SCIENCE DEPARTMENT
Physics ATAR YEAR 11 Semester 1

Time: 65 minutes **Total questions: 13**

Full working must be shown to obtain full marks. Should show answers in 3 s.f. and scientific notation.
NOTE: Where necessary use the constants supplied on the SCASA formula sheet.

Question 1 (3 marks)

Within a nuclear reactor, uranium-235 is bombarded by a neutron to split into two daughter products also emitting two neutrons. Part of the nuclear equation is shown below.

$$^{235}_{92}U + {}^{1}_{0}n \rightarrow X + {}^{91}_{38}Sr + 2{}^{1}_{0}n$$

a) Write the nuclide for the missing daughter product labeled X. _____ [1]

b) Write the atomic and mass number of the daughter product:

Mass number _____ Atomic number _____ [2]

Question 2 (3 marks)

In terms of the properties of alpha and beta radiation, explain why alpha radiation cannot penetrate paper, but beta radiation can.

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Question 3 (3 marks)

Uranium-235 is commonly used to produce a self-sustaining neutron-induced chain reaction. Using U-235 as the example, draw a labeled diagram that illustrates a self-sustaining neutron-induced chain reaction.

Question 4 (2 marks)

A radioactive isotope has a count of **3.85×10^3 decays in one hour.** Calculate the activity of the source.

Question 5 (5 marks)

Calculate the binding energy per nucleon in MeV of the **helium-3 atom** given the mass of the He-3 atom is 5.00×10^{-27} kg .($m_p = 1.00766$ u, $m_n = 1.00867$ u, $m_e = 0.00055$ u)

Note: $1u = 1.66 \times 10^{-27}$ kg

Question 6 (3 marks)

If the original activity of a sample is 42.0 kBq, and it has a half-life of 4.00 days, how much activity will there be after 12.0 days?

Question 7 (4 marks)

A radiation source and a detector can be used to measure the thickness of very thin aluminum foil during manufacturing. Select a suitable radioisotope from the table to be used as a radiation source.

RADIOISOTOPE	MOST USEFUL RADIATION EMITTED	HALF-LIFE
Americium-241	alpha	432 years
Cesium-137	gamma	30 years
Cobalt-60	gamma	5.27 days
Iodine-131	beta	8.04 days
Radium-223	alpha	11.4 years
Strontium-90	beta	29 years

Choice:_____ [1]

Write three reasons why you chose this isotope. [3]

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Question 8 (3 marks)

The formation of a new element during radioactive decay is called transmutation. Explain why emitting alpha and beta radiation causes a transmutation, but emitting gamma radiation does not.

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Question 9 (8 marks)

A miner in a uranium mine is unaware he breathed in radon-222 gas, an alpha emitter. The gas has a very long half-life with an activity of 3.40 kBq, which will be unchanged during his time in the mine. Each decay of the isotope releases 3.8×10^{-12} J of energy into the body and the radioisotope is not eliminated from the body as it settles into the tissue of his lungs. After a month, the gas is discovered and the mine is closed (assume 30 days).

a) Calculate the total energy the miner absorbed into his lungs during this time [2]

b) Calculate the absorbed dose he received in one month if he has a mass of 75.0 kg.
(If you were unable to obtain a value for (a) above, use 0.035 J) [2]

c) Calculate the dose equivalent if the radiation is alpha. [2]

d) Should the miner be worried about his exposure to the gas? Explain. [2]

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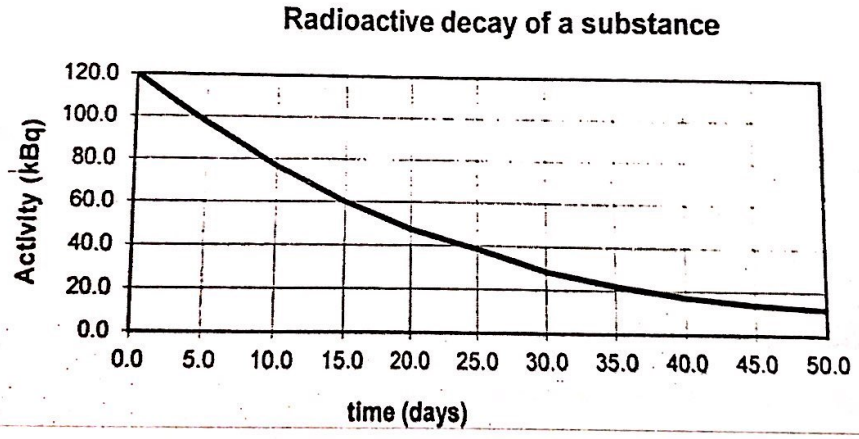
Question 10 (1 mark)

Determine the half-life of the substance from the graph.



