1 Tritium is an isotope of hydrogen that decays by emitting beta particles.

It is used in some luminous signs.

(a) (i) The symbol for tritium is $^{3}_{1}H$.

Determine the number of protons and the number of neutrons in a single atom of tritium.

(2)

number of protons .....

number of neutrons .....

(ii) Describe three differences between an alpha particle and a beta particle.

(3)

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(iii) Suggest why tritium cannot emit alpha particles.

(1)

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(b) Tritium is used in this luminous sign.



In this sign

- the letters are made up of glass tubes containing tritium gas
- the inside of each tube is coated with a phosphor
- the phosphor emits light when beta particles hit it

Suggest why this sign is safe to use even though beta particles are ionising and can be dangerous.

(2)

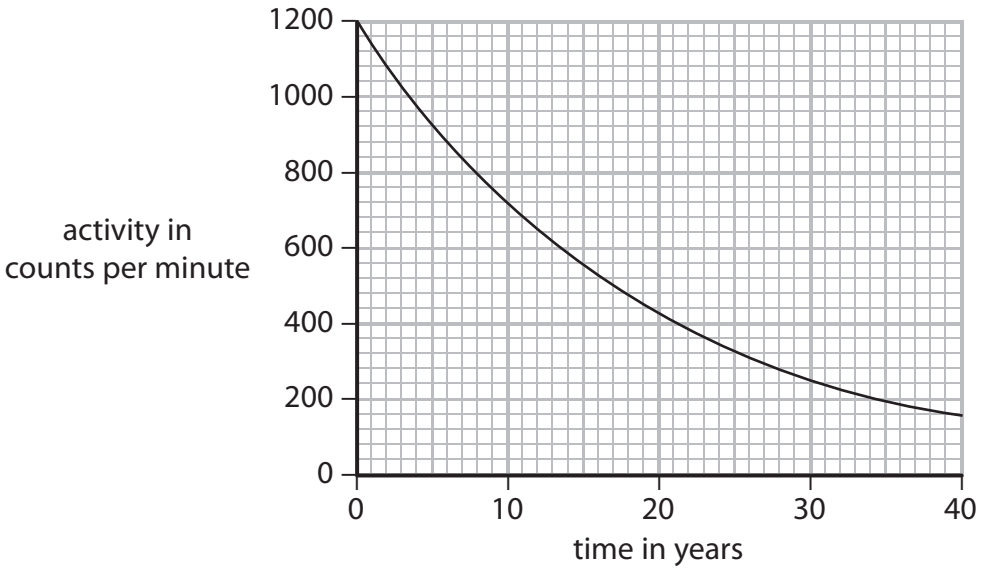
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(c) The graph shows how the activity of tritium in this luminous sign varies with time.



(i) Explain what is meant by the term **half-life**.

(2)

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(ii) Use the graph to estimate the half-life of tritium.

Show your working.

(2)

half-life = ... years

(d) The manufacturer of this luminous sign claims that the sign will work for more than 20 years.

The minimum activity required for the tubes to emit sufficient light is 400 counts per minute.

Evaluate the manufacturer's claim.

(2)

