

NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

APPLIED PHYSICS DEPARTMENT

SPH 4102 – NUCLEAR PHYSICS

BSc HONOURS PART IV: DECEMBER 2005

DURATION: 3 HOURS

ANSWER **ALL** PARTS OF QUESTION **ONE** IN SECTION A AND ANY **THREE** QUESTIONS FROM SECTION B. SECTION A CARRIES 40 MARKS AND SECTION B CARRIES 60 MARKS.

m_p	=	1.007825 u
m_n	=	1.008665 u
$M({}_{8}^{16}O)$	=	15.003065 u
$M({}_{8}^{17}O)$	=	16.999160 u
$M({}_{8}^{15}O)$	=	15.0003065 u
$M({}_{7}^{15}O)$	=	15.000109 u
a_1	=	15.760
a_2	=	17.810
a_3	=	0.711
a_4	=	23.702
a_5	=	34

SECTION A

- What is the minimum photon energy needed to dissociate 2_1H ? [4]
 - The empirical Weizsacker formula contains four terms:
 - plot each of the terms as a function of A. [6]
 - state the relative importance of each term including the fifth term. [6]
 - If the most stable nucleus with a given mass number A is that which has the maximum value of the binding energy, calculate the atomic number of the most stable nucleus for a given mass number A. [6]
 - What nuclei have a radius equal to one – half the radius of ${}^{236}U$. [4]

- (e) How much energy is required to remove a proton from ^{16}O and ^{17}O [4]
- (f) For the original Berkeley cyclotron ($R = 12.5 \text{ cm}$, $B = 1.3\text{T}$), calculate the maximum proton energy (in MeV) and the corresponding frequency of the varying voltage. [6]
- (g) Explain why it is thought that the nuclear force has a repulsive core. [4]

SECTION B

2. (a) Give an expression for the binding energy of a nucleus ${}_Z^AX$ given that its atomic mass is M . [5]
- (b) (i) From the known mass of ${}^{15}_7\text{N}$ and ${}^{15}_8\text{O}$ calculate the difference in binding energy. [7]
- (ii) Assuming that the binding energy difference arises from the difference in the Coulomb energy calculate the nuclear radius of ${}^{15}_8\text{O}$ and ${}^{15}_7\text{N}$. $m({}^{15}_7\text{N}) = 15.00109u$ $m({}^{15}_8\text{O}) = 15.003065u$ [8]
3. (a) (i) Draw a labeled diagram showing the potential that an α - particle feels when it approaches and is captured by a heavier nucleus. [8]
- (ii) Show the wave function profile in all regions that the α - goes through. [8]
- (b) Explain why it is believed the nuclear force is of short range. [4]
4. (a) Estimate the Coulomb repulsion energy of the two protons in ${}^3_1\text{H}$ assuming that they are 1.7 fm apart. [4]
- (b) Estimate the kinetic energy of a nucleon inside a nucleus, both by using the quantum - mechanical picture of a particle in a box of width 10^{-15} m and by considering the de Broglie wavelength λ of the nucleon which is of the order of $2\pi r$ where r is 10^{-15} m . [8]

- (c) A simple empirical approximation for the nuclear potential is the Yukawa potential $E_p(r) = E_0 r_0 e^{-r/r_0}$ where $E_0 = 50 \text{ MeV}$, $r_0 = 1.5 \text{ fm}$. Plot the Yukawa potential for $r = 0.1r_0, 0.5r_0, r_0, 1.5r_0, 2r_0$ and $3r_0$ and compare with the electric potential energy of two protons at the same separation. [8]
5. (a) What is a photo nuclear reaction? [4]
- (b) For a photo nuclear reaction: $^{24}\text{Mg}(\gamma, n)^{23}\text{Mg}$ determine the threshold energy of the photon. The rest masses of the parent and product nuclides are 23.98504 and 22.99412 u respectively. [6]
- (c) When ^7Li is bombarded by 0.70 MeV protons, two α - particles are produced, each with 9.0 MeV kinetic energy.
- (i) Calculate the Q of the reaction. [5]
- (ii) Calculate the difference between the total kinetic energy of the α - particle and the kinetic energy of the initial proton in the Li - frame. [5]
6. (a) Explain the fission and fusion processes pointing out which one of the two is more difficult to achieve and why? [6]
- (b) Assuming a magnetic field of 1.4T, calculate the maximum energy of protons, deuterons and α 's that can be obtained from a cyclotron of 75 cm. [4]
- (c) In the SLAC electron linac, electrons are accelerated to 30 GeV.
- (i) What is the difference in ms^{-1} between the electron's speed and the speed of light? [5]
- (ii) What would be the energy of a proton moving at the same speed? [5]

- END OF EXAMINATION -