Answers to Homework #4

1. Despite their difference in charge (one positive charge for the proton, no charge for the neutron) protons and neutrons have many things in common: Their masses differ by only 0.8%, and both have spin, both are subject to the strong interactions which is ~ 100 time stronger than the electromagnetic interaction. Thus Mr. Heisenberg grouped them into one family which he named nucleons.

2. The important experiment is the alpha scattering from Au nuclei by Professor Rutherford at Cavendish Laboratory at Cambridge University. The experiment shoed that a significant number of alpha’s were scattered backward beyond 90 degrees. This cannot happen if the nucleus is a “pudding”.

3. The most tightly bound nucleus is 56Fe with a binding energy of 8.8 MeV/nucleon. Heavier nuclei contain more and more protons who, because of their positive charge, repel each other inside the nucleus. At distances beyond very short ranges the Coulomb repulsion overpowers the strong force and leads the nucleus to fission.

4. Nuclear fission produces more net energy per unit mass than fission. This is due to two effects: First the binding energy of light nuclei shows very sharp peaks, whereas the binding energy curve of nuclei beyond Fe up to Uranium is a slowly varying curve. Secondly, there are many more nuclei in a kg of hydrogen than in a kg of Uranium. The two effects together favor fusion over fission.

5. The half life of 14C with ~ 5000 years is of the range of human or the earth’s history. Secondly, Carbon is part of the molecules of life on earth and is thus incorporated into many materials of interest. Other radioactive isotopes of biological importance, such as 11C and O15 are much too short-lived.

6. We have several ways to produce new elements and new nuclei or isotopes. One is to fission a very heavy nucleus, such as Uranium, and one of the fission products is often an isotope that is not found naturally. The second way is fusion of a light projectile with a heavier target nucleus. In this fusion process the Coulomb repulsion between the projectile and the target nucleus must be overcome. This requires an accelerated beam. The Coulomb repulsion is about 5 MeV/ nucleon.