Royal Holloway

UNIVERSITY OF LONDON

MSci EXAMINATION

NUCLEAR PHYSICS CP4510A

SUMMER 1998

Time Allowed: TWO HOURS

Answer **TWO** questions only. No credit will be given for attempting a further question.

Each question carries 20 marks. The mark *provisionally allocated* to each section is indicated in the margin.

TURN OVER WHEN INSTRUCTED

CP4510A

PART MARKS

1. Why are approximate models of the nucleus needed? State in what ways the semi-empirical mass formula and the liquid drop model are useful, but also unsatisfactory. **[4]**

Independent nucleons moving in a central potential have levels grouped in energy as follows:

$$[1s][1p][1d, 2s][1f, 2p][1g, 2d, 3s]...$$

What type of additional potential might lead to levels grouped in the following way? **[2]**

$$\left[1s_{\frac{1}{2}}\right]\left[1p_{\frac{3}{2}}, 1p_{\frac{1}{2}}\right]\left[1d_{\frac{5}{2}}, 2s_{\frac{1}{2}}, 1d_{\frac{3}{2}}\right]\left[1f_{\frac{7}{2}}\right]\left[2p_{\frac{3}{2}}, 1f_{\frac{5}{2}}, 2p_{\frac{1}{2}}, 1g_{\frac{9}{2}}\right]\left[1g_{\frac{7}{2}}, 2d_{\frac{5}{2}}, 2d_{\frac{3}{2}}, 3s_{\frac{1}{2}}, 1h_{\frac{11}{2}}\right]...$$

Find the sequence of 'magic numbers' thus generated. **[4]**

Discuss the evidence for the significance of these numbers. **[6]**

Assuming that the shells are filled in the order written, what spins and parities should be expected for the ground state of following nuclei?

$$^{7}_{3}\mathrm{Li},\ ^{16}_{8}\mathrm{O},\ ^{17}_{8}\mathrm{O},\ ^{39}_{19}\mathrm{K},\ ^{45}_{21}\mathrm{Sc}$$

State any further assumption you make. **[4]**

2. Discuss the conditions necessary to observe nuclear resonance fluorescence. **[4]**

Why is it expected that resonant absorption should decrease at low temperatures and why does it increase in the case of the 129 keV gamma radiation from ^{191}Ir? **[4]**

Describe how the Mössbauer effect can be used for nuclear hyperfine measurements and also outline its use to verify the effect of gravity on electromagnetic radiation. **[8]**

The 129 keV gamma ray transition in ^{191}Ir was used in a Mössbauer experiment in which a line shift equivalent to the full width at half maximum (Γ) was observed for a source speed of 10 mm s^{-1}. What is the value of Γ and the mean lifetime of the excited state in ^{191}Ir? **[4]**

$$\left[\text{Use } \hbar = 6.58 \times 10^{-16} \text{ eV s}\right]$$

PART MARKS

3. Discuss the main features of the Fermi theory of beta-decay and explain the terms:
   (a) nuclear Coulomb factor,
   (b) nuclear matrix element,
   (c) Kurie plot. **[10]**

   Explain the classification of beta-decay transitions as Fermi or Gamow-Teller and as allowed or forbidden. Classify the following transitions (the spin parity, J^{π}, of the nuclear states are given in brackets):

   (a) $^{14}_{8}\mathrm{O}\ (0^+) \rightarrow {}^{14}_{7}\mathrm{N}\ (0^+) + \mathrm{e}^+ + \upsilon$,

   (b) $^{6}_{2}\mathrm{He}\ (0^+) \rightarrow {}^{6}_{3}\mathrm{Li}\ (1^+) + \mathrm{e}^- + \bar{\upsilon}$.

   Why is the transition

$$^{17}_{9}\mathrm{F}\left(\frac{5^+}{2}\right) \rightarrow {}^{17}_{8}\mathrm{O}\left(\frac{5^+}{2}\right) + \mathrm{e}^+ + \upsilon$$

   called a super-allowed transition? **[6]**

   Show that, for the beta-decay of low Z nuclei emitting electrons of high energy $\left(E_0 >> m_0c^2\right)$, the half-life is proportional to E_0^{-5}. State any assumptions made. **[4]**

   [You may assume that the electron momentum probability distribution is given by $P(p)dp \propto F(Z,p)|M|^2 p^2 (E_0 - E)^2 dp$]

END