PC2302

ONE HOUR THIRTY MINUTES

A list of constants is enclosed.

UNIVERSITY OF MANCHESTER

Atoms and Nuclei

22nd May 2003, 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.

P.T.O.

1. (a) Estimate the energy of K_α X-rays of calcium (Z = 20). [5 marks]

(b) Briefly describe two atomic physics experiments that provided evidence for the existence of the intrinsic spin of the electron. [5 marks]

(c) The deuteron has only one bound state and this state has a total angular momentum $J = 1$. What does this tell us about the nucleon-nucleon force? [5 marks]

(d) What experimental data demonstrated the need to include an explicit pairing term into the semi-empirical mass formula? [5 marks]

(e) Explain the importance of delayed neutrons for the operation of a fission reactor. [5 marks]

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

$$B(A,Z) = a_V A - a_S A^{\frac{2}{3}} - a_C Z^2 A^{-\frac{1}{3}} - a_{symm} (A-2Z)^2 A^{-1} + \delta.$$

Explain the physical origin of each term. [15 marks]

Use this expression to calculate the energy released when $^{252}_{98}$Cf fissions symmetrically. [10 marks]

$a_V = 15.76$, $a_S = 17.81$, $a_C = 0.7105$, $a_{symm} = 23.8$ (in units of MeV)

3. Both α particles and electrons can be used to determine a "nuclear size". Compare the two probes with particular reference to the nature of the interactions between the probes and a nucleus. Hence explain why electrons can determine the *distribution* of charge in a nucleus. [6 marks]

Estimate the minimum kinetic energy of α particles bombarding a target of $^{124}_{50}$Sn that is required to probe nuclear effects. [6 marks]

Briefly describe the characteristics of experimental electron scattering data and how they are analysed to determine the nuclear charge distribution. [7 marks]

Estimate the energy of electrons needed to provide fine details of the charge distribution. [6 marks]

4. Sketch the radial probability distributions for the 1s and 3d states of the hydrogen atom. [6 marks]

The figure shows a schematic representation of the orbitals available for electrons in a multi-electron atom. Explain why the orbital sequence is different from the sequence of excited states of the H-atom. [8 marks]

What are the total degeneracies of each of the orbitals shown in the figure? Hence write down the electron configuration (i.e. which orbitals are occupied, by how many electrons) of the ground state of the sodium ($Z = 11$) atom. [6 marks]

Comment qualitatively on how the first ionisation potential and atomic radius of sodium compare with those for neon ($Z = 10$). [5 marks]