THE OPEN UNIVERSITY OF SRI LANKA

B.Sc. DEGREE PROGRAMME - LEVEL 05

FINAL EXAMINATION – 2007/2008

PHU 3143/PHE 5143 – ATOMIC AND NUCLEAR PHYSICS

TIME ALLOWED : TWO AND A HALF (02 ½) HOURS

014

Date : 09th June 2008 Time : 10.00 a.m. 12.30 p.m.

[Avogadro's Number = 6.025×10^{23} atoms per mol,
Plank's constant = 6.63×10^{-34} J.S,
Mass of the electron = 9.11×10^{-31} Kg,
Mass of the proton = 1.67×10^{-27} Kg,
Velocity of light = 3.0×10^{8} ms^{-1},
Charge of the electron = 1.60×10^{-19}C,
Permittivity of free space ϵ_0 = 8.85×10^{-12} Fm^{-1}
1 u = 931 MeV,]

1. a) A linear accelerator produces a pulsed beam of electrons. The pulse current is 0.50A, and pulse duration is 0.10 μs.

   i. How many electrons are accelerated per pulse?

   ii. What is the average current for a machine operating at 500 pulses/s?

   iii. If the electrons are accelerated to an energy of 50 MeV, what are the average and peak powers of the accelerator?

   b) The radius of a nucleus is 10^{-14}m. The maximum energy of a β - particle ejected by the nucleus is 3 MeV. Discuss the possibility of an electron being present inside the nucleus.

   c) Applying uncertainty principle, show that the presence of protons in a nucleus is entirely plausible.

02. a) Derive Bohr's formula:-

$$E_n = \frac{-me^4}{8\epsilon_0^2 n^2 h^2}$$

for the allowed energies of the hydrogen atom, discussing the assumptions in your derivation.

b) A photon incident upon a hydrogen atom ejects an electron with a kinetic energy of 10.7 eV. If the ejected electron was in the first excited state, calculate the energy of the photon.
What is the kinetic energy would have been imparted to an electron in the ground state?

03. a) Give an account of the variation of the binding energy per nucleon in an atomic nucleus with the mass number for stable nuclides.

b) When ^{30}Si is bombarded with a deuteron, ^{31}Si is formed in its ground state with the emission of a proton. Determine the energy released in this reaction from the following information.

$$^{31}\text{Si} \longrightarrow {}^{31}\text{P} + \beta^- + 1.50 \text{ MeV},$$
$$^{30}\text{Si} + \text{d} \longrightarrow {}^{31}\text{P} + \text{n} + 5.10 \text{ MeV},$$
$$\text{n} \longrightarrow \text{P} + \beta^- + 0.78 \text{ MeV}.$$

c) In the reaction $^{2}_{1}\text{H} + {}^{2}_{1}\text{H} \longrightarrow {}^{2}_{3}\text{He} + {}^{1}_{0}n + \text{Q}$, the energy released is 3.26 MeV. If the masses of the atoms of deuterium and helium three are 2.0147 u and 3.0170 u respectively, find the mass of the neutron.

04. a) Explain the processes:-

i. β - decay ii. positron emission iii. electron capture and
iv. inverse β - decay

What is the difference between electron capture and positron emission.
Why electron capture and positron emission are said to compete each other.

b) Based on the liquid drop model the binding energy (B.E)of a nucleus of proton number Z and mass number A can be written as;

$$B.E = 14.0\,A - 0.584\,\frac{Z(Z-1)}{A^{1/3}} - 13.1\,A^{2/3} - 18.1\,\frac{(A-2Z)^2}{A} + E_8 \text{ MeV}.$$

where $E_8 = \frac{135}{A}$, O or $-\frac{135}{A}$ according to the odd – even properties of (Z,A). Derive an expression for the atomic number of the most stable isotope of a set of isobars and hence discuss the possible modes of decay of even A = 64 isobars.

05. a) Describe briefly Giger and Marsden's experiment on the scattering of alpha particles by thin foils.

b) Given that the angle of scattering is $2\tan^{-1}\frac{a}{2b}$, where a is the least possible distance of approach, and b is the impact parameter, calculate what fraction of a beam of 0.5 MeV deutrons will be scattered through more than 90^0 by a foil of thickness 10^{-7}m of a metal of density 5×10^3 kg/m^3 atomic weight 100g and atomic number 50.

06. a) Define the activity of a radioactive isotope. What is meant by (i) transient (ii) sealer equilibrium, when applied to radioactive process?

b) The isotopes ^{238}U and ^{235}U occur in nature in the ration 140:1. Assuming that at the time of earth's formation they were present in equal ratio, make an estimate of the age of the earth. The half lives of ^{238}U and ^{235}U are 4.5×10^9 years and 7.13×10^8 years respectively.

c) The radioactive isotope $^{14}_{6}C$ does not occur naturally, but is formed at a constant rate by the action of cosmic rays on the atmosphere. It is taken up by plants and animals and deposited in the body structure along with natural carbon, but this process stops at death. The charcoal from the five pit of an ancient camp has an activity due to $^{14}_{6}C$ of 12.9 disintegrations per minute, per gram of carbon. If the percentage of $^{14}_{6}C$ compared with normal carbon in living trees is 1.35×10^{-10} %, the decay constant is 3.92×10^{-12} sec^{-1}, and atomic weight 12.01g, what is the age of the camp site?