Homework

Subject: Introduction to Nuclear and Particle Physics
Due date: Friday 20th January 2023 6pm
Submission type: on paper
Credits: 12 points, Each exercise is worth 1 point.

This homework counts as a quiz. The aim of the homework is to practice some calculations and better understand nuclear decay. Copying solutions from any source will result in a 0 grade.

Nuclear mass data table: https://www-nds.iaea.org/amdc/ame2020/mass_1.mas20.txt

1. Find the decay constant (disintegration constant) for ^{91}Sr if the half life is 9.70 h.

2. A radioactive sample initially contains 2.4×10^{-2} mol of a radioactive material whose half-life is 6.00 h. How many moles of the same radioactive material remain after 6.00 h? After 12.0 h? After 36.0 h?

3. An old campfire is uncovered during an archaeological dig. Its charcoal is found to contain less than 1/1000 the normal amount of ^{14}C. Estimate the minimum age of the charcoal, noting that 2^{10}=1024 and the half life of ^{14}C is 5700 years.

4. Find the Q value (total released energy) for the following decays:

   $^{247}\mathrm{Bk} \rightarrow {}^{243}\mathrm{Am} + \alpha$

   $^{242}\mathrm{Pu} \rightarrow {}^{238}\mathrm{U} + \alpha$

   $^{208}\mathrm{Po} \rightarrow {}^{196}\mathrm{Pt} + {}^{12}\mathrm{C}$

5. Find the kinetic energy for the daughter particles in exercise 4.

6. In the decay of ^{242}Cm to ^{238}Pu, the maximum α energy is 6112.9 ± 0.1 keV. Given the mass of ^{238}Pu = 238.049558 u, find the mass of ^{242}Cm.

7. Use the semi-empirical mass formula to estimate the α-decay energy of ^{242}Cf and compare with the measured value of 7.351MeV. Do the two values agree, what is the reason?

8. Compute the Q values for the following decays:

   $^{65}\mathrm{Ni} \rightarrow {}^{65}\mathrm{Cu}$

   $^{10}\mathrm{C} \rightarrow {}^{10}\mathrm{B}$

9. The maximum kinetic energy of the positron spectrum emitted in the decay $^{11}C \rightarrow {}^{11}B$ is 1.983 $\pm$ 0.003 MeV. Use this information and the known mass of ^{11}B=11.009305 u to calculate the mass of ^{11}C.

10. In the decay of ^{47}Ca to ^{47}Sc, what energy is given to the neutrino when the electron has a kinetic energy of 1.100 MeV

11. Classify the following decays according to degree of forbiddenness (e.g. first forbidden decay, second forbidden decay etc.):

    (a) $^{89}Sr(\frac{5}{2}^+) \rightarrow {}^{89}Y(\frac{1}{2}^-)$

    (b) $^{36}Cl(2^+) \rightarrow {}^{36}Ar(0^+)$

    (c) $^{26}A1(5^+) \rightarrow {}^{26}Mg^*(2^+)$

    (d) $^{26}Si(0^+) \rightarrow {}^{26}A1^*(0^+) \rightarrow {}^{26}Mg(0^+)$

12. Add the missing parts of the decays:

    (a) $\bar{\nu} + {}^3He \rightarrow$

    (b)$^6He \rightarrow {}^6Li + e^-$

    (c) $e^- + {}^8B \rightarrow$

    (d) $\nu + {}^12C \rightarrow$

    (e) $^{40}K \rightarrow \nu$

    (f) $^{40}K \rightarrow \bar{\nu}$