PC3322

ONE HOUR THIRTY MINUTES

A list of constants is enclosed.

UNIVERSITY OF MANCHESTER

Nuclear Physics

28th May 2003, 2.00 p.m. - 3.30 p.m.

Answer **ALL** parts of question 1 and **TWO** other questions

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Electronic calculators may be used, provided that they cannot store text.

The numbers are given as a guide to the relative weights of the different parts of each question.

1. (a) Estimate the angle at which the first minimum occurs in the differential cross section for the elastic scattering of 800 MeV electrons from ^{12}C nuclei. [$\hbar c$=197 MeV fm] [5 marks]

(b) Explain why processes of nuclear fission and nuclear fusion can both release energy. [5 marks]

(c) *State* an experimental method that would be suitable for each of the following:

(i) Measuring the mean square charge radius of a radioactive nucleus. [2 marks]

(ii) Demonstrating the existence of a neutron halo in a short-lived neutron-rich nucleus. [2 marks]

(iii) Measuring the matter distribution of a stable nucleus. [2 marks]

(iv) Establishing that the ground state of an even nucleus is well-deformed. [2 marks]

(v) Setting an upper limit on the neutrino mass. [2 marks]

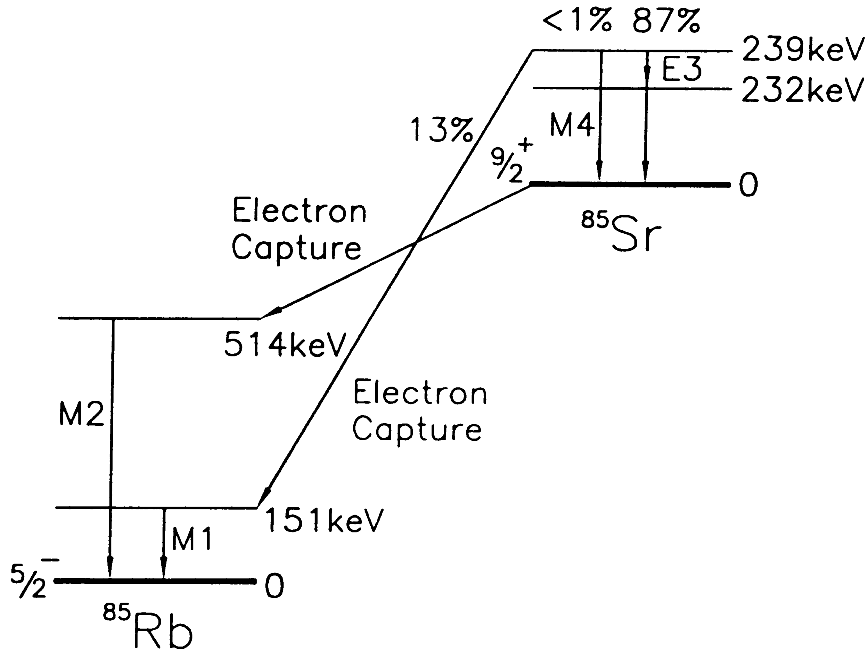
(d) Explain why a change in Q-value for α-decay by a factor of two leads to a change in the nuclear half-life by more than 20 orders of magnitude. [5 marks]

2. Describe the sequence of levels (including spin and parity) that you would expect to see in (a) a well-deformed, rotational, even nucleus, and (b) a spherical, vibrational, even nucleus. [10 marks]

For each type of nucleus give predictions for the ratio of level energies $E(4_1^+)/E(2_1^+)$, explaining your reasoning. [6 marks]

Describe the appearance of the gamma-ray decay spectrum of a rotational even nucleus produced in a heavy-ion reaction. Outline the properties of the nucleus that could be deduced from an analysis of the gamma-ray spectrum. [9 marks]

3. The diagram shows some energy levels in $^{85}_{37}$Rb (atomic mass= 84.9118 u) and $^{85}_{38}$Sr (atomic mass = 84.9129 u). The 239 keV level in ^{85}Sr has a 13% probability of decaying by electron capture to ^{85}Rb. The multipolarities (σL) of some observed gamma-ray transitions are marked. [The atomic mass unit, u = 931.5 MeV/c^2.]



(a) Describe the process of *electron capture.* Why does the ^{85}Sr ground state not decay by β^+ emission to the 514 keV level in ^{85}Rb? [6 marks]

(b) Discuss the possible spin and parity assignments for the levels shown in the diagram, given the two ground state assignments. [12 marks]

(c) Make an estimate of the lifetime of the 232 keV state in ^{85}Sr, stating any assumptions you make. Why is an electron capture decay branch not observed from the 232 keV state? [9 marks]

[Weisskopf single-particle estimates in units of s^{-1}, where E is the gamma-ray energy in MeV:

$\lambda(E1) = 1.0 \times 10^{14} A^{2/3} E^3$ $\qquad$ $\lambda(M1) = 5.6 \times 10^{13} E^3$

$\lambda(E2) = 7.3 \times 10^{7} A^{4/3} E^5$ $\qquad$ $\lambda(M2) = 3.5 \times 10^{7} A^{2/3} E^5$]

4. Describe the basic assumptions of (a) the liquid drop model, and (b) the shell model. [8 marks]

In each case give an example of a nuclear property which the model explains successfully. [6 marks]

Sketch the ordering of the shell model single-particle levels arising from the 1s, 1p, 1d and 2s orbitals. Make a prediction for the ground state spin and parity of ${}^{15}_{7}N_8$. [6 marks]

Use the shell model to predict the possible spins and parities of the first excited state of ${}^{16}_{8}O_8$. [5 marks]