Physics 325 Assignment 4
Due Tuesday 2/24/09

1. In gamma decay, the energy released in the decay is equal to the difference in energy of the initial (excited) state and the final state, $\Delta E = E_i - E_f$. The energy of the emitted gamma ray is slightly smaller than the energy released ($E_\gamma < \Delta E$) because the recoiling nucleus also carries away some energy. This problem is to derive the energy of the gamma ray E_γ given ΔE and the mass of the recoiling nucleus M.
a) Start with conservation of energy and conservation of momentum, and use the fact that the photon is massless and the recoiling nucleus is non-relativistic (since its kinetic energy will be only a few MeV at most, compared to its rest energy of more than a GeV). Show that $\Delta E = E_\gamma + \frac{E_\gamma^2}{2Mc^2}$.
b) Using the result from a), find E_γ for the case of the decay of the first excited state of ^{17}O (p. 93). By what fraction does it differ from ΔE?
c) What is the recoil energy of the nucleus in this case? Compare this to the few eV of molecular binding—is it enough to drive the decaying O atom out of the molecule?

2. a) Fill in the blank for this induced fission reaction: $^{235}U + n \rightarrow {}^{90}Kr + {}^{144}Ba +$ _____
b) Using atomic masses (tables in any Modern Physics book), calculate the energy release (Q value) for this fission reaction.

3. Which of the following heavy nuclei would you expect to have large cross sections for fission by slow (thermal) neutrons? Use the concept of neutron pairing energy.
a) ^{251}Cf
b) ^{253}Es
c) ^{237}Np
d) ^{238}Np

4. a) Show that a nuclear power plant producing 1000 MW "consumes" about 1 kg of ^{235}U in one day.
b) Consider a conventional power plant that burns natural gas (primarily methane). What mass of methane is required for a 1000 MW power output (see problem 9.1 for some data)? What mass of the greenhouse gas CO_2 is produced as a result?

5. a) Calculate the height of the Coulomb barrier for D-T fusion.
b) If D-T fusion is taking place at a plasma temperature of 20 keV, is tunneling important? Explain.

6. In analogy with the CNO cycle, fusion of ^1H to ^4He can occur with ^{20}Ne as a catalyst. Suggest a sequence of reactions, similar to those of the CNO cycle, by which this could occur. (Hint: you will have to check the product at each stage to see if it is beta-stable before deciding what the next reaction is.)