CHUKA  **UNIVERSITY**

UNIVERSITY EXAMINATIONS

THIRD YEAR EXAMINATION FOR THE AWARD OF DEGREE OF BACHELOR OF SCIENCE IN BIOCHEMISTRY

PHYS 394: RADIOBIOLOGY AND RADIOTRACER TECHNIQUE

STREAMS:BSC (BMED) **TIME:2 HOURS**

DAY/DATE: FRIDAY 21/04/2023 **2.30 P.M. –4.30 P.M.**

INSTRUCTIONS

- Answer Question One in Section A and any other Two Questions in Section B
- Do not write anything on the question paper
- This is a closed book exam, No reference materials are allowed in the examination room
- There will be No use of mobile phones or any other unauthorized materials
- Write your answers legibly and use your time wisely

SECTION A

a. Describe briefly three types of radionuclides decay that releases ionizing particles. (3 marks)

b. Exposure to low doses of radiation may result to the following effects. Define each effect briefly

   1. Genetic
   2. Somatic
   3. In-Utero (3 marks)

c. A patient is injected with a radiopharmaceutical labeled with technetium-99m , half-life of 6.0 h, in preparation for a gamma ray scan to evaluate kidney function. The original activity of the sample was 48 μCi.

   i. What activity is μCi remains after 18 hr? (2 marks)

   ii. After 48 hr? (1 mark)

d. List and explain four advantages of radioimmunoassay. (4 marks)

e. Positron emission tomography (PET) is a medical imaging technique that uses positron emitters, such as Fluorine-18.

i. Other isotopes are Fluorine-19 and Fluorine-20. Explain why Fluorine-18 is suitable for PET and not the others. (2 marks)

ii. What type of radiation is detected with PET? (1 mark)

iii. Write the equation for the positive beta decay decay of Fluorine-18. (2 marks)

f. i. What is autoradiography? (1 mark)

ii. List four uses of autoradiography. (4 marks)

g. What is a MUGA scan? (2 marks)

h. A doctor uses the radioactivity isotope technetium 99 m to find out if a patient kidneys are working properly. The doctor injects a small amount of technetium-99 into the patient's bloodstream. Possible patterns of the level of radiation emitted from the kidneys are as shown in the graphs (a) – (c) of Figure 1. Kindly sketch the graphs in your answer booklet and label which curve/pattern shows

a. Normal functioning kidney pattern. (1 mark)

b. Obstructed kidney (1 mark)

c. Dilated non-obstructed kidney (1 mark)

d. Indicate on the graph where there is a diuretic injection. (1 mark)

e. Give a reason for your conclusions in a-d above (1 mark)

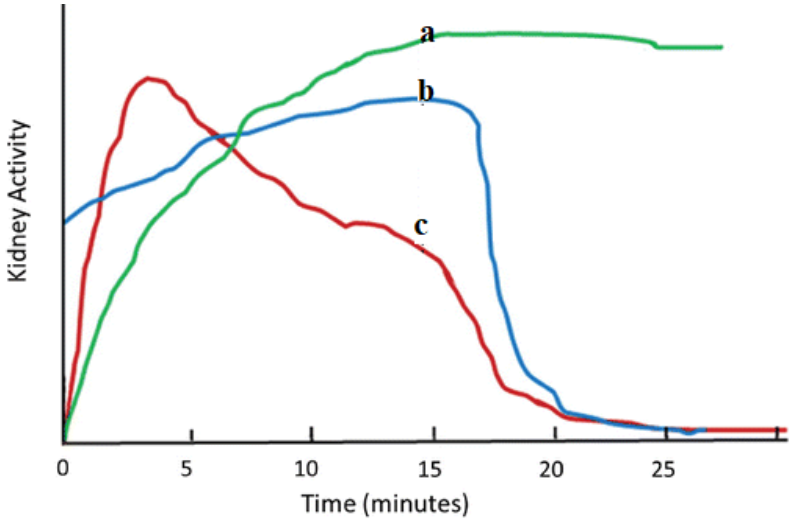

Figure 1

SECTION B

QUESTION TWO (20 MARKS)

