NPA Mid-Term Exam Nov 2007

Answer All Questions

1) Lithium (Li) is the 3rd element in the periodic table. A particular isotope of this element known as Lithium-5. Give the atomic number, atomic mass and neutron number of Lithium-5. [3]

2) Write down the formulae for the nuclear mass, and atomic mass of an element, in terms of nucleon masses and the binding energy B. [4]

3) What is the difference between atomic and nuclear masses? [2]

4) Briefly explain what nuclear binding energy is. [4]

5) For a nucleus ${}^{A}_{Z}X_{N}$ write down the equations for α, β^{+}, β^{-}, γ, decay to a nucleus Y [4]

6) Explain what is meant by the mean lifetime, half life and decay constant of a nuclear decay process. [3]

7) The binding energy per nucleon for ${}^{235}_{92}U$ is 7.5 MeV, whilst for the fission fragments ${}^{92}_{36}Kr$ and ${}^{141}_{56}Ba$ the binding energy per nucleon is 8.5 MeV. Estimate the energy release in this fission process. [2]

8) Describe very briefly what is meant by the term "magic numbers", and give two examples of experimental observations that exhibit "magic number behaviour". [3]

9) Sketch the energy spectra of alpha, beta and gamma radiation giving an estimate of the energy ranges of the emitted particles. Explain qualitatively any differences between them [6]

10) If the energy levels of a nucleus are: $\mathbf{1s_{1/2}}$ $\mathbf{1p_{3/2}}$ $\mathbf{1p_{1/2}}$ $\mathbf{1d_{5/2}}$ $\mathbf{1d_{3/2}}$ $\mathbf{2s_{1/2}}$ $\mathbf{1f_{7/2}}$ what is the nuclear spin & parity of ${}^{15}_{6}C$? [2]

11) ${}^{242}Cm$ decays via alpha emission to an excited state of ${}^{238}Pu$, which further decays to the ground state via gamma emission. The Q value of alpha decay is 4.6MeV and the gamma ray energy is 2.1MeV. Draw an energy level diagram of the decay processes. [4]

12) Explain what is meant by a "tunnelling process". Why is this relevant to alpha decay? [2]

13) Explain <u>why</u> neutrons from the fission of ${}^{235}U$ in a nuclear reactor need to be moderated. [3]

14) The isotope ${}^{14}_{8}O$ is a positron emitter, decaying to an excited state of ${}^{14}_{7}N$. The gamma rays from this latter have an energy of 2.313 MeV and the maximum energy of the positrons is 1.835 MeV. The mass of ${}^{14}_{7}N$ is 14.003074 u and that of the electron is 0.000549 u. Write the equation for the decay of the oxygen isotope and sketch an energy level diagram for the process. Given that one atomic mass unit (u) is equal to 931.502 MeV/c^2 find the mass of ${}^{14}_{8}O$. [6]

15) In Rutherford's scattering experiment alpha particles of 10 MeV kinetic energy are fired at a foil of ${}^{197}Au$ nuclei. The differential cross section for alpha particle scattering is observed to be a smoothly varying function of the scattering angle θ.

a) Draw a sketch of the observed cross section as a function of θ from 0 to 180 degrees.
b) Sketch a similar graph for np scattering, explaining any differences.
c) Explain <u>quantitatively</u> why no diffraction pattern is seen in the Rutherford scattering cross section, justifying your reasoning. [6]