War & Peace Cluster, Summit Program
Physics Assignment 8 Answers

Fission reactions

1. Given the fission reaction

$$n + {}^{235}U \text{ --> } {}^{141}La + X + 4n$$

   a. What nucleus is represented by the X? (Hint: both atomic number and mass number has to be conserved.)
      i. Initially there are 92 charges, and so there must be a total of 92 after the reaction. Of those 57 are in the La nucleus, and so the remaining 35 are in the nucleus X, which makes it bromine (Br).
      ii. The initial total atomic mass is 1+235 = 236, which must be the final total atomic mass. With 141 accounted for in the La, and 4 in the neutrons, there remaining 81 are in the Br nucleus.
      iii. The "X" is therefore ^{81}Br.
   b. What is the (combined) kinetic energy of the neutrons? (Assume that the incident neutron has negligible kinetic energy.)
      i. The total mass before the reaction is 1.008665 + 235.0439 = 236.0526
      ii. The total mass after the reaction is 140.9110 + 80.9340 + 4 * 1.008665 = 235.8796
      iii. There is a mass loss of 236.0526 – 235.8796 = 0.173 u
      iv. There is an energy gain of 0.173 * 931.4 = 162 MeV

2. Using the answer to the previous question, how many reactions per second are needed to produce a reactor rates at 200 MW?
   a. Each reaction produces 162 MeV of energy = 162 * 1.6 x 10^{-13} = 2.59 x 10^{-11} J
   b. In each second, to get 200 MJ = 2 x 10^{8} J we need 2 x 10^{8} / 2.59 x 10^{-11} = 7.7 x 10^{18} reactions.

3. How many ^{235}U atoms are needed to operate the reactor for a year?
   a. Each ^{235}U atom has a mass of 235 u = 235 * 1.66 x 10^{-27} = 3.9 x 10^{-25} kg
   b. Total mass used in one second = 7.7 x 10^{18} * 3.9 x 10^{-25} = 3 x 10^{-6} kg
   c. Total mass used in one year = 3 x 10^{-6} * 60 * 60 * 24 * 365 = 94.9 kg

4. What is the mass of uranium need to operate the reactor for a year if
   a. Only ^{235}U is used? 94.9 kg
   b. Natural uranium containing only 0.7 % ^{235}U is used?
      i. We still need 94.9 kg of 235U, but this is now only 0.7% of the total mass
      ii. 0.007 M = 94.9 kg
      iii. M = 13,600 kg
   c. Enriched uranium containing 4 % ^{235}U is used?
      i. We still need 94.9 kg of 235U, but this is now 4% of the total mass
      ii. 0.04 M = 94.9 kg
      iii. M = 2400 kg