, which is made up of atoms themselves composed of a *nucleus* (containing protons and neutrons) and *electrons*. The nucleus is small (10^{-15} m), and contains almost all the mass, while the electrons orbit further out (10^{-10} m) and occupy most of the volume. Chemical reactions involve changes in the distribution of electrons, whereas nuclear reactions involve the nucleus.

We noted that a chemical element is defined by the number of protons in the nucleus (for a neutral atom, this equals the number of electrons). Different isotopes of an element differ in having different numbers of neutrons in their nuclei – e.g. most carbon nuclei have 6 protons and 6 neutrons, but the carbon 13 nucleus has 6 protons and 7 neutrons.

Nuclear fission involves splitting heavy nuclei (e.g. uranium) into lighter pieces. Nuclear fusion involves joining together light nuclei (e.g. hydrogen) to make heavier ones. Fusion is hard because electric forces between the protons tend to repel nuclei – we need high temperatures (large average kinetic energy or velocity) to create collisions violent enough for fusion to occur.

Lecture #4 – textbook Chapter 14 (4th edition) or 15 (3rd edition): `Our star'

We defined the units of energy (joules) and power (watts). Energy is conserved, while power is the rate of energy flow. We showed that neither chemical reactions (e.g. stuff burning) nor gravitational contraction could yield an energy reservoir large enough to keep the Sun shining for the billions of years implied by the ages of rocks and meteorites, though gravitational contraction *is* an important process that explains how gas collapsing to form stars gets hot in the first place.

Einstein's special theory of relativity revealed that mass was a form of energy, with the conversion between the two expressed via the equation $E = mc^2$. Because the speed of light is so large, mass is a very `concentrated' form of energy, but under normal circumstances there is no way to liberate that energy. When light nuclei fuse together, however, **the product nucleus has less mass than the starting nuclei**, with the `balance' being released as energy. Although fusing hydrogen into helium releases only 0.7% of the rest mass of the hydrogen as energy, this is still more than enough to power the Sun for billions of years.

The actual fusion process going on in the Sun is called the proton-proton chain – a moderately involved sequence of reactions that result in 4 protons eventually forming a single helium nucleus (with two protons and two neutrons). The energy liberated takes a long time (thousands of years or more) to leak out to the surface as the photons get scattered multiple times along the way.