

**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**

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:

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

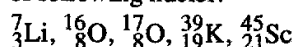
- What type of additional potential might lead to levels grouped in the following way? [2]

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

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?



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  ${}^{191}\text{Ir}$ ? [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  ${}^{191}\text{Ir}$  was used in a Mössbauer experiment in which a line shift equivalent to the full width at half maximum ( $\Gamma$ ) was observed for a source speed of  $10 \text{ mm s}^{-1}$ . What is the value of  $\Gamma$  and the mean lifetime of the excited state in  ${}^{191}\text{Ir}$ ? [4]

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

TURN OVER

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,  $J^\pi$ , of the nuclear states are given in brackets):

(a)  ${}^{14}_8\text{O} (0^+) \rightarrow {}^{14}_7\text{N} (0^+) + e^+ + \nu$ ,

(b)  ${}^6_2\text{He} (0^+) \rightarrow {}^6_3\text{Li} (1^+) + e^- + \bar{\nu}$ .

Why is the transition

$${}^{17}_9\text{F} \left( \frac{5^+}{2} \right) \rightarrow {}^{17}_8\text{O} \left( \frac{5^+}{2} \right) + e^+ + \nu$$

called a super-allowed transition?

[6]

Show that, for the beta-decay of low  $Z$  nuclei emitting electrons of high energy ( $E_0 \gg m_0c^2$ ), 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 ]  
$$P(p)dp \propto F(Z, p) |M|^2 p^2 (E_0 - E)^2 dp$$