THE CATHOLIC UNIVERSITY OF EASTERN AFRICA

A. M. E. C. E. A

MAIN EXAMINATION

SEPTEMBER – DECEMBER 2019 TRIMESTER

FACULTY OF SCIENCE

DEPARTMENT OF CHEMISTRY

REGULAR PROGRAMME

CHEM 202: NUCLEAR AND RADIATION CHEMISTRY

Date: DECEMBER 2019	Duration: 2 Hours
INSTRUCTIONS: Answer Question ONE and any other Two Questions	

Avogadro's number: 6.023×10^{23} atoms/mol.
Mass of proton is 1.00738 amu
Mass of neutron is 1.00866 amu
Mass of electron is 5.456×10^{-4} amu
1 amu = 931.5 MeV

Q1. a) Carbon-13 is a neutron rich radioactive isotope of carbon which constitutes 1.1% of the total natural occurring carbon. Using a relevant equation, explain how it regains stability **(2 marks)**

b) Iron-56 has 30 neutrons and 26 protons. If it's atomic weight is 55.9349375 amu, calculate it's binding energy per nucleon **(4 marks)**

c) Using relevant diagram(s), explain the composition and function of the following parts of a nuclear reactor:
    i. Control rods
    ii. Fuel rods **(6 marks)**
    iii. Moderator

d) Uranium-238 decays to Thorium-234.
    i. Calculate the amount of Uranium 238 remaining after 10,000 years if the initial mass is 129g. (The half-life of U-238 is

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4.468*10⁹ years.)

(4 marks)

ii. The $t_{1/2}$ of Uranium-238 and Thorium-234 are 4.468*10⁹ years and 24.1 days respectively. Describe this type of radioactive equilibrium. Derive the t_{max} for this radioactive equilibrium

(6 marks)

e) Illustrate how a 3-g nucleon orbital would split according to the spin- orbit coupling model **(4 marks)**

f) Cobalt-60 emits γ- ray radiation with energies of between 1.17 MeV and 1.33 MeV useful in water disinfection. Using a well- labelled diagram, explain how such radiation with energies >1.02 MeV interact with matter

(4 marks)

Q2. a) Some archaeologists discovered a piece of wood which was a fire remnant with an observed carbon decay rate of 15.285 disintegrations per minute per gram of carbon. How long ago did the fire occur if the carbon disintegration rate in living organisms is 15.30 disintegrations per second? ($t_{1/2}$ of C-14 is 5,730 years)
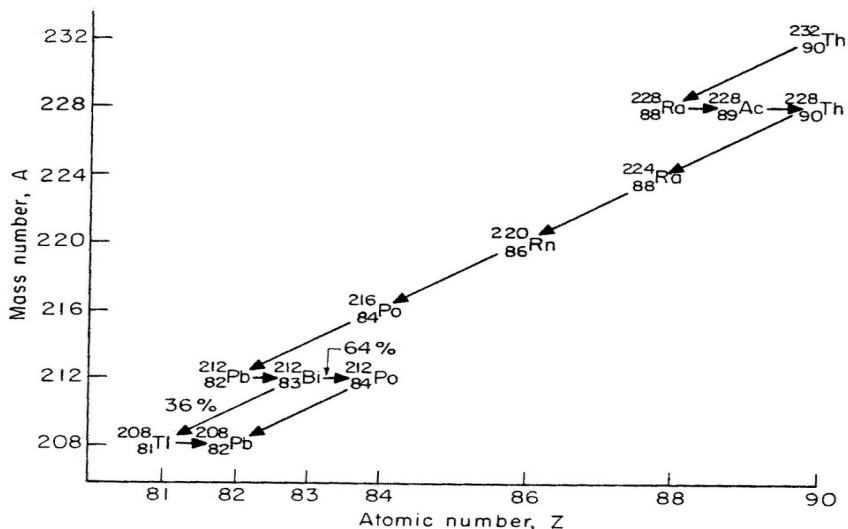
(4 marks)

b) Using a relevant diagram, explain the working principle of mass spectrometer **(6 marks)**

c) Strong nuclear forces act independent of charge. Using a relevant diagram, explain. **(5 marks)**

d) Assuming that the $\dfrac{Pb^{206}_{82}}{U^{238}_{92}}$ ratio in a rock sample is 0.45, calculate it's age (The half-life of U-238 is 4.468*10⁹ years.) **(5 marks)**

Q3. a) Use the Thorium decay series below to answer the questions that follow:

i. Explain why the Thorium series is also known as the 4n series

(3 marks)

ii. The $t_{1/2}$ of Thorium-232 and Polonium-212 are $1.4*10^{10}\, yrs$ and $3*10^{-7}\, sec$ respectively. Calculate their decay constants

(4 marks)

iii. Write the decay equations for the first four steps in the series

(4 marks)

b) α- particles are also known as high LET radiation. Using a relevant diagram, explain

(5 marks)

c) Explain the contribution of Thompson to early theories of atomic structure

(4 marks)

Q4. a) The atomic bomb is a 'weapon of mass destruction' based on the nuclear fission of Uranium- 235. Explain **(4 marks)**

b) Using relevant equations, explain the difference between α and β decay

(4 marks)

c) Describe how radiolysis of water could be used in:
   i. Water disinfection
   ii. Heavy metal removal **(4 marks)**

d) Using relevant diagrams, describe how neutrons and protons are affected by electrostatic forces **(4 marks)**

e) Phosphorus-32 could be used to monitor fertilizer uptake by crops.

Explain. **(4marks)**

Q5. a) Uranium could be isolated from it's natural decay chain using acid action. Explain using relevant equations **(6 marks)**

b) Describe the principle of an Fe^{++} dosimeter **(5 marks)**

c) Using examples, explain the difference between 'isotopes' and 'isobars'. **(4 marks)**

$d ¿ Si_{14}^{30}$ and Si_{14}^{28} consists of 3.09% and 92.23% of the total amount of natural silicon respectively. Using the stability curve, explain this phenomenon. **(5 marks)**

END

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