6.7 Exercises

Survey of Nuclear Properties

Ex 6.1. Determine the number of protons, neutrons, and nucleons in the following isotopes: (a) ${}^{18}_{8}$O, (b) ${}^{235}_{92}$U, (c) ${}^{131}_{53}$I, (d) ${}^{40}_{17}$K.

Ex 6.2. Determine (a) the missing mass, (b) the binding energy and (c) the binding energy per nucleon of ${}^{7}_{3}$Li, given that $M_{Li7} = 7.016004$ u.

Ex 6.3. A 5-MeV alpha particle is sent towards a gold nucleus ${}^{197}_{79}$Au. How close will the alpha particle get to the nucleus before turning back?

Ex 6.4. Determine the radius of the following nuclei: (a) ${}^{197}_{79}$Au, (b) ${}^{40}_{17}$K, (c) ${}^{12}_{6}$C, (d) ${}^{14}_{6}$C.

Ex 6.5. The gyromagnetic ratio of ^{13}C is $\gamma_n = 67.262\ \mathrm{s^{-1}T^{-1}}$ and the nuclear spin quantum number is $\frac{1}{2}$. (a) What is the spin angular momentum of ^{13}C nucleus? (b) What is the z-axis spin projection quantum numbers for ^{13}C? (c) What are the possible z-components of magnetic dipole moment of the nucleus?

Ex 6.6. The gyromagnetic ratio of ^{13}C is $\gamma_n = 67.262\ \mathrm{s^{-1}T^{-1}}$ and the nuclear spin quantum number is $\frac{1}{2}$. A sample of ^{13}C is placed in a strong magnetic field of 3 T. (a) Find the energy splitting of the two spin orientations with respect to the magnetic field. (b) What is the Larmor frequency for the precession in Hz of the magnetic dipole moment about the magnetic field?

Ex 6.7. The g-factor of ^{88}Rb is $g_n = 0.254$ and the nuclear spin quantum number is $I = 2$. The sample is placed in an external magnetic field of 2 T. (a) How many energy states will correspond to $I = 2$ now? (b) What will be the energy difference between adjacent states? (c) What is the wavelength of the light that will be emitted if a Rb atom makes a nuclear transition from one of these states to the next lower state?

Radioactivity

Ex 6.8. The isotope ^{32}P decays by negative beta decay with a half life of 14.28 d. (a) If there was 1.0^{10} atoms of ^{32}P in the sample at $t = 0$, how many will be left in a 142.8 days? (b) How many will be left in 365 days?

Ex 6.9. An unknown radioactive material is decaying at a rate of 5,000 counts per second. You wait two weeks and measure the activity and find that the counts now is 2,500 counts per second. What is is half life of the material?

Ex 6.10. An unknown radioactive material is decaying at a rate of 50,000 counts per min. You wait two weeks and measure the activity and find that the counts now is 1,150 counts per minute. What is is half life of the material?

Ex 6.11. (a) Compute the number of molecules of potassium chloride KCl in 1 g of KCl. (b) Suppose 1% of potassium atoms are in isotope ^{40}K. How many ^{40}K atoms will be in 1 g of KCl? (c) Normally KCl has a slight radioactivity. Supposing the radioactivity comes from ^{40}K atoms in KCl, what will be the activity in decays per second of 1 g KCl if the half life of ^{40}K is 1.3×10^9 y?

Ex 6.12. In Fukushima, Japan, 13,500 TBq (Tera Becquerel) of Cs-134 was released. Cs-134 is a beta emitter with a half life of 30.2 y. What is the total mass of Cs-134 released?

Ex 6.13. Complete the following decay reactions with appropriate symbols for the atomic species and other particles.

(a) $^{154}_{64}\text{Gd} \longrightarrow {}^{4}_{2}\text{He} + ?$

(b) $^{238}_{92}\text{U} \longrightarrow {}^{4}_{2}\text{He} + ?$

(c) $^{231}_{91}\text{Pa} \longrightarrow {}^{4}_{2}\text{He} + ?$

(d) $? \longrightarrow {}^{4}_{2}\text{He} + {}^{181}_{77}\text{Ir}.$

(e) $? \longrightarrow {}^{4}_{2}\text{He} + {}^{228}_{88}\text{Ra}.$

Ex 6.14. Complete the following beta decay reactions with appropriate symbols for the atomic species and other particles.

