GCSE Physics

Half Life and Uses

Question Paper

Time available: 55 minutes
Marks available: 50 marks

1. Americium-241 ($^{241}_{95}Am$) is an isotope of americium.

(a) Which of the isotopes given in the table below is **not** an isotope of americium?

Isotope	Mass number	Atomic number
A	243	95
B	243	94
C	242	95

Isotope _____

Give a reason for your answer.

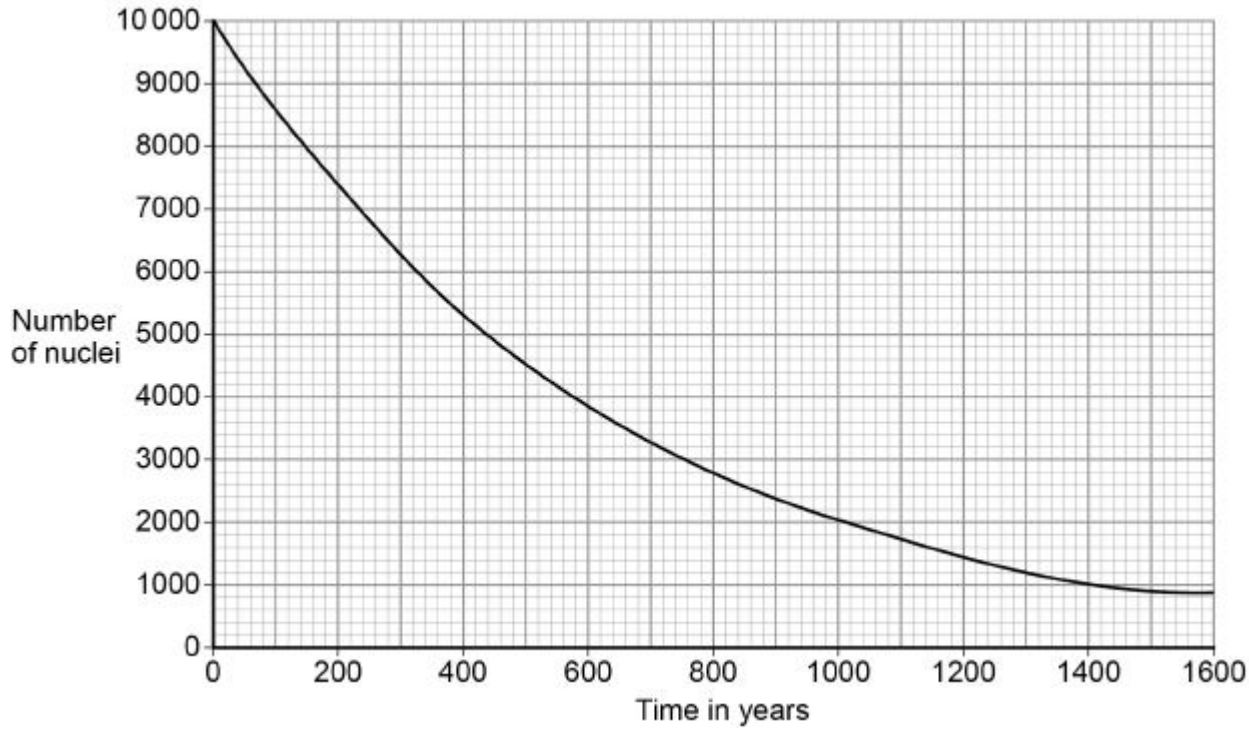
_____

_____

_____

(2)

The graph below shows how the number of americium-241 nuclei in a sample changes with time.



(b) How many years does it take for the number of americium-241 nuclei to decrease from 10 000 to 5000?

Time = _____ years

(1)

(c) What is the half-life of americium-241?

Half-life = _____ years

(1)

(Total 4 marks)

2. A teacher used a Geiger-Muller tube and counter to measure the number of counts in 60 seconds for a radioactive rock.

(a) The counter recorded 819 counts in 60 seconds. The background radiation count rate was 0.30 counts per second.

Calculate the count rate for the rock.

_____

_____

_____

_____

Count rate = _____ per second

(3)

(b) A householder is worried about the radiation emitted by the granite worktop in his kitchen.