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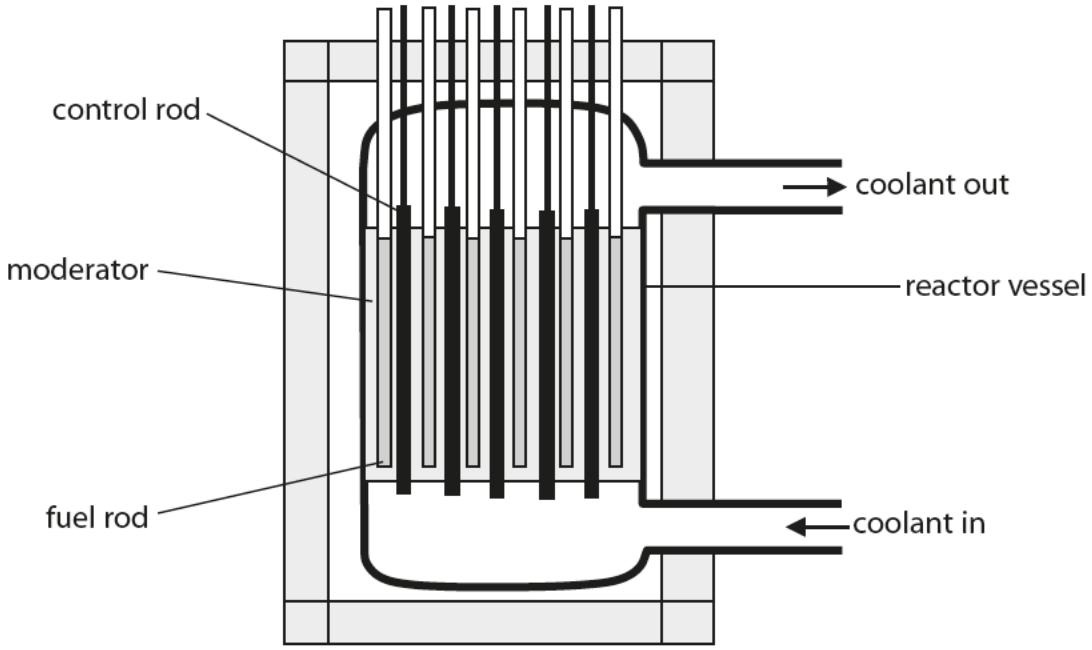
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(Total for Question 1 = 14 marks)

2 The diagram shows a nuclear reactor.



(a) A uranium nucleus in the fuel rod may split when a neutron hits it.

This process of splitting is known as

(1)

☒ **A** fission

☒ **B** moderation

☒ **C** reflection

☒ **D** refraction

(b) The control rods control the reaction by

(1)

☒ **A** absorbing some of the neutrons

☒ **B** cooling the reactor vessel

☒ **C** removing uranium nuclei from the reaction

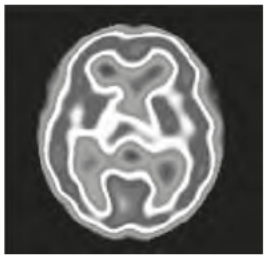
☒ **D** slowing the neutrons slightly

(Total for Question 2 = 2 marks)

3 A doctor uses gamma radiation to produce an image of a person's brain.

A radioactive isotope called technetium-99m is used in this process.

Technetium-99m emits gamma rays and has a short half-life.



(a) (i) Gamma radiation consists of

(1)

☒ **A** electromagnetic waves

☒ **B** negatively charged particles

☒ **C** positively charged particles

☒ **D** unstable atoms

(ii) What is meant by the term **half-life**?

(2)

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(b) The doctor injects a solution of technetium-99m into the patient.

A detector outside the patient receives gamma radiation to form the image.

Suggest why isotopes that emit alpha particles or beta particles are not suitable for this use.

(2)

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(c) Technetium-99m has a half-life of 6 hours.

A sample of technetium-99m has an activity of 420 MBq.

(i) Explain why the activity of a radioactive sample reduces with time.

(2)