You're running a Positron Emission Tomography (PET) scanner. The isotope you use is fluorine-18 (F-18), which is incorporated into the fluorodeoxyglucose molecule. This molecule acts like glucose in the body. This substance is introduced intravenously to the patient and the PET scanner images the radioactive decay from F-18. The resulting images will show where glucose is being consumed. There are 2 x 10^{12} unstable F-18 nuclei injected into the patient's body before PET scanning. The half-life of F-18 decay is about 110 minutes. Approximate this as 2 hours. The patient is injected at 9 am, and takes a taxi home from the hospital at 1 pm. The patient's partner returns home at 6 pm with their infant daughter. In the decay, two separate reactions occur in sequence: 1) Positron emission of F- 18 (relatively slow reaction) and then 2) Positron-electron annilation (very fast).

a) The F-18 undergoes positron emission (also known as B+ decay). Write the complete reaction for this. Nearby elements are oxygen (Z =8) and neon (Z = 10). Explain all the symbols in the equation. (5 marks)

b) Calculate the Q for positron(beta plus) decay given, Mass of F-18 is 18.000937 amu, Mass of O-18 is 17.999160 amu, 1 amu has 931.5 MeV and Rest energy of a positron is 1.022 MeV (2 marks)

c) The positron emitted in the first reaction will quickly encounter an electron and they will annihilate each other, emitting two gamma rays that go to the detector ring. Calculate the energy released in Joules. The mass of the positron is identical to the mass of the electron i.e. 9.11 $x10^{-31}kg$ (2 marks)

d) How many nuclei are left undecayed

   i. When the patient leaves the hospital? (2 marks)

   ii. What about at 6 pm? (2 marks)

   d) What is the activity at each of these times in Curies? Should the cab driver or the patient's partner be worried about radiation exposure? Should they be concerned about the infant's exposure? (3.7 x 10^{10} Bq=1 Ci) (4 marks)

   e) After 24 hours, practically all of the F-18 nuclei will be decayed. The majority of the energy absorbed by the body is due to the annihilation event. (The beta decay does release some energy; we will ignore it for this calculation.) Calculate the dose in Sieverts this patient

receives if they are 50 kg. A “low dose" is a single exposure less than 100 mSv. Is this a low dose? (3 marks)

QUESTION THREE (20 MARKS)

a. Instrumentation of radiation detection principles are based on how radiation interacts with matter. Mention three interactions that are useful in radiation detection (3 marks)

b. In an experiment to determine the working voltage of a GM tube, the following graph was obtained.

Following from the graph determine the following

i. Starting voltage (1 mark)

ii. Best operating voltage (1 mark)

iii. Breakdown voltage (1 mark)

iv. Continuous discharge region (1 mark)

c. Consider Figure 2 of a Geiger–Müller counter (also called a Geiger counter), a device commonly used to detect ionizing radiation. The probe contains a gas under low pressure.

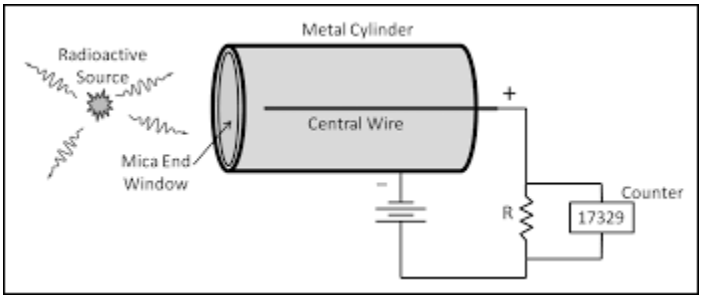

Figure 2

i. Why does this device only detect radiation that is capable of ionizing the gas contained in the probe? (1 mark)

ii. What other methods are used to detect the presence of ionizing radiation? (2 marks)

d. A major problem within the gas ionization chamber is the recombination of primary ion pairs. Explain how this problem is overcome in order to detect radioactivity effectively. (3 marks)

e. The primary ion pairs formed in gas ionization may be greatly amplified to increase the pulse detected. Discuss the process by which this occurs. (4 marks)

f. Explain why effective detection of radioactivity is not possible when the ionization chamber is operated at certain voltage ranges. (3 marks)

QUESTION FOUR (20 MARKS)

a. Explain briefly how PET is achieved. (4 marks)

b. Figure 3 shows a slice of lemon in a (very small) PET scanner. ***One*** of the pips in the lemon is radioactive and is emitting positrons. Detectors shaded with the same shade of grey show pairs of gamma rays detected at the same time.

