Problem 1

Neutrons are placed in a magnetic field with magnitude 2.30 T.
(a) What is the energy difference between the states with the nuclear spin angular momentum components parallel and antiparallel to the field?
(b) Which state is lower in energy: the one with its spin component parallel to the field or the one with its spin component antiparallel to the field?
(c) The neutrons can make transitions from one of these states to the other by emitting or absorbing a photon with energy equal to the energy difference of the two states. Find the frequency and wavelength of such a photon.

Problem 2

The most common isotope of uranium $^{238}_{92}\mathrm{U}$, has atomic mass 238.050783 u.
(a) Calculate the mass defect.
(b) Determine the binding energy (in MeV).
(c) Determine the binding energy per nucleon.

Problem 3

(a) Calculate the total binding energy of $^{12}_{6}\mathrm{C}$.
(b) Calculate the binding energy per nucleon.
(c) What percent of the rest mass of this nucleus is its total binding energy?

Problem 4

The atomic mass of $^{14}_{6}\mathrm{C}$ is 14.003242 u. Show that the β^- decay of $^{14}_{6}\mathrm{C}$ is energetically possible, and calculate the energy released in the decay.

Problem 5

(a) Calculate the energy released by the electron-capture decay of $^{57}_{27}\mathrm{Co}$.
(b) A negligible amount of this energy goes to the resulting atom $^{57}_{26}\mathrm{Fe}$ as kinetic energy. About 90% of the time, the $^{57}_{26}\mathrm{Fe}$ nucleus emits two successive gamma-ray photons after the electron-capture process, of energies 0.122 MeV and 0.014 MeV respectively, in decaying to its ground state. What is the energy of the neutrino emitted in this case?

Problem 6

The isotope $^{226}_{88}\mathrm{Ra}$ undergoes α decay with a half life of 1620 years. What is the activity of 1.00 g of $^{226}_{88}\mathrm{Ra}$? Express your answer in Bq and in Ci.

Problem 7

A 12.0 g sample of carbon from living matter decays at the rate of 180.0 decays/min due to the radioactive $^{14}_{6}\mathrm{C}$ in it. What will be the decay rate of this sample in 1000 years?

Problem 8

A person exposed to fast neutrons receives a radiation dose of 200 rem on part of his hand, affecting 25 g of tissue. The RBE of these neutrons is 10.
(a) How many rad did he receive?
(b) How many joules of energy did this person receive?
(c) Suppose the person received the same rad dosage, but from beta rays with an RBE of 1.0 instead of neutrons. How many rem would he have received?

Problem 9

The second reaction in the proton-proton chain produces a ${}_{2}^{3}\mathrm{He}$ nucleus. A nucleus produced in this way can combine with a ${}_{2}^{4}\mathrm{He}$ nucleus, ${}_{2}^{3}\mathrm{He} + {}_{2}^{4}\mathrm{He} \rightarrow {}_{4}^{7}\mathrm{Be} + \gamma$. Calculate the energy liberated in this process. (This is shared between the energy of the photon and the recoil kinetic energy of the beryllium nucleus.) The mass of a ${}_{4}^{7}\mathrm{Be}$ atom is 7.016929 u.

Problem 10

Consider the nuclear reaction, ${}_{2}^{4}\mathrm{He} + {}_{3}^{7}\mathrm{Li} \rightarrow \mathrm{X} + {}_{0}^{1}\mathrm{n}$, where X is a nuclide. What are Z and A for the nuclide X?

Problem 11

The nucleus ${}_{8}^{15}\mathrm{O}$ has a half life of 122.2 s. ${}_{8}^{19}\mathrm{O}$ has a half life of 26.9 s. If at some time a sample contains equal amounts of ${}_{8}^{15}\mathrm{O}$ and ${}_{8}^{19}\mathrm{O}$, what is the ratio of ${}_{8}^{15}\mathrm{O}$ to ${}_{8}^{19}\mathrm{O}$ after 5.00 minutes?

Problem 12

A bone fragment found in a cave believed to have been inhabited by early humans contains 0.29 times as much ${}_{6}^{14}\mathrm{C}$ as an equal amount of carbon in the atmosphere when the organism containing the bone died. Find the approximate age of the fragment.