



THE CATHOLIC UNIVERSITY OF EASTERN AFRICA

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MAIN EXAMINATION

SEPTEMBER – DECEMBER 2019 TRIMESTER

FACULTY OF SCIENCE

DEPARTMENT OF PHYSICS

REGULAR PROGRAMME

PHY 306: INTRODUCTORY NUCLEAR PHYSICS

Date: DECEMBER 2019

Duration: 2 Hours

INSTRUCTIONS: Answer Question ONE and ANY other TWO Questions

Physical Constants

Mass of proton, $m_p = 1.007276 \text{ u}$

Mass of neutron $m_n = 1.008665 \text{ u}$

Mass of electron $m_e = 0.00055 \text{ u}$

1 amu = 931.5 MeV

Speed of light, $c = 3 \times 10^8 \text{ m/s}$

Avogadro's number, $N_A = 6.023 \times 10^{23} \text{ atoms/mol}$

Electronic charge $e = 1.6 \times 10^{-19} \text{ C}$

- Q1. a) Describe the nucleus of a lithium atom which has a mass number of 7 and an atomic number of 3 **(4 marks)**
- b) Plutonium decays with a half-life of 24000 years. Determine the fraction that remains if it is stored for 72000 years **(3 marks)**
- c) The radioactivity of an old sample of a liquid due to tritium of half – life 12.5 years was found to be only about 3% of that measured in a recently purchased bottle marked 7 years old. Determine the year the sample must have been prepared. **(4 marks)**
- d) (i) What are nuclear forces **(1 mark)**
(ii) State the characteristics of the nuclear forces **(4 marks)**
- e) Define the following terms as used in Nuclear Physics
(i) Binding Energy **(1 mark)**

- (ii) Radioactive decay constant (1 mark)
 (iii) Becquerel (1 mark)
- f) An element S decays to R ($A = 222$, $Z = 85$) after emitting two alpha particles and a beta particle. Determine the mass number and atomic number of element S (2 marks)
- g) Calculate the neutron separation energy of ^{91}Zr given the mass of ^{90}Zr is 89.904703 u and of ^{91}Zr is 90.905644 u (4 marks)
- h) Show that the density of a nuclear matter can be expressed as

$$\rho = \left(\frac{A}{Z}\right) \rho_{ch} \quad (5 \text{ marks})$$

- Q2 a) Define the atomic mass unit and hence determine its energy equivalence. (7 marks)
- b) Determine the binding energy per nucleon for Li ($A = 7$, $Z = 3$) (7 marks)
- c) Consider a radioactive element whose initial number of atoms is N_0 at $t = 0$. Derive an expression for the number of atoms remaining, N after time, t (6 marks)
- Q3 (a) Ordinary potassium contains 0.012 % of the naturally occurring isotope ^{40}K , which has a half-life of 1.3×10^9 years. What is the activity of 1 kg of potassium? (10marks)
- (b) A person accidentally ingests an amount of radioactive material with a very long lifetime and activity of 0.72 Ci. The radioactive material lodges in her lungs, where all of the 4.0 MeV alpha particles emitted are absorbed within a 0.50-kg mass of tissue. Calculate the absorbed dose and the equivalent dose for one year (10marks)
- Q4 a) List the five essential components in a typical controlled thermal fission reactor and state their functions (10 marks)
- b) Briefly describe, stating any assumptions, radioactive dating using Uranium method (10 marks)

- Q5 a) Most isotopes of calcium are stable. ^{49}Ca is an exception with half-life of 8.8 minutes
- (i) How many atoms of ^{49}Ca are there in a mass of calcium which has an activity of 260 Bq **(5 marks)**
 - (ii) What is the mass of ^{49}Ca contained in this sample? **(5 marks)**
- b) (i) Estimate the average mass density of a nucleus whose radius is 1.2 fm and mass 1.66×10^{-27} Kg **(6marks)**
- (ii) Estimate the rest energy of 1A (= 10^{-10} m) of nuclear matter in MeV. **(4marks)**

END