1 kg of granite has an activity of 1250 Bq. The kitchen worktop has a mass of 180 kg.

Calculate the activity of the kitchen worktop in Bq.

_____

_____

_____

_____

Activity = _____ Bq

(2)

(c) The average total radiation dose per year in the UK is 2.0 millisieverts.

The table below shows the effects of radiation dose on the human body.

Radiation dose in millisieverts	**Effects**
10 000	Immediate illness; death within a few weeks
1000	Radiation sickness; unlikely to cause death
100	Lowest dose with evidence of causing cancer

The average radiation dose from the granite worktop is 0.003 millisieverts per day.

Explain why the householder should **not** be concerned about his yearly radiation dose from the granite worktop.

One year is 365 days.

_____

_____

_____

_____

(2)

(d) Bananas are a source of background radiation. Some people think that the unit of radiation dose should be changed from sieverts to Banana Equivalent Dose.

Suggest **one** reason why the Banana Equivalent Dose may help the public be more aware of radiation risks.

_____

_____

_____

_____

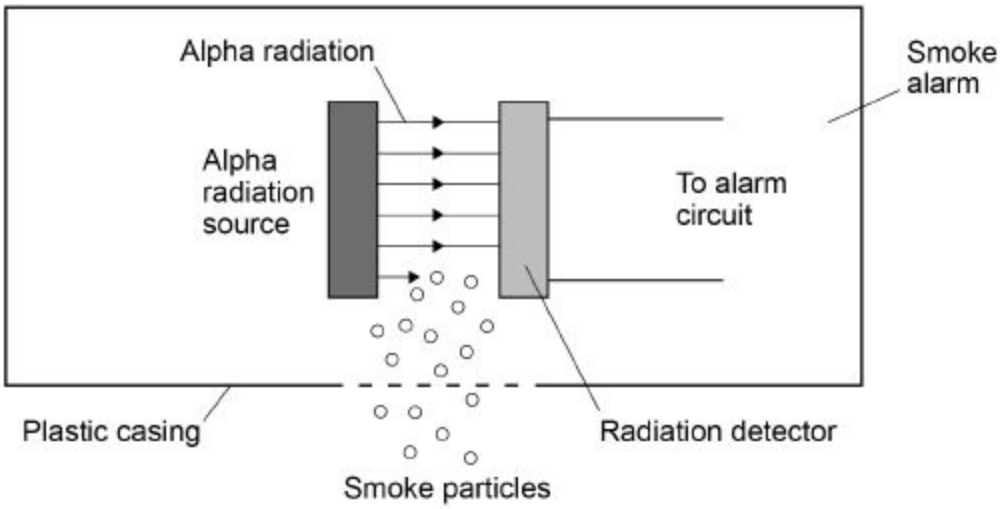
(1)

(Total 8 marks)

3. Smoke alarms contain an alpha radiation source and a radiation detector.

Figure 1 shows part of the inside of a smoke alarm.

Figure 1



(a) The smoke alarm stays off while alpha radiation reaches the detector.

Why does the alarm switch on when smoke particles enter the plastic casing?

_____

_____

_____

(1)

(b) Why is it safe to use a source of alpha radiation in a house?

_____

_____

_____

(1)

(c) The smoke alarm would not work with a radiation source that emits beta or gamma radiation.

Explain why.