Half-life _____

Question 11 (5 marks)

When Pu-238 (atomic number 94) is bombarded with a neutron, fission occurs to form Sn-128 (atomic number 50), Ru-108 (atomic number 44) and some neutrons.

a) Complete the nuclear equation showing the number of neutrons released. [1]

$$^{1}_{0}n + {}^{238}_{94}Pu \rightarrow {}^{128}_{50}Sn + {}^{108}_{44}Ru + \_\_\_\_\_ {}^{1}_{0}n$$

b) How much energy, in joules, is released during this reaction? Use the information on your data sheet and below. [4]

Pu-238 = 396.82×10^{-27} kg
Sn-128 = 212.33×10^{-27} kg
Ru-108 = 179.13×10^{-27}

$E = mc^2$
$c = 3.00 \times 10^{8}$ ms^{-1}
$^{1}_{0}n = 1.67 \times 10^{-27}$ kg

Question 12 (3 marks)

Explain the purpose and use of 'control rods'.

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Question 13 (11 marks)

Cyclotron-produced radioisotopes

Cyclotron-produced radioisotopes are used mainly to make radiopharmaceuticals for use in two diagnostic imaging systems – positron emission tomography (PET) and single photon emission computed tomography (SPECT).

Both methods involve the use of minute quantities of low-level radioactive chemicals that can be detected by the highly sensitive imaging equipment in hospitals. The radioactive materials decay rapidly and do not harm the patient.

SPECT is a sophisticated camera system that produces images of slices of the body by photographing the low-energy gamma rays emitted from radioactive tracers introduced to pinpoint disease or organ function. The radioactive tracers used contain a radioisotope compound that is specific for the organ or disease being studied. If the body slices are added together, a three-dimensional image of the organ being studied is obtained.

SPECT radiopharmaceuticals produced at the National Medical Cyclotron include:

- gallium-67, which is used to diagnose soft tissue tumours and some inflammatory lesions. It has a half-life of 78 hours.
- thallium-201, which is used to assess heart conditions. It has a half-life of 73 hours.
- iodine-123, which is used to diagnose certain thyroid diseases. It has a half-life of 13 hours.

Iodine-123 labelled tracers are also commonly used to monitor neurodegenerative diseases and cancer.

PET is a highly sensitive system that uses positron-emitting radioisotopes. A positron is a positively charged electron particle. When a positron collides with an electron the two particles annihilate one another, releasing energy as two gamma rays which shoot off in exactly opposite directions. These two rays strike crystals in a ring of detectors around a patient, enabling sophisticated computers to then turn the information into an image.

The only PET radiopharmaceutical currently routinely produced at the National Medical Cyclotron is fluorine-18. This is labelled onto a glucose molecule to form fluorodeoxyglucose (FDG). This is used to diagnose brain disease, heart viability, coronary artery disease and, increasingly, to assess the spread of cancers such as malignant melanomas. It has a half-life of 110 minutes.

a) Radiopharmaceuticals are used in diagnostic imaging systems such as PET and SPECT. Give the full name for these imaging systems [2]

PET .....

SPECT .....

b) What is a positron? [1]

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c) Use an equation to show what happens when a positron interacts with an electron. [1]

d) Explain how this interaction allows imaging of a patient's body to occur. [2]

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e) List the isotope/s involved in the diagnosis of: [2]

i) heart disease .....

ii) soft tissue tumors .....

f) The radiopharmaceuticals used for medical imaging all have a fairly short half life. What are the main advantages of this? [3]

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END OF TEST