*War & Peace Cluster, Summit Program*
*Physics Assignment 8*

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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. The total charge before the reaction is 92 (all from the uranium nucleus, the neutron is uncharged. That means that the total charge after the reaction must also be 92. The La atom has 57 charges (protons) in its nucleus, and so there are 35 left over for the unknown nucleus. Element 35 is Br (bromine).
      ii. The total atomic mass before the reaction is 236 (235 from the uranium nucleus and one from the neutron). That means that the total atomic mass after the reaction must also be 236. The La isotope has 141 and the 4 neutrons account for 4 more, and so there are 236 – (141+4) = 91 left over for the unknown nucleus. The isotope X is therefore $^{91}$Br.
   b. What is the (combined) kinetic energy of the neutrons? (Assume that the incident neutron has negligible kinetic energy.)
      i. The mass of the $^{235}$U nucleus is 235.0439, and the neutron has a mass of 1.0086.
      ii. The total mass before the reaction is therefore 236.0525.
      iii. The mass of the $^{141}$La nucleus is 140.911
      iv. The mass of the $^{91}$Br nucleus is 90.934
      v. The 4 product neutrons have a combined mass of 4 * 1.0086 = 4.0344
      vi. The total mass after the reaction is therefore 235.8794
      vii. There is a mass loss of 0.1731
      viii. There is an energy gain of 0.1731 * 931.4 = 161 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. The energy produced per reaction is 161 * 1.6 x $10^{-13}$ = 2.58 x $10^{-11}$ J
   b. Each second requires 200 MJ = 2 x $10^{8}$ J
   c. The number of reactions per second = 2 x $10^{8}$ / 2.58 x $10^{-11}$ = 7.75 x $10^{18}$

3. How many $^{235}$U atoms are needed to operate the reactor for a year?
   a. The number of reactions per second = 7.75 x $10^{18}$
   b. The number of $^{235}$U atoms needed per year = The number of reactions per year = 7.75 x $10^{18}$ * 365 * 24 * 60 * 60 = 2.45 x $10^{26}$

4. What is the mass of uranium need to operate the reactor for a year if
   a. Only $^{235}$U is used?
      i. The mass of 2.45 x $10^{26}$ $^{235}$U atoms = 2.45 x $10^{26}$ * 235.0439 * 1.66 x $10^{-27}$ = 95 kg
   b. Natural uranium containing only 0.7 % $^{235}$U is used?
      i. We still need 95 kg of $^{235}$U
      ii. If 0.7% * total mass = 95, then total mass = 95 / 0.007 = 13,600 kg
   c. Enriched uranium containing 4 % $^{235}$U is used?
      i. We still need 95 kg of $^{235}$U
      ii. If 4% * total mass = 95, then total mass = 95 / 0.04= 2385 kg
      iii. (Note that is less than 3 tons for the whole year.)