NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

APPLIED PHYSICS DEPARTMENT

SPH 2205 ATOMIC AND NUCLEAR PHYSICS

BSc HONOURS PART II : MAY 2002 DURATION: 3 HOURS

ANSWER ALL QUESTIONS IN SECTION A AND ANY THREE QUESTIONS IN SECTION B. SECTION A CARRIES 40 MARKS AND SECTION B CARRIES 60 MARKS.

Some fundamental constants in Physics

Elementary charge	e	=	1.60×10^{-19}C
Electron rest mass	m_e	=	9.11×10^{-31}kg
Proton rest mass	m_p	=	1.67×10^{-27}kg
Neutron rest mass	m_n	=	1.68×10^{-27}kg
Planck constant	h	=	6.62×10^{-34}JS

SECTION A

1. (a) Explain the reasons for the fact that the sizes of all the atoms are about the same? [4]

(b) State Pauli's exclusion principle [3]

(c) The value of an antisymmetic total eigenfunction changes when its particle labels are exchanged. Explain why such eigenfunctions are used to give an accurate description of a system of electrons. [4]

(d) Write down the lowest energy terms for the ground states of $^{56}_{28}Ni$, $^{60}_{29}Cu$ and $^{62}_{30}Zn$. [6]

(e) Write down any form of the three-electron eigen function showing that:

(i) It is antisymetric with respect to the change of labels. [5]

(ii) It is identically equal to zero, if any two of the electrons have the same space and spin quantum numbers. [5]

(f) (i) Give two examples each of the following: Leptons, Mesons and Baryons. [6]

(ii) State the criteria on which on which this classification of particles is based on. [3]

(g) Which of the above group of particles take part in strong interactions and what is the collective name given those particles, which take part in strong interactions? [4]

SECTION B

2. (a) For an atomic state with quantum numbers $L = 2$, $S = 1$ and $J = 3$ find the angle between the total magnetic moment and the direction antiparallel to the total angular momentum. [6]

(b) Determine the ground state configuration for the atoms Mg (Z = 12), Al (Z =13) and Si (Z =14) [7]

(c) Predict the L - S coupling quantum numbers for the ground state of each of the elements in 2 (b) above. [7]

3. (a) Explain what is meant by " independent particle model" of the atom. [6]

(b) Write down the total Hamiltonian operator for the Lithium atom, stating which terms are added or ignored, if the independent particle model is adopted for the Lithium atom. [7]

(c) Given that the normalized wave function for a two electron atom is

$$\varphi(r_1, r_2) = \tfrac{1}{2}K[\phi_a(r_1)\varphi_b(r_2) - \varphi_a(r_2)\varphi_b(r_1)]$$

Find the value for K if each electron wave function is the normalized. [7]

4 (a) Calculate the angle between the total orbital and spin angular momenta for the ${}^4D_{3/2}$ state. [3]

(b) Give the S-, L-, and J- values for the terms ${}^2S_{1/2}, {}^3P_2, {}^3F_4, {}^5D_1 and {}^6F_{9/2}$ [4]

(c) (i) Estimate the minimum accelerating voltage required for an X-ray tube with a W (Z = 74) anode to emit a L_β line of its spectrum. [8]

(ii) Also estimate the wave length of the K_α photon for this atom. [5]

5. (a) Explain the fact that fusion of low – A nuclei in thermal motion is the source of energy from the sun. [5]

(b) In the following fusion reaction of two heavy hydrogen nuclei

$^2_1H + ^2_1H \rightarrow X + Y + 3{;}2MeV$

Find the products X and Y of this reaction and name the energy 3,2 MeV released in this reaction. [6]

(c) Explain, which of the two reactors, "fusion" or "fission" is more difficult to build? You should include diagrams and the principle involved in working of the reactors to support your answer. [10]

6. (a) What is the name given to the resultant angular momentum **I** of a nucleus? Also give the magnitude of **I** defining all the quantities involved. [4]

(b) If this angular momentum is designated as **I** what is its magnitude? [4]

(c) What are the possible values of its components in the Z – direction? [6]

(d) If the Z – component of the angular momentum is $L_z = \hbar m_l$ show that the Z – component of the orbital magnetic moment for a proton in a nucleus is given by:

$M_{L_z} = \mu_N m_l$

Name the constant μ_N and find its value. [6]

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