MACHAKOS UNIVERSITY

University Examinations 2022/2023 Academic year

SCHOOL OF PURE AND APPLIED SCIENCES

DEPARTMENT OF PHYSICAL SCIENCES

THIRD YEAR SECOND SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE (ANALYTICAL CHEMISTRY)

SAN 309: NUCLEAR AND RADIATION CHEMISTRY

DATE: 13/3/2023 **TIME: 8:30 – 10:30 AM**

INSTRUCTIONS:

- The paper consists of **two** sections.
- Section **A** is **compulsory** (30 marks).
- Answer any **two** questions from section **B** (each 20 marks).

SECTION A

QUESTION ONE (30 MARKS)

a) Explain the following nuclear transformations. (4 marks)

(i) Nuclear decay.

(ii) Nuclear reaction

b) The nucleus is 10,000–100,000 times smaller than the atom, yet it contains over 99.9% of the total mass of the atom. Explain this contradiction. (2 marks)

c) Use the Borh model, to explain the electronic structure of the atom, identifying the charge and the approximate mass of the compositions. (4 marks)

d) With relevant equations, explain three types of beta decay. (9 marks)

e) Complete the following equations and indicate the type of nuclear decay in each. (3 marks)

(i) $^{40}_{19}\mathrm{K} + \_\_ \rightarrow {}^{40}_{18}\mathrm{Ar}$

(ii) $^{235}_{92}\mathrm{U} \rightarrow {}^{231}_{90}\mathrm{Th} + \_\_\_$

(iii) $^{232}_{90}\mathrm{Th} + \rightarrow {}^{232}_{89}\mathrm{Ac} + \_\_\_$

f) Explain three circumstances in which a nuclide might be stable. (3 marks)

g) Write out possible decay equation for the following nuclides to attain stability. (2 marks)

(i) $^{32}_{15}P$

(ii) $^{100}_{44}Ru^{*}$

h) Calculate the average atomic mass of naturally occurring magnesium Mg-24 = 78.99%, Mg-25 =10%, Mg-26 = 11.01%. (3 marks)

SECTION B:

QUESTION TWO (20 MARKS)

a) Explain why radioactive decay is isotropic. (2 marks)

b) One of the naturally occurring decay series begins with $^{232}_{90}Th$ and ends with $^{208}_{82}Pb$. Explain the minimum number of alpha and beta decays required for this series. (4 marks)

c) Explain the term 'Half-life'. (2 marks)

d) It takes 35 days for a 512 g sample of element X to decay to a final amount of 4 g. Determine the half-life of element X. (3 marks)

e) A ^{210}Pb source was calibrated at 0.0202 μCi 31.0 years ago. Under the detector used, it records 2.16×10^3 cpm. Calculate the detector's percent efficiency given that the half-life of ^{210}Pb is 22.3 a (annum). (4 marks)

f) Define the term 'Radioactive dating'. (2 marks)

g) The specific activity of carbon from the Shroud of Turin is 12.8 dpm/g today. Determine when the plants killed to make this cloth, if the half-life and the activity of carbon then were 5715 a and 14 dpm/g respectively. (3 marks)

QUESTION THREE (20 MARKS)

a) Define the term 'mass defect' and explain how it is converted into binding energy. (2 marks)

b) Calculate the total binding energy for the nucleus of $^{222}_{86}Rn$ (actual atomic mass = 222.017574 u), if the combined mass of proton and electron are 1.007825 u, while that of neutron is 1.008665 u (1u = 931.5 MeV). (3 marks)

c) Differentiate between nuclear fission from nuclear fusion. (2 marks)

d) Explain the term fissile, and give two examples of the commonly used fissile. (3 marks)

e) With the help of a schematic diagram, explain the working of the following. (10 marks)

(i) Inorganic scintillator

(ii) Photomultiplier Tube

QUESTION FOUR (20 MARKS)

a) Define and explain the use of cyclotrons in the nuclear and radiation fields. (3 marks)

b) Define the term "Specific activity" (2 marks)

c) Calculate the specific activity of ^{133}Xe if its half-life is 5.243 days. (3 marks)

d) Differentiate between the following terms. (4 marks)

(i) Liquid drop model and shells model

(ii) Resolving time and Recovery time

e) Describe four recommended qualities of radiodiagnostic agents. (8 marks)

QUESTION FIVE (20 MARKS)

a) State and explain 2 odd features found in gamma spectroscopy. (4 marks)

b) Differentiate between exoergic and endoergic reactions. (2 marks)

c) From the following shorthand equation representation; $^{51}V(n,\gamma)^{52}V$, write the full generic nuclear reaction indicating; target, projectile, product, and emitted particle or photon. (4 marks)

d) Given the following equation; $^{240}_{94}Pu + ^{4}_{2}He \rightarrow ^{243}_{96}Cm + ^{1}n$, where; ^{240}Pu (204.053814u), ^{4}He (4.002603u), ^{243}Cm (243.061389u), and ^{1}n (1.008665u), calculate;

(i) The minimum energy required to make the reaction proceed in good yield. (2 marks)

(ii) The threshold energy that account for both mass and momentum. (2 marks)

(iii) The minimum amount of energy required to overcome Coulomb barrier. (2 marks)

e) Explain four health issues which may result from nuclear radiations. (4 marks)