_____

_____

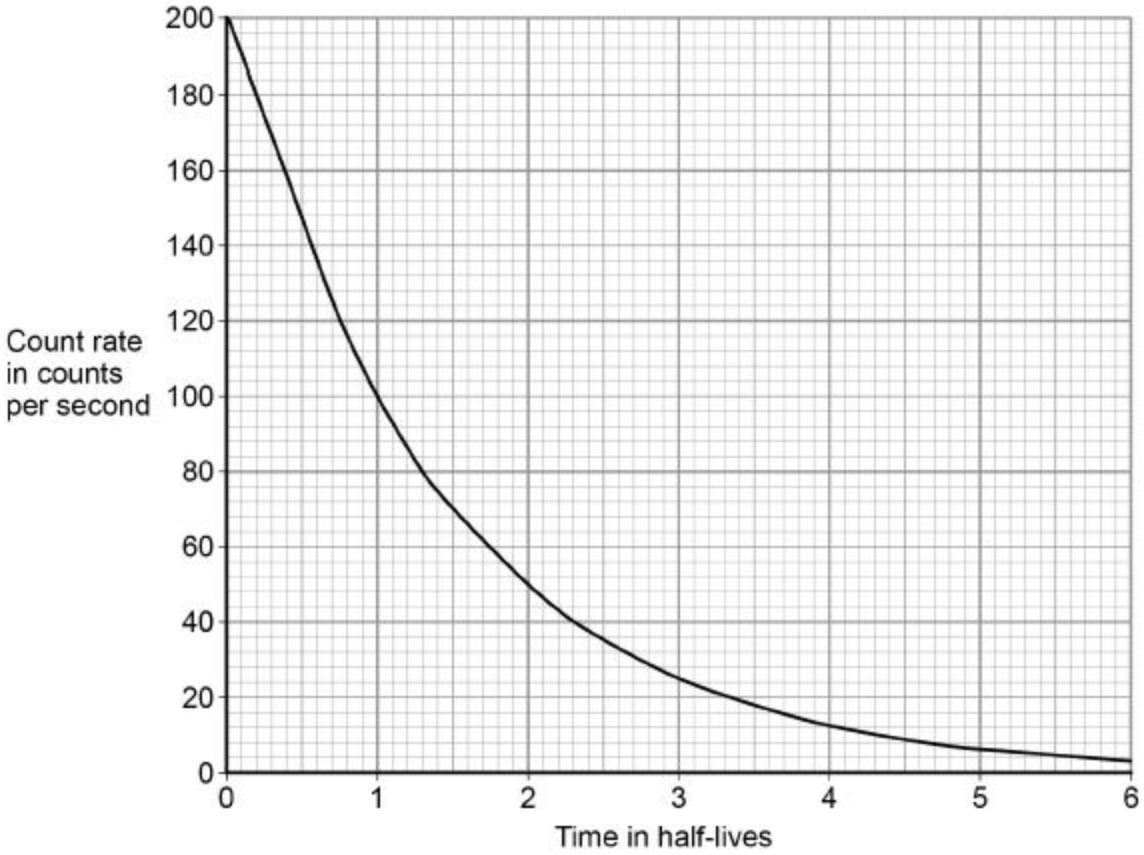
_____

_____

(2)

(d) **Figure 2** shows how the count rate detected from the radiation source in the smoke alarm changes with time.

Figure 2



The smoke alarm switches on when the count rate falls to 80 counts per second.

Explain why the radiation source inside the smoke alarm should have a long half-life.

_____

_____

_____

_____

(2)

(e) **Figure 3** shows a patient who has been injected with a radioactive source for medical diagnosis.

Figure 3

Explain the ideal properties of a radioactive source for use in medical diagnosis.

(4)

(Total 10 marks)

4. A student models the random nature of radioactive decay using 100 dice.

He rolls the dice and removes any that land with the number 6 facing upwards.

He rolls the remaining dice again.

The student repeats this process a number of times.

The table below shows his results.

Roll number	Number of dice remaining
0	100
1	84
2	70
3	59
4	46
5	40
6	32
7	27
8	23

(a) Give **two** reasons why this is a good model for the random nature of radioactive decay.

