05

(University of Choice)

MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY (MMUST)

UNIVERSITY EXAMINATIONS 2021/2022 ACADEMIC YEAR

FIRST YEAR FIRST SEMESTER SPECIAL/SUPPLEMENTARY EXAMINATIONS

FOR THE DEGREE OF MASTER OF SCIENCE IN PHYSICS

COURSE CODE: SPH 817

COURSE TITLE: NUCLEAR AND PARTICLE PHYSICS

DATE: THURSDAY 4TH AUGUST, 2022 **TIME:** 8 AM - 11 AM

INSTRUCTIONS TO CANDIDATES

TIME: 3 Hours

Answer any five questions. All questions carry equal marks (14mks)
Symbols used bear the usual meaning.

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Assume where necessary:

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Plank's constant	$h = 6.626 \times 10^{-34}\ Js$
Charge on electron	$e = 1.602 \times 10^{-19}\ C$
Speed of light	$c = 3.0 \times 10^{8}\ ms^{-1}$
Atomic mass unit	$1\,u = 931.5\,MeV/c^2$
Number of atoms	$1\ mole = 6.023 \times 10^{23}\ atoms$

QUESTION ONE

(a) Find the Coulomb barriers of ${}^{16}_{8}O$, ${}^{93}_{41}Nb$ and ${}^{209}_{83}Bi$ as seen by a proton. [$R_0 = 1.4\ fm$]

(4 marks)

(b) Compare the Coulomb barriers obtained in 5(a) with the threshold energy for the reaction

${}^{16}_{8}O\ (p,d)\ {}^{15}_{8}O$, ${}^{93}_{41}Nb\ (p,d)\ {}^{92}_{41}Nb$ and ${}^{209}_{83}Bi\ (p,d)\ {}^{208}_{83}Bi$

Take: - ${}^{16}_{8}O = 15.994915\ u$; ${}^{15}_{8}O = 15.003070\ u$; ${}^{93}_{41}Nb = 92.906382\ u$; ${}^{92}_{41}Nb = 91.907211\ u$;

${}^{209}_{83}Bi = 208.980394\ u$; ${}^{208}_{83}Bi = 207.979731\ u$; $p = 1.007825\ u$; $d = 2.014102\ u$;

(10 marks)

QUESTION TWO

(a) Separation energy is the amount of energy needed to remove a nucleon from the nucleus. Show that the neutron and proton separation energy are defined by

$$S_n = \left(m\left({}^{A-1}_{Z}X_{N-1}\right) - m\left({}^{A}_{Z}X_{N}\right) + m_n\right)c^2 \text{ and}$$

$$S_p = \left(m\left({}^{A-1}_{Z-1}X_{N}\right) - m\left({}^{A}_{Z}X_{N}\right) + m\left({}^{1}H\right)\right)c^2$$

respectively. The symbols have usual meaning. (7 marks)

(b) Calculate the proton separation energy of ${}^{197}Au$. Take ${}^{196}Pt = 195.964926\ u$, ${}^{197}Au = 196.9665430\ u$ and ${}^{1}H = 1.007825\ u$. (3 marks)

(c) Mirror nuclei have the same odd value of mass number A but the values of the neutron number N and proton number Z are interchanged. Determine the mass difference between the two mirror nuclei which have N and Z differing in one unit. (4 marks)

QUESTION TWO

(a) Show that the kinetic energies of the daughter nucleus (K_D) and α – particle (K_α) emitted in alpha decay in terms of the disintegration energy (Q value) is

$$K_\alpha = \left(\frac{A-4}{A}\right)Q; \qquad K_D = \frac{4Q}{A}$$

where A is the mass of the parent nucleus? (6 marks)

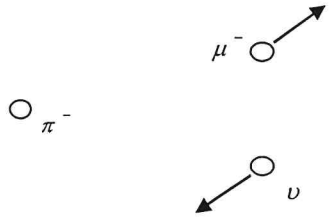
(b) (i) Obtain the expression for the number of particles scattered from a beam from a beam of area A containing N_0 particles after it transverses a thickness T of target material containing n scattering centers per unit volume of cross sectional area σ.

(5 marks)

(ii) For a hypothetical scattering target $10^{-3}\%$ of an incoming neutron beam is scattered. If the target has density of $1.06\times10^{4}\ kg\,m^{-3}$, $A = 200$ and the total neutron cross section per nucleus $\sigma = 1.1\,barns$, find the target thickness? (3 marks)

QUESTION FOUR

4 (a) A pion at rest decays into a muon plus a neutrino as shown in figure 2



What is the speed of the muon? (9 marks)

(b) Apply the sloping coordinate system to construct a strangeness number versus charge number plot for nine spin-0 mesons listed in table 1. Discuss the features of the resulting symmetry pattern. (5 marks)

QUESTION FIVE

5 (a) Determine the number of different baryon combination that can be made from 1, 2, 3, 4, 5 or 6 different quark flavors? What is the general formula for n flavors? (9 marks)

(b) Using four quarks (u, d, s, *and* c), construct a table of all possible baryon species. How many combinations carry a charm of 0, +1, +2 and +3? (5 marks)

QUESTION SIX

6 (a) Table 1 show the properties of elementary particles (antiparticles), use it to determine the identity of particle X in the following strong reaction?

(i) $\kappa^- + p \rightarrow \kappa^+ + X$

(ii) $p + p \rightarrow \pi^+ + n + \Lambda^0 + X$ (7 marks)

(b) A particle called xi-meson (Ξ^-) decays as follows:

$$\Xi^- \rightarrow \Lambda^0 + \pi^-$$

The Λ^0 particle and the π^- particle are unstable and decay in cascade until stable products remain:

$$\Lambda^0 \rightarrow p + \pi^- \qquad \pi^- \rightarrow \mu^- + \overline{\upsilon}_\mu$$

$$\mu^- \rightarrow e^- + \nu_\mu + \overline{\nu}_e$$

(i) Is the Ξ^- particle a lepton or a hadron? If the latter is it a baryon or a meson?

(ii) What is your opinion about the spin of the Ξ^- particle based on its decay? (7 marks)