PC3322

ONE HOUR THIRTY MINUTES

A list of constants is enclosed.

UNIVERSITY OF MANCHESTER

Nuclear Physics

2 June 2000, 9.45 a.m. - 11.15 a.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) What are the assumptions made in estimating the transition rate of a single-particle electric-multipole γ-ray decay?

[5 marks]

(b) Given that the angular momentum and parity of the ground state of $^{17}_{8}$O is $\frac{5}{2}^{+}$, explain the observation that the angular momentum and parity of the ground state of $^{19}_{9}$F is $\frac{1}{2}^{+}$.

[5 marks]

(c) The first four excited states of ^{118}Cd are (in keV):

488 ($J^{\pi} = 2^{+}$); 1165 (4^{+}); 1270 (2^{+}); 1285 (0^{+}).

What nuclear model best describes these levels? Explain any deviations from the model predictions.

[5 marks]

(d) Briefly discuss the process of *superallowed* β decay, explaining its importance in weak interaction physics.

[5 marks]

(e) Explain why the nucleus ^{184}Os is tabulated as stable despite the fact that it has a positive Q-value for α decay.

[5 marks]

2. Describe two pieces of evidence that demonstrate that nuclei in the A = 160 region are non-spherical.

[6 marks]

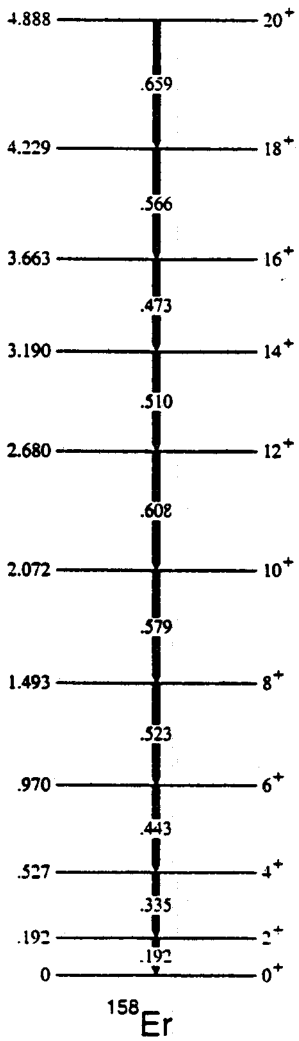
Show that the moment of inertia I of a deformed nucleus as a function of the angular momentum J can be written as

$$I \quad = \quad \frac{2J-1}{E_J - E_{J-2}} \qquad (\hbar^2 \; MeV^{-1}).$$

[6 marks]

The diagram below gives the levels and γ-ray transitions (in MeV) of the ground-state rotational band of ^{158}Er. Calculate the moment of inertia I as a function of rotational frequency ω. Sketch your results and explain the features of this sketch.

[13 marks]



3. The binding energy term of the semi-empirical mass formula can be written as:

B(A,Z) = a_VA - a_SA$^{2/3}$ - a_C Z^2 A$^{-1/3}$ - a_{symm} $\frac{(A-2Z)^2}{A}$ + δ.

Briefly explain the physical origin of each term.

[15 marks]

For odd-mass nuclei show that the most stable nucleus of a given mass A has

$$Z = \frac{A}{2 + bA^{2/3}} ,$$

$$\text{where } b = \frac{a_C}{2a_{symm}}.$$

[7 marks]

Hence calculate the Z of the most stable element with A = 209.

[3 marks]

[a_C = 0.711 MeV; a_{symm} = 23.7 MeV]

4. Give a qualitative description of how the charge density distribution of a nucleus is determined from elastic electron scattering.

[11 marks]

Sketch a typical nuclear charge distribution, indicating and explaining the principal features.

[9 marks]

A 1 GeV electron scatters from a stationary ^{208}Pb nucleus at an angle of 30°. Calculate the momentum transfer for this scattering event in units of fm^{-1}.

[5 marks]