1. _____

_____

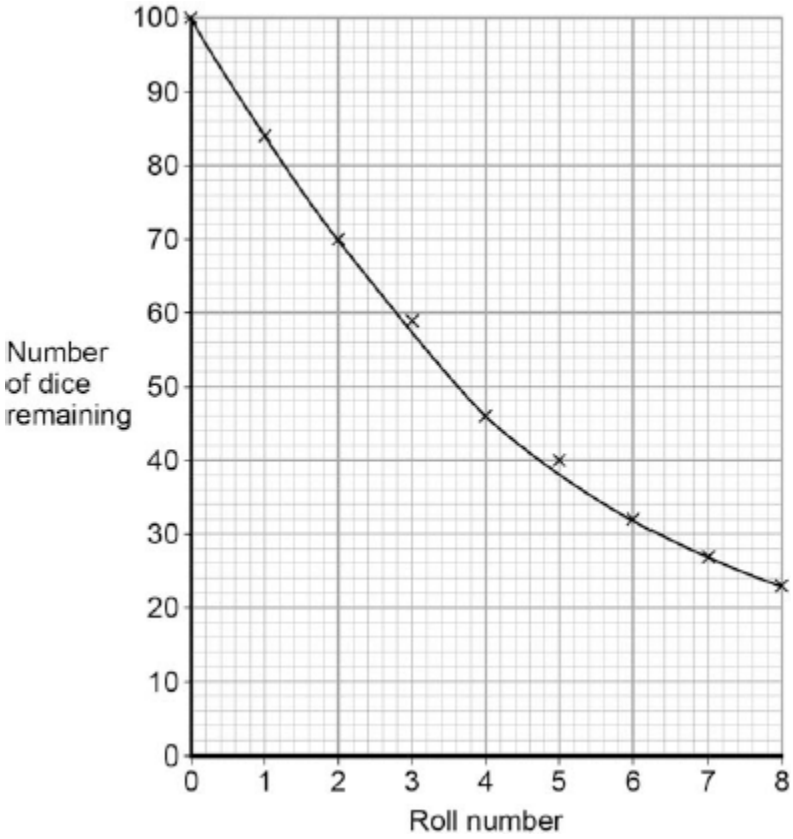
2. _____

_____

(2)

(b) The student's results are shown in **Figure 1**.

Figure 1



Use **Figure 1** to determine the half-life for these dice using this model.

Show on **Figure 1** how you work out your answer.

Half-life = _____ rolls

(2)

(c) A teacher uses a protactinium (Pa) generator to produce a sample of radioactive material that has a half-life of 70 seconds.

In the first stage in the protactinium generator, uranium (U) decays into thorium (Th) and alpha (α) radiation is emitted.

The decay can be represented by the equation shown in **Figure 2**.

Figure 2

$$^{238}_{92}U \longrightarrow \square^{234}Th + \alpha$$

Determine the atomic number of thorium (Th) 234.

Atomic number = _____

(1)

(d) When protactinium decays, a new element is formed and radiation is emitted.

The decay can be represented by the equation shown in **Figure 3**.

Figure 3

$$^{234}_{91}Pa \rightarrow ^{234}_{92}X + radiation$$

When protactinium decays, a new element, **X**, is formed.

Use information from **Figure 2** and **Figure 3** to determine the name of element **X**.

_____

(1)

(e) Determine the type of radiation emitted as protactinium decays into a new element.

Give a reason for your answer.

_____

_____

_____

_____

(2)

(f) The teacher wears polythene gloves as a safety precaution when handling radioactive materials.

The polythene gloves do **not** stop the teacher's hands from being irradiated.

Explain why the teacher wears polythene gloves.

_____

_____

_____

_____

(2)

(Total 10 marks)

5. (a) There are many isotopes of the element molybdenum (Mo).

What do the nuclei of different molybdenum isotopes have in common?

_____

(1)

(b) The isotope molybdenum-99 is produced inside some nuclear power stations from the nuclear fission of uranium-235.

(i) What happens during the process of nuclear fission?

_____

_____

(1)

(ii) Inside which part of a nuclear power station would molybdenum be produced?

_____

(1)

(c) When the nucleus of a molybdenum-99 atom decays, it emits radiation and changes into a nucleus of technetium-99.

$$^{99}_{42}Mo \longrightarrow {}^{99}_{43}Tc + \text{Radiation}$$

What type of radiation is emitted by molybdenum-99?

_____

Give a reason for your answer.

_____

_____

(2)

(d) Technetium-99 has a short half-life and emits gamma radiation.

What is meant by the term 'half-life'?