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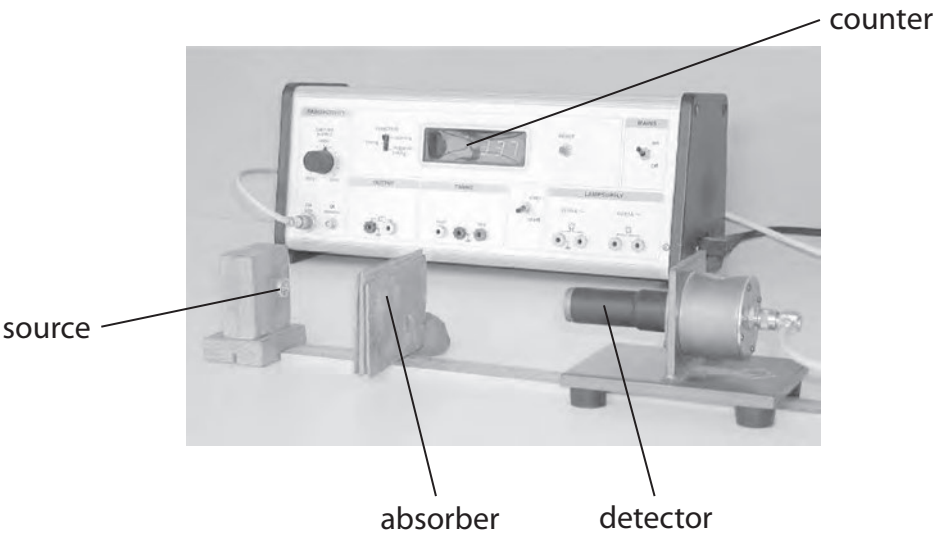
(ii) Calculate the activity of the technetium-99m sample after 24 hours.

(3)

activity = ... MBq

(Total for Question 3 = 10 marks)

4 A teacher uses this apparatus to demonstrate radioactivity to his students.



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(a) The teacher needs to take some safety precautions.

Put one tick (✓) on each row to show whether the safety precaution is needed or not.

Two have been done for you.

(2)

safety precaution	needed	not needed
not touch the source with bare hands	✓	
use tongs		
wear gloves		✓
wear goggles		
students sit at least two metres away		
wear a lead apron		
store source in a lead box		

(b) The teacher uses this method to investigate radioactivity.

- place the detector 10 cm from the radioactive source
- record the count with different absorbent materials between the source and the detector
- repeat the investigation using a different radioactive source
- also repeat the investigation without a source

The table shows his results.

Source used	Counts in 30 s for each material					
	5 mm of aluminium	5 mm of lead	0.2 mm of paper	5 mm of plastic	5 mm of stone	5 mm of wood
barium-133	3 843	1 989	not taken	4 551	10 408	4 557
strontium-90	14	15	42 770	182	13	331
none	15	15	14	15	14	15

(i) State why the teacher keeps the distance constant between the source and the detector.

(1)

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(ii) Explain why there is a reading when no source is used.

(2)

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(iii) Explain which of the materials the teacher used is the best absorber of radiation.

(3)

(iv) A student makes this conclusion.

'Stone is the worst absorber of radiation.'

Evaluate this conclusion.

(3)

(v) Explain what type of radiation strontium-90 emits.

(3)

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(vi) Suggest why the teacher does not take a reading for barium-133 and paper.

(1)

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(vii) Barium-133 and strontium-90 both have a half-life of over 10 years.

Suggest why isotopes with a much shorter half-life are not suitable for this investigation.

(1)

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(Total for Question 4 = 16 marks)

5 Sodium-24 is a radioactive isotope.

(a) What are isotopes?

(2)

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(b) Sodium-24 decays by emitting beta particles.

(i) Describe the nature of a beta particle.

(1)

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(ii) Name a piece of equipment that can be used to detect beta particles.

(1)

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(iii) Describe how a detector can be used with sheets of lead, aluminium and paper to show that a sample of sodium-24 emits beta particles.

(2)

