NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

APPLIED PHYSICS DEPARTMENT

SPH 4103 NUCLEAR PHYSICS

EXAMINATION

BSc HONOURS PART IV: DECEMBER 2004 DURATION: 3 HOURS

ANSWER ALL PARTS OF QUESTION 1 IN SECTION A AND ANY THREE QUESTIONS FROM SECTION B. SECTION A CARRIES 40 MARKS WHILE SECTION B CARRIES 60 MARKS. DRAW NEAT DIAGRAMS WHEREVER NECESSARY.

Planck's Constant	h	$= 6.63 \times 10^{-34}$ Js
Boltzmann's Constant	k	$= 1.38 \times 10^{-23}$ JK^{-1}
Speed of light	c	$= 2.99 \times 10^{8}$ ms^{-1}
Charge on an electron	e	$= 1.60 \times 10^{-19}$ C
Mass of an electron	m_e	$= 9.10 \times 10^{-31}$ kg
Atomic Mass Unit	u	$= 1.66 \times 10^{-27}$ kg
Permittivity of free space	ε_o	$= 8.85 \times 10^{-12}$ Fm^{-1}
Permeability of free space	μ_o	$= 4\pi \times 10^{-7}$ Hm^{-1}

SECTION A

1. (a) Explain various nuclear disintegration processes. [6]

(b) What are the parities of the following electron states of the hydrogen atom?

(i) $\psi_{100} = \frac{1}{\sqrt{\pi}} \left(\frac{1}{a_0}\right)^{\frac{3}{2}} \exp -(\frac{r}{a_0})$

(ii) $\psi_{210} = \frac{1}{4\sqrt{2\pi}} \left(\frac{1}{a_0}\right)^{\frac{1}{2}} \frac{r}{a_0} (\exp -(\frac{r}{2a_0})) \cos\theta$

(iii) $\psi_{21-1} = \frac{1}{8\sqrt{2\pi}} \left(\frac{1}{a_0}\right)^{\frac{3}{2}} \frac{r}{a_0} (\exp -(\frac{r}{2a_0})) \sin\theta$

[3]

(c) Calculate the electrostatic self-energy of a uniformly charged sphere of total charge e and radius 1 fm. [4]

(d) Obtain an expression for the semi-empirical mass formula. [6]

(e) $^{8}_{4}Be$ decays to two alpha particles with a kinetic energy release of 0.094 MeV. Calculate its mean life time. Derive the formula you use. You may take $\tau_o = 7.0 \times 10^{-23}$ s. [8]

(f) $^{238}_{94}Pu$ decays by alpha emission: with a mean life of 128 years.

$$^{238}_{94}Pu \rightarrow ^{234}_{92}U + \alpha + 5.49 \text{ MeV}.$$

The mean lifetime of $^{234}_{92}U$ is much longer 2.5×10^{8} years. Space probes to the outer planets use $^{238}_{94}Pu$ as a power source. Estimate the mass of $^{238}_{94}Pu$ needed to supply a minimum of 1 kW of heat for 50 years. [8]

(g) Why unstable lighter nuclei for which A < 150 do not disintegrate by alpha decay process? [2]

(h) Why spontaneous fission process is not normally observed for $\frac{Z^2}{A} < 48$? [3]

SECTION B

2 (a) Derive the relation between the incident impact parameter and final asymptotic angle of deflection for alpha scattering process. Hence or otherwise find the number of such scattered alpha particles within a small solid angle $d\Omega$. [12]

(b) An infinitely collimated beam of alpha particles (z=2) having a current of 1 μA bombards a metal of thickness 2 g m^{-2} of an element of atomic weight 107.8. A detector of projected area 10^{-4} m^2 at a distance of 0.1 m from the foil counts 6×10^4 particles per second. Calculate the collision diameter if the angle of observation is 60°. [8]

3. (a) Explain the following terms:

(i) Leptons, (ii) Mesons and (iii) Baryons. [3]

(b) Name the four basic interaction field found in nature. Illustrate with a neat diagram the scales over which these reactions act. What is the collective name given to the particles that take part in strong interaction? [4]

(c) Discuss briefly the transmission of a plane wave past a potential barrier. [5]

(d) Find an expression for the transmission probability of an alpha particle penetrating the potential barrier. Show that

$$G = \frac{\pi}{\hbar\, c}\left(\frac{Z_d\, e^2}{2\,\pi\,\varepsilon_o}\right)\sqrt{\frac{2\,m\,c^2}{B_c}}\;\;\gamma\left(\frac{R_c}{b}\right)$$

where the symbols have their usual meanings. [8]

4 (a) Which of the nuclides decay by β^- and β^+ disintegration processes? [4]

(b) Obtain an expression for the momentum spectrum for the electrons emitted in allowed β transition. Discuss briefly the outcome of the theory. [10]

(c) The atomic masses of $^{74}_{32}$ Ge, $^{74}_{33}$ As $^{74}_{34}$ Se are 73.9218, 73.92393 and 73.92248 in AMU. Calculate the Q values for the possible decay schemes linking these nuclei. You may disregard the electron binding energy. [6]

5 (a) How fusion energy is produced? Give the conditions and advantages of fusion reactor. [8]

(b) Explain the principle of a Tokamak reactor. [4]

(c) Outline the theoretical considerations of magnetic confinement in a Tokamak reactor. Give in brief the operational details of the fusion power plant. [8]

6. Write short notes on:

(a) Betatron
(b) Scintillation Detector
(c) Spontaneous fission
(d) Cyclotron. [20]

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