_____

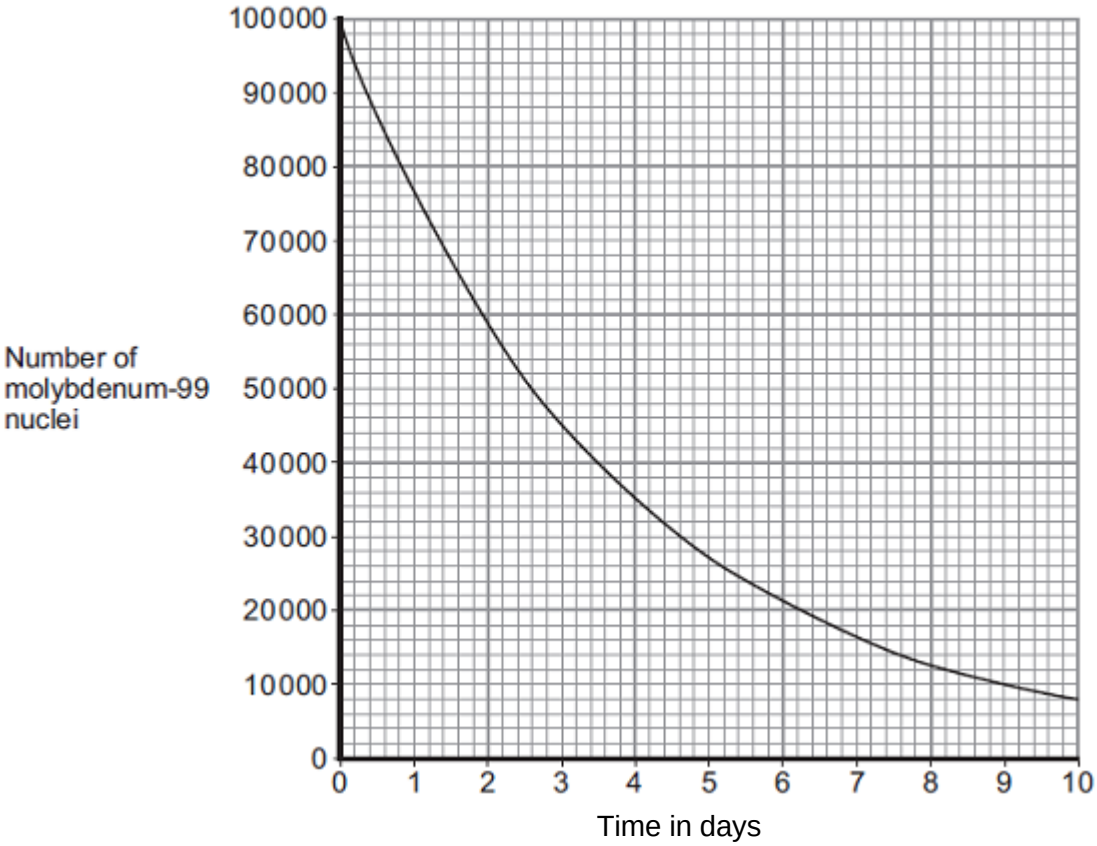
_____

_____

(1)

(e) Technetium-99 is used by doctors as a medical tracer. In hospitals it is produced inside a technetium generator by the decay of molybdenum-99 nuclei.

(i) The figure below shows how the number of nuclei in a sample of molybdenum-99 changes with time as the nuclei decay.



A technetium generator will continue to produce sufficient technetium-99 until 80% of the original molybdenum nuclei have decayed.

After how many days will a source of molybdenum-99 inside a technetium-99 generator need replacing?

Show clearly your calculation and how you use the graph to obtain your answer.

_____

_____

_____

Number of days = _____

(2)

(ii) Medical tracers are injected into a patient's body; this involves some risk to the patient's health.

Explain the risk to the patient of using a radioactive substance as a medical tracer.

_____

_____

_____

_____

(2)

(iii) Even though there may be a risk, doctors frequently use radioactive substances for medical diagnosis and treatments.

Suggest why.

_____

_____

(1)

(Total 11 marks)

6. There are many different isotopes of gold. The isotope, gold-198, is radioactive. An atom of gold-198 decays by emitting a beta particle.

(a) Complete the following sentences.

All atoms of gold have the same number of _____

and the same number of _____ .

