The Open University of Sri Lanka
B.Sc. Degree Programme – Level 05
Final Examination – 2009/2010
Atomic and Nuclear Physics
PHU 3143 / PHE 5143

Duration: Two and a Half Hours (2½ Hrs.)

Date: 17.06.2010 **Time: 09.30 am *to* 12.00 noon**

Some useful physical constants

Electron mass, m_e,	=	9.109×10^{-31} kg
Elementary charge, e,	=	1.602×10^{-19} C
Permittivity of free space, ε_0,	=	8.854×10^{-12} C^2 N^{-1} m^{-2}
Planck's constant, h,	=	6.626×10^{-34} J s
Speed of light, c,	=	2.998×10^{8} m s^{-1}

ANSWER FOUR QUESTIONS ONLY

1. (a) What are alpha particles? Describe briefly the Rutherford's atomic model and Rutherford's alpha particle scattering theory.

   (b) Using Rutherford's atomic model, find the probability per unit solid angle of scattering of alpha particles of energy E through an angle θ from a foil of thickness t containing N atoms per unit volume. State your assumptions, if any, clearly.

   (c) An alpha particle, having an impact parameter 150 fm, is found to scatter through 30^o when incident on a silver foil (Atomic number for Ag = 47). Calculate the energy of the alpha particle.

2. (a) Assuming circular orbits and Coulomb force between the electron and the nucleus, show that the energies ($\boldsymbol{E_n}$) of the quantum states of hydrogen can be given by,

$$\boldsymbol{E_n} = -\frac{\boldsymbol{me^4}}{\boldsymbol{8\,\varepsilon_0^2\,h^2}}\left(\frac{\boldsymbol{1}}{\boldsymbol{n^2}}\right) \qquad \text{n = 1, 2, 3 ...}$$

   where m is mass of the electron, e is the charge on the electron, h is the Planck's constant, $\boldsymbol{\varepsilon_0}$ is the permittivity of free space and n is the quantum number.

(b) Derive an expression for the wavelength λ of a photon emitted corresponding to an electronic transition from a higher energy state n_h to a lower energy state n_l.

(c) The Balmer series for hydrogen atom corresponds to electronic transitions from higher energy states to the state with quantum number n_l = 2. Find the longest wavelength photon emitted in the Balmer series and determine its frequency and energy.

3. (a) Explain briefly what is meant by the spin – orbit interaction for an electron.

(b) Determine the magnetic moment *(μ)* of an electron moving in a circular orbit of radius *r* about a proton, in terms of r, *m* (mass of the electron), and *e* (charge on the electron).

(c) Calculate the frequency *(ω_p)* of precession of orbital magnetic moment of an electron in a magnetic field *B*.

4. (a) Write down the semi-empirical mass formula for the mass on an atom, stating clearly the assumptions made, if any.

(b) Describe the significance of each term in the semi-empirical mass formula.

(c) Show that for isobaric nuclei, the mass *m* (*Z, A*) can be expressed in the parabolic form,

$$m(Z, A) = aA + bZ + cZ^2 \pm \delta$$

where, *Z* is atomic number, *A* is mass number, δ is pairing energy and a, b, & c are constants.

5. (a) Explain the nature of radioactivity. Describe the meaning of the terms *activity*, *decay constant*, *half-life* and *mean life*.

(b) Deduce the exponential law of decay, stating clearly the assumptions made.

(c) The activity of a radioisotope sample is found to decrease by a factor of 8 in 36 hours.

(i) Find the half-life of the radioisotope.

(ii) Find the decay constant of the radioisotope.

(iii) If the present activity of the sample is 400 mCi, what will be the activity after 72 hours?

6. (a) Write down the characteristics of the four fundamental forces in nature.

   (b) Discuss briefly the conservation laws in particle interaction.

   (c) Which of the following reactions are forbidden? Justify your answer?

   (i) $n^0 \longrightarrow p^+ + e^- + \tilde{\gamma}_e$

   (ii) $p^+ \longrightarrow e^+ + \gamma$

   (iii) $\pi^- \longrightarrow \mu^- + \tilde{\gamma}_\mu$

   (iv) $p^+ + \pi^- \longrightarrow \Lambda^0 + K^0$

   (v) $p^+ + p^+ \longrightarrow 2n^0 + 2e^+$

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