MACHAKOS UNIVERSITY

University Examinations for 2021/2022 Academic Year

SCHOOL OF PURE AND APPLIED SCIENCES

DEPARTMENT OF PHYSICAL SCIENCES
THIRD YEAR SECOND SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE (APPLIED PHYSICS AND TECHNOLOGY)

BACHELOR OF EDUCATION (SCIENCE)

SAN 309 NUCLEAR AND RADIATION CHEMISTRY

DATE: **TIME: 2 HOURS**

INSTRUCTIONS:

ANSWER YOUR QUESTIONS IN ANSWER BOOKLET PROVIDED.

ANSWER QUESTION ONE [COMPULSORY] AND ANY OTHER TWO QUESTIONS.

QUESTION ONE (COMPULSORY)

a) The half life of a certain radioactive element is such that of a given quantity decays in 12 days. What fraction remains undecayed after 24 days? (2 marks)

b) Eplain why excited electrons cannot emit radiations (2 marks)

c) Explain what forces and energy makes a nucleus of an atom retain its volume without collapsing (3 marks)

d) Give the number of protons, the number of neutrons, and the neutron-to-proton ratio for each isotope. (4 marks)

a. Iron-57

b. ^{185}W

c. potassium-39

d. ^{131}Xe

e) Confirm using effective nuclear charge that the experimentally observed electronic configuration of K, $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$, is energetically more stable than the configuration $1s^2 2s^2 2p^6 3s^2 3p^6 3d^1$. For K, Z = 19. Each of the electrons in the n-1 shell contributes S = 0:85 and each of the electrons in the n - 2 or lower shells contributes S = 1:00. (5 marks)

f) Calculate the value of A_r for naturally occurring chlorine if the distribution of isotopes is 75.77% for $^{35}_{17}Cl$ and $^{37}_{17}Cl$ is 24.23% Cl. Accurate masses for ^{35}Cl and ^{37}Cl are 34.97 and 36.97. (5 marks)

g) Chromium has four isotopes, $^{50}_{24}\boldsymbol{Cr}$, $^{52}_{24}\boldsymbol{Cr}$, $^{53}_{24}\boldsymbol{Cr}$ and $^{54}_{24}\boldsymbol{Cr}$ how many electrons, protons and neutrons does each isotope possess? (4 marks)

h) Hydrogen possesses three isotopes, but tritium (H), which is radioactive, occurs as less than 1 in 10^{17} atoms in a sample of natural hydrogen. If the value of A_r for hydrogen is 1.008, estimate the percentage abundance of protium, ^{1}H, and deuterium, ^{2}H (or D) present in a sample of natural hydrogen. Point out any assumptions that you may make and explain your answer. (5 marks)

QUESTION TWO (20 MARKS)

a) The decay products of several isotopes are listed here. Identify the type of radiation emitted and write a balanced nuclear equation for each. (4 marks)

i. $^{218}Po \rightarrow {}^{214}Pb$

ii. $^{32}Si \rightarrow {}^{32}P$

iii. An excited state of an iron-57 nucleus decaying to its ground state

iv. Conversion of thallium-204 to lead-204

b) Isotopes emit γ rays in random directions.

i. What difficulties do these emissions present for medical imaging? (2 marks)

ii. How are these difficulties overcome? (2 marks)

c) Given that the mass defect in Li originates solely from the interaction of protons and neutrons in the nucleus,

i. Estimate the nuclear binding energy of $^{7}_{3}\boldsymbol{Li}$ given the following data: Observed atomic mass $^{7}_{3}\boldsymbol{Li}$=7.016 00 u, 1u= 1.660 54 x10^{-27} kg, Electron rest mass = 9.10939 x 10^{-31}kg, Proton rest mass = 1.672 62 x 10^{-27} kg, Neutron rest mass = 1.67493x10^{-27} kg, c = 2.998x10^8ms^{-1} (3 marks)

ii. Determine the average binding energy per nucleon. (3 marks)

d) There are 82 protons in a lead nucleus. Explain why doesn't the lead nucleus burst apart due to their mutual electrostatic repulsion? (6 marks)

