THE OPEN UNIVERSITY OF SRI LANKA

B.Sc. DEGREE PROGRAMME - LEVEL 05

FINAL EXAMINATION – 2008/2009

PHU 3143/PHE 5143 – ATOMIC AND NUCLEAR PHYSICS

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

Date : 17th June 2009 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.]

01. i. Two vertical parallel plates are spaced 20mm apart. A charged oil droplet is observed falling between the two plates at a constant speed of 0.08mm s^{-1} vertically downwards.

Calculate:-

a) the droplet's radius gien the viscous force equals 3.34×10^{-4} RV where R is the droplet's radius and V is the speed. Density of oil = $900kgm^{-3}$.
b) The droplet's mass
c) The charge on the droplet if a potential difference of 480 V across the plates makes it move downwards at 45^0 to the vertical at steady speed. (acceleration due to gravity = 9.8 ms^{-2})

ii. Electrons in a narrow beam travelling at a steady speed of 5×10^7 ms^{-1} are directed into the space between two oppositely charged parallel plates 50mm apart. The potential difference between the plates is 2500V. The initial direction of the beam is parallel to the plates.

Calculate:-

a) the force on each electron between the plates.
b) the time each electron spends between the plates if the plates are each 100mm in length.
c) the speed and direction of the electrons on leaving the plates.
d) A fluorescent screen is positioned 300mm from the end of the plates of right angles to the plates so that the beam of electrons hit the screen after passing through the plates. Calculate the displacement of the spot on the screen produced by the electrons when the plates potential difference is switched from off to on.

iii. 5 Mev alpha particles are directed at a sheet of polythene causing protons to be knocked out from the nuclei of the sheet.

Calculate:-

a) the initial speed of the alpha particles, given the specific charge of an alpha particle is 4.79×0^7 C Kg^{-1},

b) the maximum speed of ejection of the protons from the sheet.
Assume a head – on collision between an alpha particle (mass = 4u) and a stationary proton (mass = 1u.)

02. a) Radioactive disintegration is a random process yet it is possible to calculate reasonably accurately the number of atoms in a radioactive source of known activity and half-life. Explain why?

b) Living wood has an activity of 16.0 counts min^{-1} g^{-1} which is due to the disintegration of carbon – 14 atoms in the wood. The half-life of ^{14}C is 5568 years. Calculate the number of carbon -14 atoms in 1g of living wood.

c) A sample of wood of mass 0.5g from an ancient ship is found to have an activity of 6.5 counts min^{-1}. Calculate the age of the ship

d) The back-up power of a certain satellite is provided by the heat generated by a radioactive source. Calculate the mass of $^{226}_{88}Ra$ that will generate 50W of power. The half life of Ra-226 is 1620 years and it units 4.78 MeV alpha particles.

03. a) Natural uranium contains 0.7% U – 235($ie\,^{235}_{92}U$). When a U^{-235} nucleus is fissioned, approximately 200 McV of energy is released.
Calculate the total energy released, in joules, when the U-235 content of 1Kg of natural uranium is completely fissioned.

b) One of the fusion processes by which energy is generated inside the Sun is called the proton – proton cycle. This involves fusing four protons step by step to form a helium -4 nucleus.

$$^1_1p + {}^1_1p \rightarrow {}^2_1H + {}^0_{+1}\beta(positron) + Q_1$$

$$^2_1H + {}^1_1p \rightarrow {}^3_2He + Q_2$$

$$^3_2He + {}^3_2He \rightarrow {}^4_2He + 2{}^1_1p + Q_3.$$

Calculate the energy released in each reaction, and hence calculate the total energy released when four protons are fused to form a ${}_{2}^{4}He$ nucleus.
Masses in u : proton 1.00728, positron 0.00055

${}_{1}^{2}H$ atom 2.01410,

${}_{2}^{3}He$ atom 3.01603,

${}_{2}^{4}He$ atom 4.00260.

c) The Sun radiates energy into space at a rate of 4×10^{26} W. Its mass is 2×10^{30} kg. Estimate its lifetime, assuming that 0.7% of its mass can be converted into energy.

04. a) Explain how a beam of electrons may be produced in a vacuum tube, and describe an arrangement by which the beam may be deflected by a magnetic field. Draw a diagram showing clearly the directions of the beam, the field and the deflection.

b) An electron moving at velocity V passes simultaneously through a magnetic field of uniform flux density B and an electric field of uniform intensity E. It emerges with direction and speed unaltered.

i. Explain how the fields are arranged to achieve this results.
ii. Derive the relationship between V, B and E.

c) An electron is travelling at 2.0×10^{6} ms^{-1} at right angles to a magnetic field of flux density 1.2×10^{-5} T; its path is a circle.
Uniform circular motion of an electron is accompanied by the emission of electromagnetic radiation of the same frequency as that of the circular motion.
[Take the specific charge of the electron e/me to be 1.8×10^{11} Ckg^{-1}, and the speed of the electromagnetic radiation in air C to be 3×10^{8} ms^{-1}]

i. Explain why the path of the electron is a circle.
ii. Calculate the radius of the circle.
iii. Calculate the frequency of the circular motion of the electron.
iv. Calculate the wavelength of the electromagnetic radiation emitted and identify in which part of the electromagnetic spectrum this radiation lies.
v. How would this wavelength be affected by a decrease in the speed of the electron?

05. a) State Bohr's postulates and use them to determine the expression for total energy of the electron in a hydrogen atom in the n^{th} state. Explain hydrogen spectrum on the basis of it. What are the limitations?

b) How much energy is required to raise hydrogen form the ground state n = 1 to the excited state n = 5? What is the wavelength of the line emitted if the atom returned directly to the ground state again?

06. a) Describe briefly Geiger and Marsden's experiment on the scattering of alpha-particles by thin foils.

b) In Rutherford's analysis of scattering of alpha particles by thin foils prove that the angle of scattering of an incident alpha particle θ is given by;

$$Cot\frac{\theta}{2} = \frac{2b}{a}$$ where a is the closest distance of approach and b is the impact parameter.

c) The kinetic energy of alpha particles in the Geiger-Marsden's experiment was 7.7 MeV. Calculate what fraction of a beam of such alpha particles is scattered through angles of more than 45^0 when incident upon a gold foil of 3×10^{-7}m thick.
[Atomic weight of gold = 197 kg,
Density of gold = 19300 Kg m^{-3},
Atomic number of gold = 79]