ΕΡΩΤΗΣΕΙΣ & ΑΣΚΗΣΕΙΣ ΚΕΦΑΛΑΙΟΥ 8

1. Why are there no nuclei with *A* larger than about 240 ?
   (a) Because their binding energy *B* becomes negative.
   (b) Because the kinetic energy forces them to break to two pieces.
   (c) Because it is both favorable and feasible energetically to break to two pieces
   (d) Because it so happened that the conditions for their formation were never realized

2. Why do nuclei with large *A* have smaller binding energy $|B/A|$ per nucleon?
   (a) Because the average number of nearest neighbors is smaller
   (b) Because the Coulomb repulsion is relatively larger
   (c) Because the kinetic energy is larger
   (d) Because the kinetic energy is smaller

3. Estimate the order of magnitude of nuclear energy per nucleon from its kinetic energy knowing that the volume per nucleon is $4\pi r^3/3,\ r = 1\text{fm}$. The result is about
   (a) 4GeV, (b) 400MeV (c) 40MeV (d) 40 keV

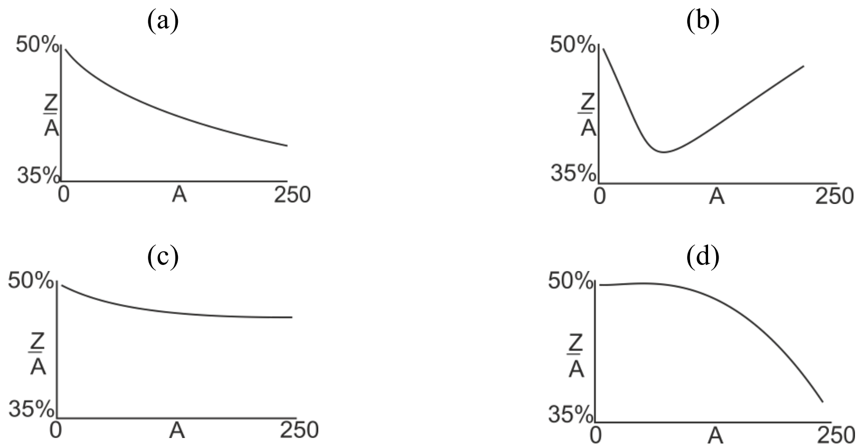
4. Why do nuclei with very small *A* have smaller binding energy per nucleon?
   (a) Because their kinetic energy is smaller
   (b) Because their kinetic energy is larger
   (c) Because their Coulomb repulsion is larger
   (d) Because the average number of nearest neighbors per nucleon is smaller

5. The binding energy *B/A* per nucleon for uranium-238 is approximately
   (a) 3.6MeV (b) 5.6 MeV (c) 7.6MeV (d) 9.6MeV

6. The binding energy *B/A* per nucleon for iron-56 is approximately
   (a) 9MeV (b) 7MeV (c) 5MeV (d) 3MeV

7. The binding energy *B/A* per nucleon for helium-4 is approximately
   (a) 4.1MeV (b) 5.1MeV (c) 6.1MeV (d) 7.1MeV

8. The percentage of protons in a nucleus as a function of *A* is as follows:



9. Why is U^{235} fissionable, while U^{238} is not ?
   (a) Because U^{235} has fewer neutrons. As a result the incorporation of an additional neutron offers enough energy to overcome the potential barrier. U^{238} has too many neutrons for this to happen.
   (b) The binding energy per nucleon *B*/*A* is larger for U^{235} than that for U^{238}. As a result the potential barrier is lower for the former isotope than for the latter.

(c) The energy of U^{236} after the reaction $n + U^{235} \to U^{236}$ is about 6.25MeV above the ground state energy of U^{236}, i.e. higher than the potential barrier of 6.2MeV, while the energy of U^{239} after the reaction $n + U^{238} \to U^{239}$ is only 5.1MeV above the ground state energy of U^{239}, i.e. 1.1MeV below the top of the barrier. This difference between 6.25MeV and 5.1MeV is due to the smaller number of neutrons in U^{236} than in U^{239}.

(d) The energy of U^{236} after the reaction $n + U^{235} \to U^{236}$ is about 6.25MeV above the ground state energy of U^{236}, i.e above the potential barrier of 6.2MeV, while the energy of U^{239} after the reaction $n + U^{238} \to U^{239}$ is only 5.1MeV above the ground state energy of U^{239}, i.e. 1.1MeV below the top of the barrier. This difference between 6.25MeV and 5.1MeV is due to the fact that in the case of U^{235} the incorporation of neutron transforms an [e,o] nucleus to an [e,e] one, while, in contrast, in the case of U^{238} the transformation is from an [e,e] nucleus to an [e,o] one.

10. Why does the fission of U^{235} in a nuclear reactor produces radioactive nuclei ?

(a) Because each fragment has a lot of kinetic energy (about 90MeV)

(b) Because the two fragments have in general unequal number of neutrons which tends to become equal by β-decay

(c) Because the percentage of neutrons in the fragments is almost equal to that of U^{235} which is higher than the one which corresponds to equilibrium for their size

(d) Because they collide violently with other nuclei and tend to break

11. *An isolated neutron breaks down according to the exothermic reaction* $n \to p + e + \bar{\nu}_e + 0.78$ *MeV. Why all neutrons in a nucleus do not undergo this reaction ?*

12. *The composition of natural uranium is 99.3% U-238 and 0.7% U-235. Their half-lifes are* 4.51×10^9 s and 7.1×10^8 s *respectively. Obtain limits for the age of our planetary system and the age of the Universe.*

13. *The distribution of the mass number of the fragments of the neutron induced fission of U-235 in a nuclear reactor exhibits a double peak at A=92 and A=140. (See p.654 of Eisberg-Resnick, Quantum physics* [23].) *On the contrary, the fragments of a fission bomb exhibit a broad single maximum at* $A \approx 116$. *What may be the reason for this disparity, which is also a useful tracer of nuclear bomb testing?*

14. Why nuclear reactors employ a material as a moderator? A moderator slows down fast neutrons released during the fission so that they reach thermal kinetic energies i.e a fraction of an eV. Why heavy water is the best moderator?

15. What is the so-called depleted uranium? How one can separate the two isotopes of natural uranium? By chemical or physical methods? Assume that the protons are arrange within the nucleus as to create a uniform positive electric charge. Show then that

$$E_c = \frac{1}{2}\sum_{i,j=1}^{Z} \frac{e^2}{r_{ij}} = \frac{Z(Z-1)}{2}\frac{e^2}{r}, \text{ with } r = \tfrac{5}{6}R$$