Neap

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

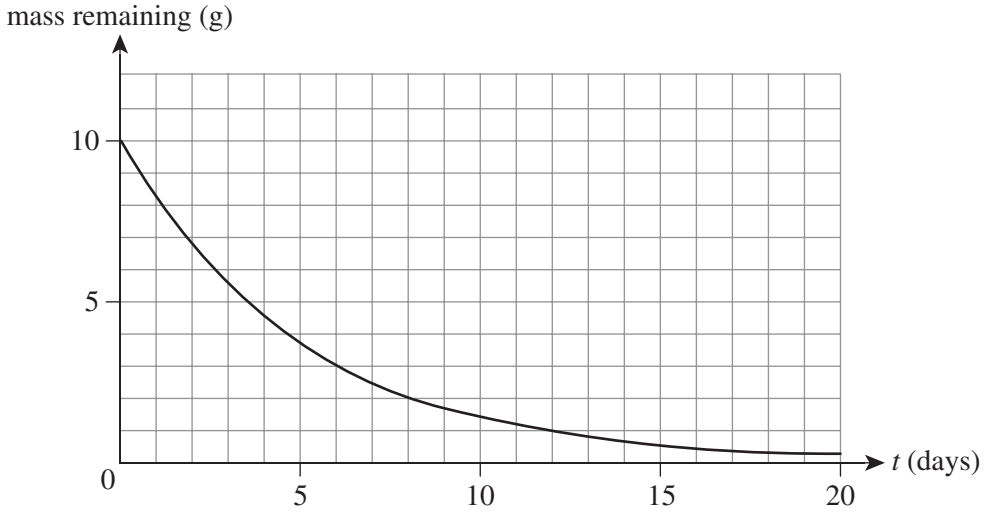
B. 0.80 Sv

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

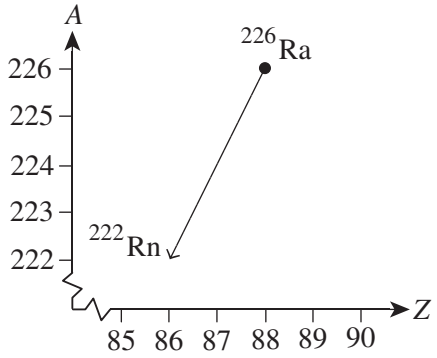
B. 1.5 g

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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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.

$$^{239}_{94}\text{Pu} \rightarrow {}^{235}_{92}\text{U} + {}^{4}_{2}\alpha + \text{energy}$$

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

$$^{99}_{43}\text{Tc*} \rightarrow$$

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

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	${}^{3}_{2}\mathrm{He}$	5.022664×10^{-27}	7.718058
helium-4	${}^{4}_{2}\mathrm{He}$	6.665892×10^{-27}	28.295674
hydrogen-1	${}^{1}_{1}\mathrm{H}$	1.678256×10^{-27}	

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

$$ {}^{3}_{2}\mathrm{He} + {}^{3}_{2}\mathrm{He} \rightarrow {}^{4}_{2}\mathrm{He} + 2\,{}^{1}_{1}\mathrm{H} + \text{energy} $$

Data

Product nuclei	helium-4 and 2 × hydrogen-1
Initial reacting nuclei	2 × 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