

Diagnostic Topic Test 2023

VCE Physics Units 1&2

Question and Answer Booklet

Test time: 45 minutes

Total marks: 35 marks

Test 3: How is energy from the nucleus utilised?

- Radiation from the nucleus
- Nuclear energy

Student's Name: _____

Teacher's Name: _____

Instructions

Write your **name** and your **teacher's name** in the space provided above on this page.

A formula sheet is provided.

Unless otherwise indicated, the diagrams in this booklet are **not** drawn to scale.

Answer **all** questions in the spaces provided.

SECTION A – MULTIPLE-CHOICE QUESTIONS**Instructions for Section A**

Circle the response that is **correct** or that **best answers** the question.

A correct answer scores 1; an incorrect answer scores 0.

Marks will **not** be deducted for incorrect answers.

No marks will be given if more than one answer is completed for any question.

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Take the value of g to be 9.8 m s^{-2} .

Question 1

Radiation can be classified as ionising radiation or non-ionising radiation.

Which one of the following statements is **incorrect**?

- A. Ionising radiation can sometimes cause cell damage due to the creation of free radicals.
- B. Microwaves are an example of ionising radiation.
- C. X-rays are an example of ionising radiation.
- D. Ionising radiation can cause genetic mutations.

Question 2

Which one of the following statements explains why some nuclei are radioactive and some are not?

- A. Some nuclei are unstable, resulting in the emission of radiation.
- B. Some nuclei decay faster than others due to their mass, resulting in the emission of radiation.
- C. Some nuclei have an excess of electrons, resulting in the emission of radiation.
- D. Some nuclei have insufficient internal energy, resulting in the emission of radiation.

Question 3

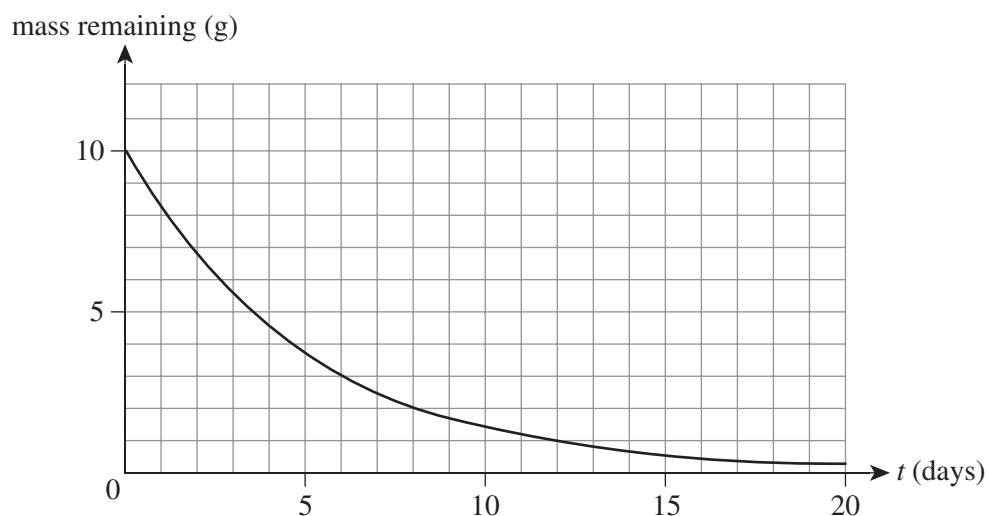
A 50 g cancer tumor absorbs 0.04 J of alpha radiation.

Taking the quality factor of alpha radiation to be 20, the absorbed dose equivalent is

- A. 0.016 Sv
- B. 0.80 Sv
- C. 16 Sv
- D. 25 Sv

Use the following information to answer Questions 4 and 5.

The number of grams remaining versus time graph for a sample of the radioisotope radon-222 is as follows.



Question 4

What is the half-life of radon-222?

- A. 1.5 days
- B. 3.5 days
- C. 8 days
- D. 12 days

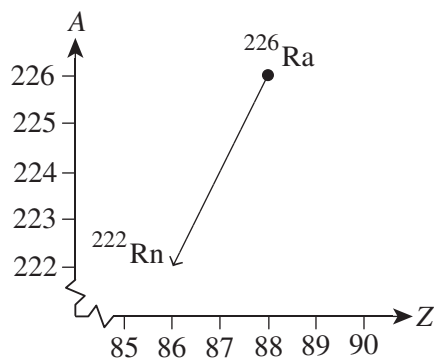
Question 5

How many grams of radon-222 nuclei will be present after 10 days have elapsed?

- A. 0.05 g
- B. 1.5 g
- C. 5 g
- D. 10 g

Question 6

The following graph shows part of the decay series of radium-226.



What is the decay equation for radium-226?

- A. ${}^{223}_{88}\text{Ra} \rightarrow {}^{224}_{86}\text{Rn} + {}^4_2\alpha + \text{energy}$
- B. ${}^{226}_{88}\text{Ra} \rightarrow {}^{222}_{86}\text{Rn} + {}^4_2\beta + \text{energy}$
- C. ${}^{226}_{88}\text{Ra} \rightarrow {}^{222}_{86}\text{Rn} + {}^4_2\gamma + \text{energy}$
- D. ${}^{226}_{88}\text{Ra} \rightarrow {}^{222}_{86}\text{Rn} + {}^4_2\alpha + \text{energy}$

Question 7

Humans can be exposed to internal and external radiation sources.

Rosemary eats some oysters containing small traces of radioactive uranium, which decays via alpha decay.