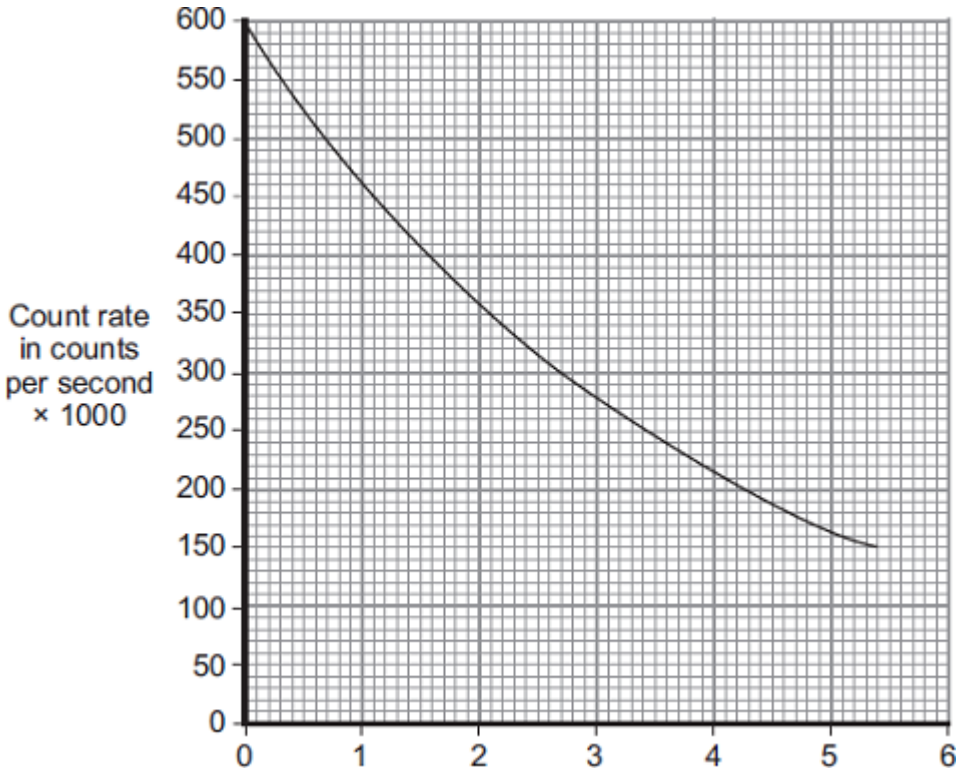
The atoms from different isotopes of gold have different numbers of _____ .

A beta particle is an _____ emitted

from the _____ of an atom.

(3)

(b) The graph shows how the count rate from a sample of gold-198 changes with time.



Use the graph to calculate the half-life of gold-198.

Show clearly on the graph how you obtain your answer.

_____

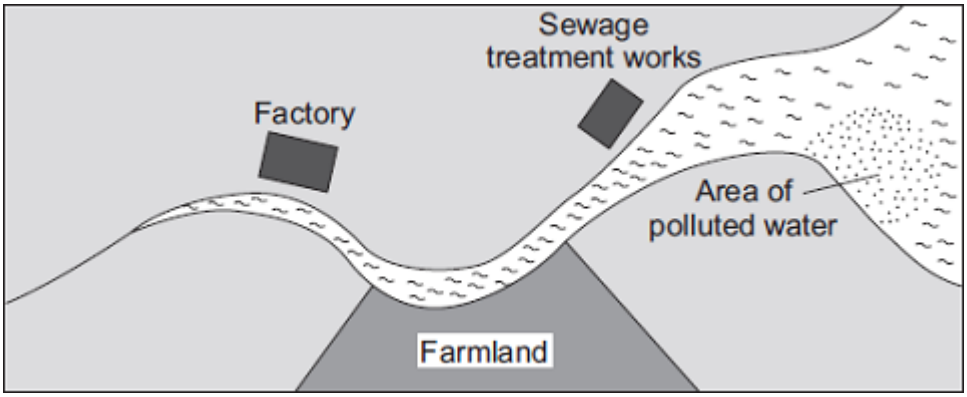
_____

Half-life = _____ days

(2)

(c) The diagram shows a map of a river and the river estuary.

Environmental scientists have found that water flowing into one part of the river estuary is polluted. To find where the pollution is coming from, the scientists use a radioactive isotope, gold-198.



The gold-198 is used to find where the pollution is coming from.

Explain how.

_____

_____

_____

_____

(2)

(Total 7 marks)