Nuclear Weapons and Warfare

Physics 20061, Fall 2006
Homework 2

1. Fill in the missing nuclide in each of the reactions $^{238}U\ (?,\gamma)^{239}U$, $^{32}S(\alpha,n)?$, $?(p,n)^{7}Be$

2. What is the purpose of a neutron moderator? Name the two most likely moderators and explain why?

3. What is the purpose of neutron absorbers in reactor operations? List two kind of absorbers frequently used in reactors.

4. Both Walter Bothe (Germany) and Enrico Fermi (USA) measured that contrary to theoretical expectations graphite seemed to be a bad moderator. Leo Szilard has suggested that the reason is neutron capture on Boron (^{11}B) impurities in the graphite. Calculate the yield of 0.05 MeV neutron scattering on a d=0.1cm thick graphite layer (ρ=2.25g/cm^3) and compare it with the yield of neutron capture on 1% ^{11}B impurity in the graphite material (use the same density). (hint: use the cross sections given in the lecture, watch out for units.)

5. Areal fire bombing during the Second World War caused hurricane like firestorms through the chimney effect. During the fire bombing of Dresden on February 1945 the temperatures reached 2500K (with 270K air temperature). The heat column reached heights of 1000 m. Calculate the wind velocity in the storm and compare it with wind velocities reached by a nuclear bomb explosion generating a heat column of ~10,000 m and an internal temperature of ~10,000 K.

6. What is the advantage of thermalizing neutrons for the fission of ^{239}Pu? Can the same technique be applied for fissioning ^{238}U (explain!)?

7. What are the three means of separating ^{235}U from ^{238}U to reach the enrichment necessary for a chain reaction in a ^{235}U fission bomb?

8. The plutonium isotope ^{239}Pu is produced as a by-product in nuclear reactors and hence is accumulating in reactor fuel elements. It is radioactive, decaying by alpha decay with a half-life of 2.41 x 10^4 y.
    a. What is the decay rate of this amount?
    b. Its activity in curies?
    c. Explain the production of ^{239}Pu in a breeder reactor. What is the required enrichment for weapon grade plutonium?

9. The plutonium isotope ^{239}Pu decays by alpha decay with a half-life of 24,000 y. How many grams of helium are produced by an initially pure 10 kg sample of ^{239}Pu after 12,000 y? (Recall that an alpha particle is a helium nucleus)

10. The characteristics of a nuclear chain reaction is that the number of neutrons N_n multiplies with the number of fission events k according to $N_n \approx 2^k$. Calculate how many neutrons you have generated after k=10, 50, 100, and 1000 fission events!