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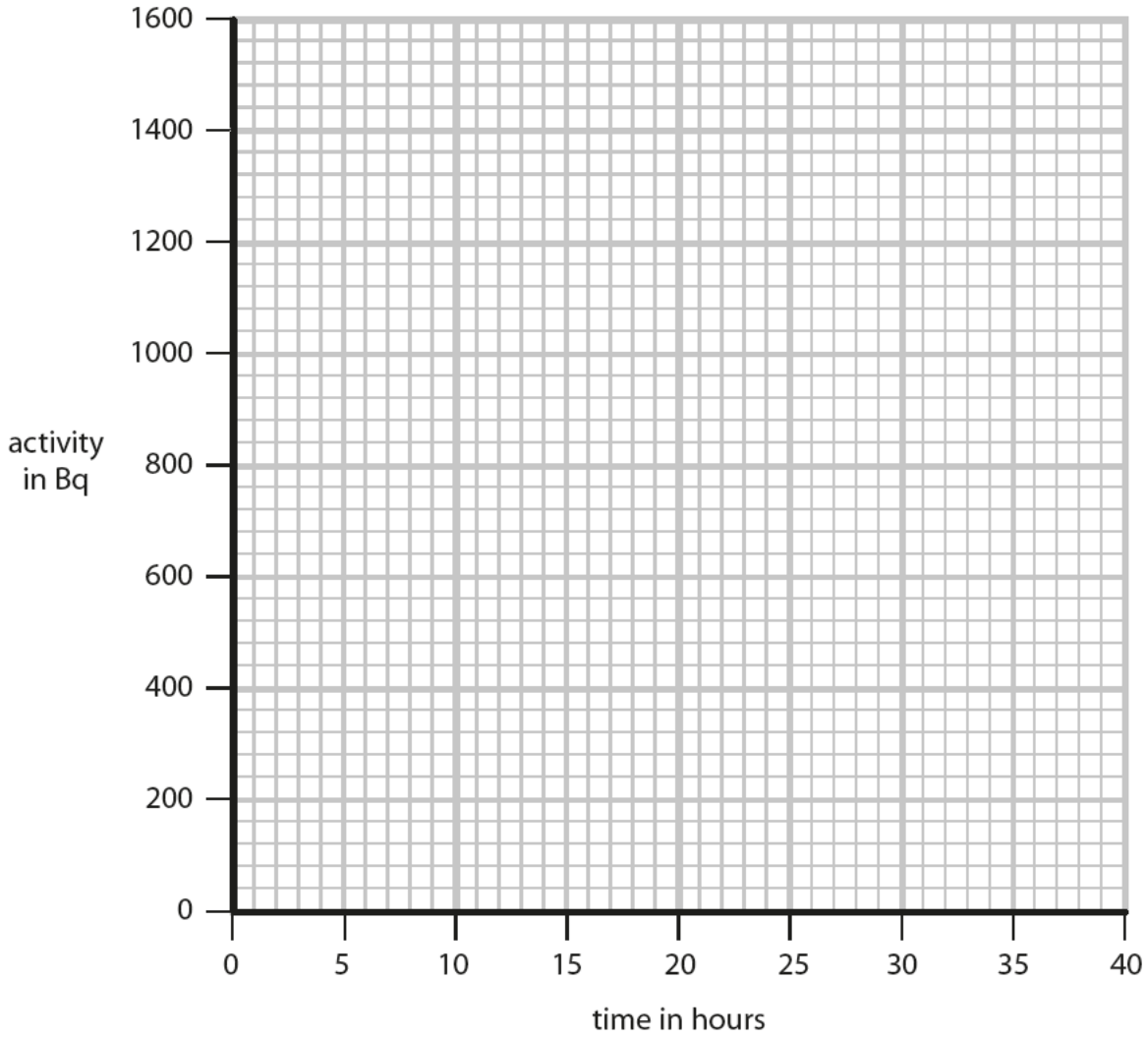
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(c) A sample of sodium-24 has an activity of 1400 Bq.

On the axes, sketch a graph to show how the activity of this sample changes over the next 40 hours.
(the half-life of sodium-24 is 15 hours)

(3)



(d) Granite is a rock.

It contains a radioactive isotope of uranium that decays very slowly.

(i) Explain how scientists can use this radioactivity to find the age of a piece of granite.

(4)

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(ii) Suggest why the age of a piece of granite could **not** be found using a uranium isotope with a half-life of 15 hours.

(2)

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(Total for Question 5 = 15 marks)