THE OPEN UNIVERSITY OF SRI LANKA
B.Sc. DEGREE PROGRAMME - LEVEL 03
FINAL EXAMINATION - 2006/2007
PHU 3143/PHE 5143 – ATOMIC AND NUCLEAR PHYSICS
TIME ALLOWED : TWO AND A HALF (02 ½) HOURS

Date : 26th April 2007 Time : 10.00 a.m. 12.30 p.m.

[Avogadro's Number = 6.02×10^{26} Atoms per Kmole,

$\frac{1}{4\pi \epsilon_0}$ = 9×10^9 Nm^2 C^{-2},

e = 1.6×10^{-19} C,

1U = 931.5 MeV,

1MeV = 1.6×10^{-13}J,

m_e = 9.1×10^{-31} Kg.

h = 6.625×10^{-34} Js,

C = 3×10^8 ms^{-1}]

1. a) Estimate the average mass density of a sodium atom assuming its size to be about 2.5 $\overset{0}{A}$. Compare it with the density of sodium in its crystalline phase 970kgm^{-3}. Are the two densities of the same order of magnitude?

b) Nuclear sizes roughly obey the following empirical relation $r = r_0 A^{1/3}$ where r is the mean radius of the nucleus, A its mass number and r_0 is a constant equal to about 1.2f. Show that the rule implies that the nucleus mass density is nearly constant for different nuclei. Estimate the mass density of sodium nucleus (^{23}Na). Compare it with the average mass density of sodium atom obtained above in (a). (If = 10^{-15} m).

c) In a Ruthesford sealtering experiment a bean of alpha particles, each with charge $q_\alpha = 2e$ and energy E_α = 1MeV is incident on a gold foil. What is the distance of closest possible approach d of an alpha particle to a gold nucleus (charge q_{AU}=79e)?

What is the ratio of an alpha particle's kinetic energy T_α, and its electric potential energy U when it is a distance 2d from a gold nucleus?

d) An accelerator creates an electron beam equivalent to a current of I = 10^{-4} A and energy $E_e = 10^6$ eV per electron. How many electron would hit a target in 1 sec and how much energy would be deposited if the electrons stay in the target?

02. a) Binding energy can be looked upon as a direct measure of nuclear stability. Why?

b) When fission occurs, several neutrons are released and the fission fragments are beta radioactive. Why?

c) Why does fusion reaction take place only at high temperature?

d) A coin has a mass of 3.0gms. Calculate the nuclear energy that would be required to separate all the neutrons and protons in this coin. Ignore the binding energy of the electrons, and for simplicity assume that the coin is made entirely of ${}^{63}_{29}Cu$ atoms (of mass 62.92960 U). The masses of the proton and the neutron are 1.00783 and 1.00867u respectively.

e) The fusion reaction $2{}^{2}_{1}H \rightarrow {}^{4}_{2}He +$ energy, is proposed to be used for the production of industrial power. Assuming the efficiency of the process to be 30%, find how many kilograms of deuterium will be consumed in a day for an output of 50 megawatts.

[Mass of :
${}^{2}_{1}H = 2.014102U$,
${}^{4}_{2}He = 4.002604U$.]

03. a) Investigate theoretically the problem of growth and decay of a radioactive substance which is the decay of another radioactive substance. Explain secular equilibrium and transient equilibrium.

b) A radium source contains 1.00 milligram of ^{226}Ra, which decays with a half life of 1600 years to produce ^{222} Rn, a nobel gas. This radon isotope in turn decays by alpha emission with a half life of 3.82 days.

i. What is the rate of disintegration of ^{226} Rn in the source?

ii. How long does it take for the radon to come to secular equilibrium with the radium parent?

iii. At what rate is the radon then decaying?

iv. How much radon is in equilibrium with its radium parent?

04. a) The quantization condition of Bohr's theory of the hydrogen atom is $m_e v_n r_n = \frac{nh}{2\pi}$, where v_n, r_n are velocity and radius of the n^{th} electron orbit. Use Bohr's quantization condition and classical mechanics to find the total energy of a single electron revolving round a stationary nucleus (of charge Ze where Z is the atomic number and e is the magnitude of the electron charge) in the n^{th} orbit.

b) It required 47.2 eV to excite the electron from the second Bohr orbit to the third Bohr orbit. Find

i. the value of Z

ii. the energy required to excite the electron from third to the fourth Bohr orbit.

iii. the wavelength of the electromagnetic radiation required to remove the electron from the first Bohr orbit to infinity.

iv. the radius of the first Bohr orbit.

v. the kinetic energy, potential energy and the angular momentum of the electron in the first Bohr orbit.

05. i. Show in Rutherford's analysis of the scattering of alpha particles by thin foils the angle of scattering of an incident particle ,ϕ, is given by : $Cot\, \phi/2 = 4\pi \in_0 (\frac{Mv^2}{ZeE})p$. Where M,v and E are the mass, velocity and charge respectively of the alpha particle and p is the impact parameter, Z is the atomic number of the material of the scattering foil.

ii. Use the above expression to derive a relation for the probability that the particle should be scattered through an angle greater than ϕ on passing through a thin foil.

iii. An alpha particle that has been accelerated through a potential difference of 10^5 volts is incident normally on a foil of copper 10^{-4} cm thick. Copper has density 8.8 x 10^3Kg m^{-3}. Calculate the probability that the alpha particle will be scattered through an angle less than 60^{0}.

[Atomic number of copper =29, Atomic weight of copper = 63.540000u.]

06. a) Find an expression for the coulomb energy of a nucleus with atomic number Z. Discuss the other factors which contribute to the binding energy of nuclei and derive a formula for the atomic man M(Z,A). Show that for odd A isobars;

$$M(Z,A) - M(Z_0,A) = \gamma(Z-Z_0)^2.$$

Where γ is a coefficient depending upon A, and Z_0 is the charge of the most stable isobar.

b) Evaluate γ and Z_0 for A=51 from the following reactions.

$^{51}_{23}V(p,n)^{51}_{24}Cr$, Q = -1.53MeV,

$^{3}_{1}H\,(p,n)^{3}_{2}He$, Q = -0.76 MeV,

$^{51}_{22}Ti \rightarrow \beta^- + ^{51}_{23}V + 2.44\text{ MeV}$,

$^{3}_{1}H_2 \rightarrow \beta^- + ^{3}_{2}He_1 + 0.02\text{MeV}$.