Rosemary has

- A. been exposed to an external radiation source.
- B. been exposed to an internal radiation source.
- C. been exposed to both internal and external radiation sources.
- D. not been exposed to either an internal or external radiation source.

Question 8

Which one of the following statements is correct?

- A. Artificial radioisotopes can be produced by the process of neutron absorption.
- B. Natural radioisotopes can be produced by the process of neutron absorption.
- C. Natural radioisotopes can be produced by the process of positron emission.
- D. Artificial radioisotopes can be produced by the process of electron absorption.

Question 9

A spherical sample of a fissile material will have the lowest critical mass of any shape.

This is because a spherical sample will have the

- A. highest density for a given volume of mass.
- B. largest surface area for a given volume of mass.
- C. lowest density for a given volume of mass.
- D. smallest surface area for a given volume of mass.

Question 10

Which of the following considerations would be **least** significant when assessing the viability of nuclear energy as a power source for Australia?

- A. whether Australia could safely store and dispose nuclear waste
- B. the up-front cost of building and maintaining a nuclear power plant
- C. whether Australia could mine and transport uranium locally
- D. the time required to construct a nuclear power plant

END OF SECTION A

SECTION B**Instructions for Section B**

Answer **all** questions in the spaces provided.

Where an answer box is provided, write your final answer in the box.

If an answer box has a unit printed in it, give your answer in that unit.

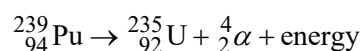
In questions where more than one mark is available, appropriate working **must** be shown.

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Take the value of g to be 9.8 m s^{-2} .

Question 1 (4 marks)

Plutonium-239 is an element that can be used in nuclear weapons. The half-life of plutonium-239 is 24 100 years. Plutonium-239 decays naturally via alpha decay; the decay equation is as follows.



- a.** Explain what is meant by the term ‘half-life’ for plutonium-239. 2 marks

- b.** A 200 g sample of plutonium-239 undergoes radioactive decay.
How many grams of plutonium-239 will there be after 72 300 years have elapsed?
Show your working. 2 marks

g

Question 2 (6 marks)

The radioactive isotope technetium-99m is a short-lived gamma-ray emitter that is often used for medical diagnosis in hospitals. The half-life of technetium-99m is 6.01 hours.

- a. Complete the decay equation below for technetium-99m. 2 marks



Jill, a hospital patient, drinks a specially formulated drink that has a very small amount of technetium-99m in it.

- b. Calculate the fraction of technetium-99m that remains in Jill's kidneys after 12.02 hours. Show your working. 2 marks

- c. Jill is allowed to leave the hospital when the amount of technetium-99m remaining in her kidneys has reduced to $\frac{1}{8}$ of the original amount.

Calculate the number of hours it will take for the amount of technetium-99m in Jill's kidneys to reduce to $\frac{1}{8}$ of the original amount. Give your answer to the nearest whole number.

Show your working. 2 marks

h

Question 3 (8 marks)

Naturally occurring radioactive elements emit various forms of radiation. The radiation forms include alpha particles (α), beta particles (β) and gamma rays (γ).

- a. Complete the table below with the appropriate symbols (α , β or γ).

2 marks

Radiation characteristic	Radiation symbol
The radiation has very high penetration.	
The radiation is always positively charged.	
The radiation is part of the electromagnetic spectrum.	

Caesium-137 is an isotope of the element caesium (Cs), which is a by-product of nuclear fission reactions. The atomic number of caesium is 55. The half-life of caesium-137 is 30.23 years.

Caesium-137 is used in hospitals to treat cancer and decays by emitting a beta-minus particle followed by a gamma ray. Sources of caesium-137 need to be highly active to ensure they produce a sufficient quantity of gamma radiation.

Some of the elements adjacent to caesium in the periodic table are shown in the table below.

53 I	54 Xe	55 Cs	56 Ba	57 La
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- b. Write the nuclear transformation equation for the beta-minus decay of caesium-137.

2 marks

- c. Explain why gamma radiation is used to treat cancers inside the brain instead of alpha or beta radiation.

2 marks

- d. It is very important to carefully dispose of decommissioned caesium sources used in gamma-ray therapy machines in hospitals.

With reference to the half-life of caesium-137, explain why this is the case.

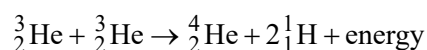
2 marks

Question 4 (7 marks)

The following table shows data for helium-3, helium-4 and hydrogen-1. The table is incomplete.

Particle	Symbol	Mass (kg)	Total binding energy (MeV)
helium-3	${}^3_2\text{He}$	5.022664×10^{-27}	7.718058
helium-4	${}^4_2\text{He}$	6.665892×10^{-27}	28.295674
hydrogen-1	${}^1_1\text{H}$	1.678256×10^{-27}	

One of the processes involved in nuclear fusion in stars is the following reaction.

**Data**

Product nuclei	helium-4 and $2 \times$ hydrogen-1
Initial reacting nuclei	$2 \times$ helium-3

- a. Calculate the difference between the binding energies of the helium-4 nucleus and the two helium-3 nuclei. Give your answer correct to two decimal places. Show your working. 2 marks

MeV

- b. Clearly show that the mass defect in this fusion reaction is 2.2924×10^{-29} kg. 2 marks

kg

c. Data

$1 \text{ eV} = 1.602176 \times 10^{-19} \text{ J}$
$c = 2.997924 \times 10^8 \text{ m s}^{-1}$

Using $E = mc^2$, calculate the energy equivalence of the mass defect, in MeV, correct to two decimal places. Show your working.

3 marks

MeV

END OF TEST