KENYATTA UNIVERSITY

UNIVERSITY EXAMINATIONS 2011/2012

SECOND SEMESTER EXAMINATION FOR THE DEGREE OF BACHELOR OF SCIENCE AND BACHELOR OF EDCATION (SCIENCE)

SPH 425: NUCLEAR PHYSICS

DATE: WEDNESDAY, 4TH APRIL 2012 **TIME:** 11.00 A.M – 1.00 P.M

INSTRUCTIONS:

Question one is compulsory. Attempt any two other questions from the remaining four questions. Question one carries 30 marks while each of the others carries 20 marks. *Credit will be awarded for clear explanations and illustrations.*

The following information may be useful

1. Avogadro's constant, N_A $= 6.023 \times 10^{26}\ \text{kmol}^{-1}$
2. Speed of light, V $= 3.0 \times 10^{8}\ \text{m/sec}$
3. Density of Al $= 2700\ \text{kg/m}^3$
4.

Nuclide	Atomic Mass
n^1	1.0089830
H^1	1.0081437
H_e^{14}	4.0038727
N^{14}	14.0075179
O^{17}	17.0045293
M_0^{98}	97.905
X_e^{136}	135.917

5. 1 a.m.u. = 1.660×10^{-27} kg = 931.5 MeV
6. Half-life of uranium 2.5×10^5 years

Question one (compulsory)

a. A rock initially contains 12.0 milligrams of a radioactive material whose mass number is 234. Calculate the weight of the material, which the rocks will contain after a period of 150 000 years. [5]

b. When lithium is bombarded by 10 MeV deuterons, neutrons are observed to emerge at right angles to the direction of the incident beam. Calculate the energy of the emerging neutrons. [5]

c. Explain how the Pb^{206} content of a uranium-containing mineral can be used as a radioactive clock for geologists. [5]

d. The 0.014 MeV gamma ray that follows electron capture in C_0^{57} is used in a study of the Mossbauer effect. Calculate the relative source-absorber velocity required to obtain resonance absorption, assuming that the recoil momentum is effectively distributed between 1000 neighbouring atoms in the crystal lattice. [5]

e. What will be the mass of a 10-curie sample of C_{Co}^{60} given that its half-life is 5.26 years? [5]

f. If the relative stopping power of aluminum is 1.7×10^3, calculate the thickness of aluminium that is equivalent in stopping power to 1 metre in air. [5]

Question two

(a) Discuss nuclear reaction kinematics by means of the principles of conservation of momentum and energy and consequently obtain the expression for the energy balance for nuclear reactions. Your discussion should include the following:

(b)

- A schematic diagram of a nuclear reaction process.
- The definition of the Q-value of a nuclear reaction.
- Specification of the conservation laws employed in the analysis.
- A discussion of the significance of the Q-value as obtained from your derivation. [14]

(b) One of the nuclear reactions which occurs when nitrogen is bombarded with protons is $N^{14}(\alpha, p)_Z X^A$.

(i) Complete the reaction, writing it in a way which shows the balance of atomic and mass numbers and indicate the compound nucleus.

(ii) Calculate the Q-value of the reaction in joules and in MeV. State whether the reaction is exoergic or endoergic. [2,5]

Question three

(a) (i) What do you understand by the term "*gravitational redshift*"?
(ii) On the basis of the principle of equivalence of an accelerated system, derive the gravitational red shift by applying the Mossbauer technique. *(Hint: Begin with definitions of the intensity I of the earth's gravitational field and the gravitational potential ϕ at a point R due to the earth)* [3,10]

(b) A wooden piece of great antiquity weighs 0.05 kg and shows a C^{14} activity of 5.33 disintegrations per second. Estimate the length of time which has elapsed since this piece was part of living plant. Assume that living plants show a C^{14} activity of 200 disintegrations per second per kilogramme. Half-life of C^{14} is 5730 years. [7]

Question four

(a) There are two general techniques of employing radioisotopes. Explain the tracer technique with one suitable example from diagnostic medicine. [5]

(b) What is the most important difference between fermions and bosons? [3]

(i) Give a comprehensive definition of the term *average life* for a radioactive element.
(ii) Consequently, establish a relationship between *average life* and the disintegration constant λ. [5,7]

Question five

(a) **(i)** How is energy production in the sun and in stars of comparatively low temperatures accounted for?
(ii) Show the sequence of reactions involved in the processes in (i). [3,4]

(b) The fission of the compound nucleus (U^{236}), may be represented by the following reaction

$$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{98}_{42}M_{0} + {}^{136}_{54}X_{e} + 2\,{}^{1}_{0}n.$$

(i) Calculate the energy, in MeV, released in the reaction.
(ii) Evaluate the amount of energy which would be associated with the complete fission of 1 gram of U^{235} and hence explain the occurrence of a nuclear bomb. [5,5]

(c) If the relative stopping power of aluminum is 1.7×10^{3}, calculate the range of a 9 MeV α - particle in aluminium. [3]