CHUKA UNIVERSITY

UNIVERSITY EXAMINATIONS

EXAMINATION FOR THE AWARD OF DEGREE OF BACHELOR OF SCIENCE

CHEM 417: RADIATION AND NUCLEAR CHEMISTRY

STREAMS: BSC **TIME: 2 HOURS**

DAY/DATE: FRIDAY 26/03/2021 **8.30 A.M – 10.30 A.M.**

INSTRUCTIONS: Answer question ONE and any other TWO questions

QUESTION ONE (30 MARKS)

(a) (i) Compare the properties of Alpha Rays, Beta Rays and Gamma Rays [6 marks]

(ii) $^{210}_{82}Pb$ is a $\beta-emitter$ and $^{226}_{88}Ra$ is an $\propto -emitter$. What will be the atomic masses and atomic numbers of daughter elements of these radioactive elements? Predict the position of daughter elements in the periodic table. [2 marks]

(iii) Explain how ionization chamber can be used to detect and measure the radioactive radiation [3 marks]

(b) (i) Write short notes on

Radioactive series [4½ marks]

(ii) Explain using suitable examples why radioactive half-life is important [3 marks]

(iii) Suppose you analyzed mineral sample and found that it contained 33,278 parent atoms and 14,382 daughter atoms. Further, suppose that the half-life of the parent atom is 2.7 million years. How old is the mineral samples? $(\lambda = 0.5)$

[3 marks]

(c) (i) Discuss the radioactive equilibrium [2½ marks]

(ii) $^{60}_{27}Co$ decays with a half-life of 5.27 years to produce $^{60}_{28}¿$

(I) Calculate the decay constant for the radioactive disintegration of cobalt – 60 [½ mark]

(II) Calculate the fraction of a sample of the $^{60}_{27}Co$ isotope that will remain after 15 years [½ mark]

(III) How long does it take for sample of $^{60}_{27}Co$ to disintegrate to the extent that only 2.0% of the original amount remains? [1 mark]

(iii) An igneous rock contains $9.58\,x\,10^{-5}\,g$ of $u-238$ and $2.51\,x\,10^{-5}\,g$ of $Pb-206$, and much, smaller amount of $Pb-208$. The $u-238$decays into $Pb-206$ with a half-life of $4.5\,x\,10^{9}\,y$ [3 marks]

(d) (i) State three advantages of accelerator mass spectrometer over liquid scintillation counter [2 marks]

(ii) Explain why there is a need to measure $\sigma^{13}C$ [1½ marks]

(iii) State one limitation of radiocarbon dating [½ marks]

QUESTION TWO (20 MARKS)

(a) (i) Give six differences between nuclear fusion and nuclear fission [6 marks]

(ii) Discuss the stability of nucleus in terms of neutron-proton ratio and binding energy [6 marks]

(b) (i) Outline the seven principal advantages and five drawbacks of semiconductors [6 marks]

(ii) Calculate the binding energy per nucleon in KJ/Mole for an alpha particle whose mass defect is calculated as 0.029 Z amu

$\left[1\,amu=1.6606\,x\,10^{27}\,kg\,,C=2.9979\,x\,10^{8}\,m/s\right]$ [2 marks]

QUESTION THREE (20 MARKS)

(a) Discuss the principles of the two quantitative radiochemical methods of analysis listed below

(i) Neutron activation analysis [7 marks]

(ii) Isotope dilution analysis [3 marks]

(b) (i) The concentration of Mn in steel can be determined by a neutron activation analysis using the method of external standards. A 1.00g sample of an unknown steel sample and a 0.95 g sample of standard steel known to contain 0.463% W/W Mn are irradiated with neutrons in a nuclear reaction for 10h. After a 40 min delay the gamma ray emission is 2542 cPM (counts per minute) for the unknown and 1984 cPM for the external standard. Calculate the % W/W Mn in the unknown

[2 marks]

(ii) The concentration of insulin in a production vat is determined by isotope dilution. A 1.00 mg sample of insulin labeled with $^{14}_{C}$ having an activity of 549 cPM is added to a 10.0ml sample taken from the production vat. After homogenizing the sample, a portion of the insulin is separated and purified yielding 18.3 mg of pure insulin. The activity for the isolated insulin is measured at 148 cPM . Calculate the mg of insulin in the original sample.

[1 mark]

(c) (i) Outline the eight stringent requirements set against radiation detectors for nuclear instrument [4 marks]

(ii) What is the significance of magic number of protons or neutrons? What is the relationship between the number of stable isotopes of an element and whether the element has a magic number of protons? [1 mark]

(iii) Potassium has three common isotopes $^{39}_{K}$, $^{40}_{K}$ and $^{41}_{K}$,but only potassium – 40 S radioactive (a beta emitter), suggest a reason for the instability of $^{40}_{K}$

[1 mark]

(iv) What is the most common decay process for elements in row 5 of the period table that contain too few neutrons for the number of protons present? Why?

[1 mark]

QUESTION FOUR (20 MARKS)

(a) Discuss the uses of radiation under the following headings

(i) Medical uses [4 marks]

(ii) Academic and scientific applications [3 marks]

(iii) Industrial uses [4 marks]

(b) Explain the difference between ionizing and nonionizing radiation and their effects on matter [4 marks]

(c) Write short notes on storage and disposal of radioactive waste [2 marks]

(d) The activity of a 10.00 ml sample of water containing $^{90}_{38}Sr$ is $9.07\ x\ 10^{6}$ disintegration s/S.

Calculate the molar concentration of $^{90}_{38}Sr$ in the sample. The half-life for $^{90}_{38}Sr$ is 28.1 yrs

$\left(N_A = 6.022\ x\ 10^{23}\right)$ atoms/mole [3 marks]