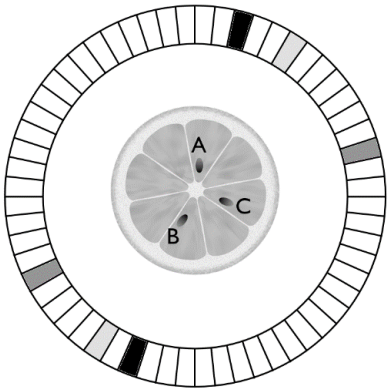

Figure 3

i. Which one of the pips is radioactive? (1 mark)

ii. How are these gamma rays created after a positron is emitted? (1 mark)

iii. Why do the gamma rays travel in opposite directions? (1 mark)

c. Different isotopes of fluorine are shown below.

Isotope	**Stability**
Fluorine-18	Unstable, beta plus decay
Fluorine-19	Stable,
Fluorine-20	Unstable, beta minus decay

i. What is an isotope? (1 mark)

ii. Why is fluorine useful for making a radiotracer? (2 mark)

iii. The isotope used in PET is flourine-18. Explain why the other isotopes of fluorine listed above are not suitable for PET. (2 marks)

d. The radioactive isotope carbon-11 used in PET is produced by firing high speed protons at nitrogen atoms.

i. Why do the protons need to be travelling at high speed? (2 marks)

ii. How are protons accelerated up to high speeds? (1 mark)

iii. The nuclear reaction for the production of carbon-11 is shown below. Suggest what the particle (X) emitted in this process is. (1 mark)

$$^{14}_{7}N + ^{1}_{1}p \rightarrow ^{11}_{6}C + \mathrm{X}$$

e. Explain how PET would help to diagnose the following medical diseases and conditions

i. Alzheimer disease (2 marks)

ii. Brain Tumor (2 marks)

QUESTION FIVE (20 MARKS)

a. Figure 4 shows the heart.

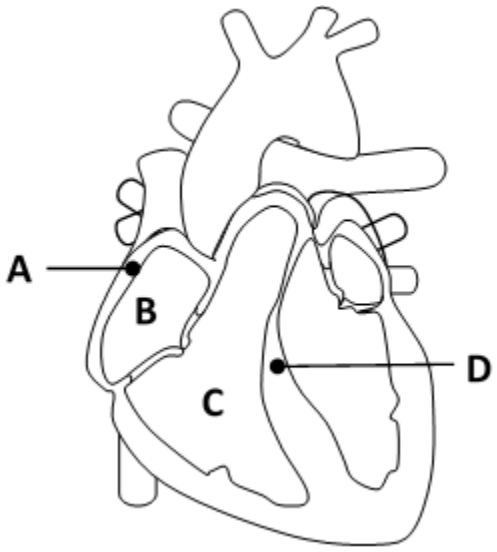

Figure 4

i. Which chamber of the heart is labelled with the letter B? (1 mark)

ii. Which letter represents the SA node? (1 Mark)

iii. What does the SA node do? (1 mark)

2. Figure 5 is an electrocardiogram (ECG) of a patient.

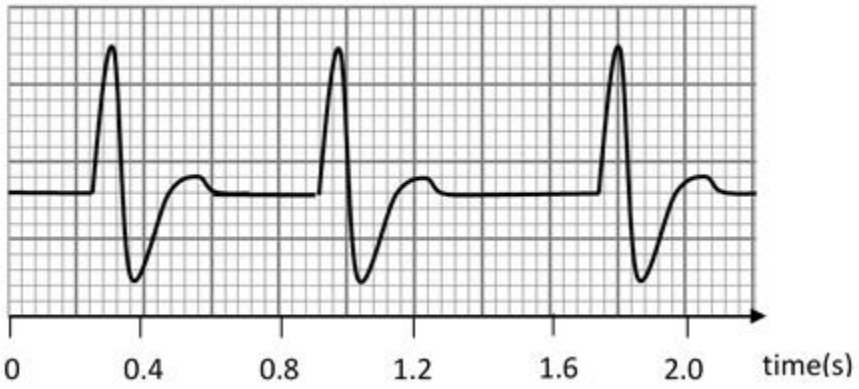

Figure 5

i. Time is plotted on the horizontal axis. Which quantity is plotted on the vertical axis? (1 mark)

ii. Use the ECG to work out the *average* time period of the heartbeat. Show your working. (1 mark)

iii. Work out the heart-rate in beats per minutes (1 mark)

iv. A doctor viewing the ECG is concerned that the person may have a heart problem. Explain why the doctor is concerned (2 marks)

b. Radiopharmaceuticals in the heart can detected after administration. Explain how Multiple Gated Acquisition (MUGA) Studies are done and give 4 examples of different parameters for ventricular functions that can obtained. (7 marks)

c. List Five uses of Autoradiography (5 marks)