QUESTION THREE (20 MARKS)

a) Balance each nuclear reaction. (6 marks)

i. $^{208}Po \rightarrow \alpha + Pb$

ii. $^{226}Ra \rightarrow \alpha + Rn$

iii. $^{228}Th \rightarrow Ra + \alpha + \gamma$

iv. $^{231}Pa \rightarrow Ac + \alpha + \gamma$

v. $Ho \rightarrow {}^{166}Er + \beta^{-} + \gamma$

vi. $Ac \rightarrow {}^{226}Th + \beta^{-} + \gamma$

b) Radioactive isotope decays by alpha and β^{-} particle emission. Over a number of decays the nucleon number decreases by 4 while the proton number is unchanged. Calculate how many alpha and β particles have been emitted (2 marks)

c) In a radioactive decay series there are several examples in which a nucleus emits an alpha particle followed by two β^{-} particles. Explain the change in mass number between the original and final nuclei (2 marks)

d) Explain why are neutrons preferred to protons when preparing new isotopes of the lighter elements (3 marks)

e) If a stable nucleus breaks into its constituent nucleons, was energy added to the nucleus, or was energy released by the nucleus. Explain your answer. (3 marks)

f) In nuclear reactors, two different but interrelated factors must be controlled to prevent a mishap that could cause the release of unwanted radiation. How are these factors controlled? (4 marks)

QUESTION FOUR (20 MARKS)

a) Propose an explanation for the observation that elements with even atomic numbers are more abundant than elements with odd atomic numbers. (2 marks)

b) Two radioactive isotopes P and Q have half-lives of 10 minutes and 15 minutes respectively. Freshly prepared samples of each isotope initially contain the same number of atoms as one another. After 30 minutes calculate is the ratio of $\frac{number\ of\ atoms\ of\ P}{number\ of\ atoms\ of\ Q}$ (2 marks)

c) Potassium has three common isotopes, ^{39}K, ^{40}K, and ^{41}K, but only potassium-40 is radioactive (a beta emitter). Suggest a reason for the instability of ^{40}K. (3 marks)

d) Explain what mass number of an atom represent? Which particles have a mass number of zero? (3 marks)

e) Predict the mode of decay and write a balanced nuclear reaction for each isotope. (4 marks)

a. $^{235}_{92}\mathrm{U} \rightarrow \square + {}^{231}_{90}\mathrm{Th}$

b. $\square\mathrm{Es} \rightarrow {}^{4}_{2}\alpha + {}^{250}_{97}\mathrm{Bk}$

c. $^{36}_{16}\mathrm{S} \rightarrow {}^{0}_{-1}\beta + \square\mathrm{Cl}$

d. $^{99}_{42}\mathrm{Mo} \rightarrow \square + {}^{99m}_{43}\mathrm{Tc}$

f) Explain the liberation of energy produced by fission using uranium as an example (6 marks)

QUESTION FIVE (20 MARKS)

a) Atoms that emit ionizing radiation are called? (1 mark)

b) Which type of nuclear radiation has the shortest range in tissue? (assume equal energy) (2 marks)

c) Define an Ionizing radiation (2 marks)

d) Describe Compton mass attenuation coefficient for materials in Compton region (2 marks)

e) Complete each nuclear fission reaction. (2 marks)

a. $^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{145}_{57}\mathrm{La} + ? + 3{}^{1}_{0}\mathrm{n}$

b. $? + {}^{1}_{0}\mathrm{n} \rightarrow {}^{95}_{42}\mathrm{Mo} + {}^{139}_{57}\mathrm{La} + 2{}^{1}_{0}\mathrm{n} + 7{}^{0}_{-1}\beta$

f) The process whereby energy is transferred from a photon beam to electrons in the medium is called? (2 marks)

g)

i. Describe what happens when protons interact with soft tissue (2 marks)

ii. Do Protons undergo exponential attenuation? (2 marks)

iii. Discuss neutron interactions with matter (5 marks)