RAJARATA UNIVERSITY OF SRI LANKA
FACULTY OF APPLIED SCIENCES

Bachelor of Science in Applied Sciences
Second Year Semester II Examination – Jan / Feb 2023

PHY 2106 – ATOMIC AND NUCLEAR PHYSICS

Time: One and a half ($1\ ^1/_2$) hours

Answer All Questions.

Unless otherwise specified, symbols have their usual meaning.

A non-programmable calculator is permitted.

Electron mass, m_e	$= 9.11 \times 10^{-31}$ kg	Rydberg constant, R	$= 1.097 \times 10^{7}$ m^{-1}
Proton mass, m_p	= 1.0072765 u	Planck constant, h	$= 6.624 \times 10^{-34}$ Js
Neutron mass, m_n	= 1.0086650 u	Speed of light, c	$= 3.0 \times 10^{8}$ ms^{-1}
Reduced Planck constant, $\hbar = 6.624 \times 10^{-34}$ Js		1 eV	$= 1.6 \times 10^{-19}$ J

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1) a) Explain how Rutherford's experiment on alpha particle scattering led to the concept of nuclear model of atom. Clearly indicate observations and conclusion of the experiment.

(03 marks)

b) How does Rutherford's model of the atomic structure differ from Bohr model?

(03 marks)

c) An electron in a Hydrogen atom transitions from the energy level $n = 6$ to 2 .

i. Determine the wavelength of the photon.
ii. Calculate the energy of the emitted photon.

(04 marks)

d) An electron is confined between two impenetrable walls of 0.3 nm apart.

i. Determine the energy of the electron at energy levels for n = 1, 2, 3, separately in eV.
ii. Find the speed of the electron in the n = 1 state.

(05 marks)

Contd.

e) i. Define the term "space quantization".

(03 marks)

ii. Consider an atomic electron in the $n = 3$ state.

a. Write down all possible angular momentum (l) and magnetic quantum numbers (m_l).

(06 marks)

b. Calculate the magnitude L of the orbital angular momentum and the allowed values of L_Z.

(06 marks)

2) a) List three quantities that are conserved in a nuclear reaction.

(03 marks)

b) A nuclear reaction is denoted as ${}^{17}_{8}O\ (n,\alpha)\,{}^{14}_{6}C$

i. Define the Q value of a reaction.

(02 marks)

ii. Define the terms exothermic and endothermic in a nuclear reaction.

(04 marks)

iii. Write down the above reaction in a usual manner separating the products and the reactants.

(02 marks)

iv. The nuclear masses of ${}^{17}_{8}O$, ${}^{4}_{2}He$ (α) and ${}^{14}_{6}C$ are 16.999131 u, 4.002603 u, and 14.000000 u respectively. Identify the above reaction is exothermic or endothermic for each of elements.

(04 marks)

3) a) Define the terms, "nuclear binding energy" and "mass defect".

(04 Marks)

b) Sketch the variation graph of binding energy per nucleon with the atomic mass number. Briefly explain, how it accounts for nuclear fission and fusion.

(05 Marks)

c) From the liquid drop model of nucleus, a semi-empirical mass formula of an atom can be obtained;

$$m_N(A,Z) = Zm_p + (A-Z)m_n - \left[a_v A - a_s A^{\frac{2}{3}} - a_c \frac{Z^2}{A^{\frac{1}{3}}} - a_a \frac{(A-2Z)^2}{A} \pm a_p \frac{1}{A^{\frac{3}{4}}}\right] / c^2$$

Where the symbols have their usual meanings.

i. Evaluate the binding energy of ${}^{22}_{10}Ne$ in MeV. Given that, $a_v = 15.6\ MeV, a_s = 16.8\ MeV, a_c = 0.72\ MeV, a_a = 23.3\ MeV$ and $a_p = 34.0\ MeV$.

(03 marks)

ii. Calculate the binding energy per nucleon.

(03 marks)

End.