(a) $^{131}_{51}\text{I} \longrightarrow ?$ (beta minus)

(b) $^{247}_{95}\text{Am} \longrightarrow ?$ (beta minus)

(c) $^{40}_{19}\text{K} \longrightarrow ?$ (beta plus)

(d) $^{23}_{12}\text{Mg} \longrightarrow ?$ (beta plus)

Ex 6.15. Find the amount of energy released when ^{238}U decays into ^{2}34Th by an alpha decay process. Data: M(U238) = 238.0507847 u, M(Th234) = 234.036596 u.

Ex 6.16. An unbound neutron decays rapidly by beta decay. Find the maximum energy of the electron in the beta decay of a neutron.

Ex 6.17. The isotope ^{223}Ra has a potential use in cancer therapy. It decays by alpha decay into radon. (a) Find the Q of the reaction. (b) If an atom of Ra at rest decays, what is the kinetic energy of the alpha particle that comes out? (c) What is the kinetic energy of the radon atom that forms? Data: M(Ra223) = 223.018497 u, M(Rn219) = 219.00948 u.

Ex 6.18. The isotope ^{137}Cs is a beta minus emitter. (a) Write the equation of the beta decay. (b) Determine the Q of the reaction? (c) What is the maximum kinetic energy of the electron released? (d) What is the maximum energy of the antineutrino released?

Ex 6.19. The half lives of the two isotopes of Uranium are: (^{235} U, 7.04×10^8 y), (^{238} U, 4.47×10^9 y). The current abundances of the two isotopes, ^{235} U and ^{238} U in natural deposits are 0.7% and 99.3% respectively. What were the corresponding abundances when Earth was formed 4.54 billion years ago?

Ex 6.20. Prove $N(t) = N_0 2^{-t/T_{1/2}}$.

Biological Effects

Ex 6.21. Positron emission tomography exposes the head of mass 10 kg with a dosage 25 mSv. Using RBE = 1.5 for positron, what is the total energy of the radiation absorbed?

Ex 6.22. In a dental X ray 1 kg of the tissue was exposed with dosage 3 mGy. Using RBE =1.0, what is the effective dosage in (a) Sv and (b) rem?

Ex 6.23. A scientist works with radioactive nuclide that emit gamma rays. Every day for four hours the upper body of the scientist is exposed to radiation at the activity level of 10,000 Bq. (a) What will be his exposure in one month in Gy? (b) What will be his effective exposure in rem?

Nuclear Reactions

Ex 6.24. Complete the missing information in each of the nuclear reaction. (a) ^{9}Be(p, α) ?, (b) ?(p, n)^{18}F (c) ^{7}Li(p, ?)^{7}Be, (d) ^{19}F(?, α)^{16}O.

Ex 6.25. (a) Find the Q of the following reaction, ^{18}O(p, n)^{18}F. (b) Determine the threshold energy.

Nuclear Fission and Fusion

Ex 6.26. (a) Find disintegration energy of the following channel of disintegration of ^{235}U.

$$^{235}\mathrm{U} + \mathrm{n} \longrightarrow\ ^{140}\mathrm{Xe} +\ ^{94}\mathrm{Sr} + 2\mathrm{n}.$$

The data needed: $M_{U235} = 235.043924$ u, $m_n = 1.008664$ u, $M_{Xe140} = 139.92164$ u, $M_{Sr94} = 93.915361$ u. (b) Compute the disintegration energy per nucleon.

Ex 6.27. A 500 MW fission plant is being considered. How much ^{235}U would the plant use up in a year?

Ex 6.28. For two deuterons to fuse into a triton and a proton the two deuterons must come within a distance of 10 fm. (a) What is the electrical repulsive force between the two deuterons at that distance? (b) What should be the kinetic energies of the two deuterons if they are to overcome the repulsive force? (c) What should be temperature of the plasma if the deuterons are to have the required kinetic energy?