Write your name, centre number and candidate number in the boxes below.

Surname	Other names

Centre number | | | | | |

Candidate number | | | | |

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Radioactivity

Time allowed: 1 hour 10 minutes

Subject code **0625**

Physics

Questions from Paper 3 and Paper 4

You must have: a ruler marked in centimetres and millimetres, a protractor, compasses, a pen, an HB pencil and an eraser.

Total marks

/ 70

Instructions

- Answer every question in the space provided on this paper.
- Write in black or dark blue ink. Pencil may be used for diagrams and graphs.
- Fill in your name, centre number and candidate number above.
- Show your working: a correct method can earn marks even if the answer is wrong.

Information

- This paper has 10 questions worth 70 marks in total.
- The marks for each question or part are shown in brackets, for example [3].

Advice

- Read every question through once before you write anything.
- Use the marks in brackets to judge how long to spend on each part.
- If you finish early, go back and check your working.

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Print at 100% (Actual size) so diagrams keep their real measurements.

1 A teacher determines the types of emission from a radioactive source. He uses different materials to absorb the emissions. Fig. 11.1 shows the equipment.

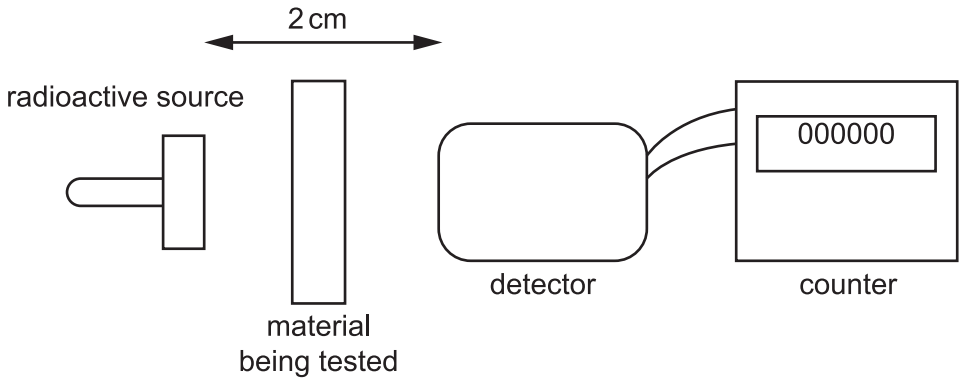


Fig. 11.1 (not to scale)

The teacher places a material between the radioactive source and the detector. The counter shows the count rate for the emission that reaches the detector. The teacher records the count rate. He repeats the experiment for different materials.

Table 11.1 shows the results.

Table 11.1

material being tested	count rate / counts / s
air (no object in gap)	480
thin sheet of paper	481
2 mm sheet of aluminium	479
10 mm block of lead	120

(a) State whether the source emits α (alpha)-particles.
Use information from Table 11.1 to give a reason for your answer.

.....

.....

..... [2]

(b) State whether the source emits γ (gamma)-rays.
Use information from Table 11.1 to give a reason for your answer.

.....

.....

..... [2]

[Total: 4]

Alpha, beta and gamma radiation Click for more variations

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1(a)	alpha (particles) not emitted	**M1**
	any **one** from idea that count rate for paper is similar to count rate for air OR if alpha emitted count rate for paper would decrease/be less (than 480)	**A1**
1(b)	gamma (rays) emitted	**M1**
	any **one** from idea that count rate for (10 mm) lead is less (than count rate for (2 mm) aluminium/air/paper owtte) OR (most/some of) gamma (rays) are absorbed by lead	**A1**

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2 A teacher is investigating radioactivity.

The teacher measures the background radiation in the laboratory.

(a) State **one** source of background radiation.

..... [1]

(b) A teacher measures the count rate of a radioactive isotope.

Fig. 12.1 shows the graph of her results.

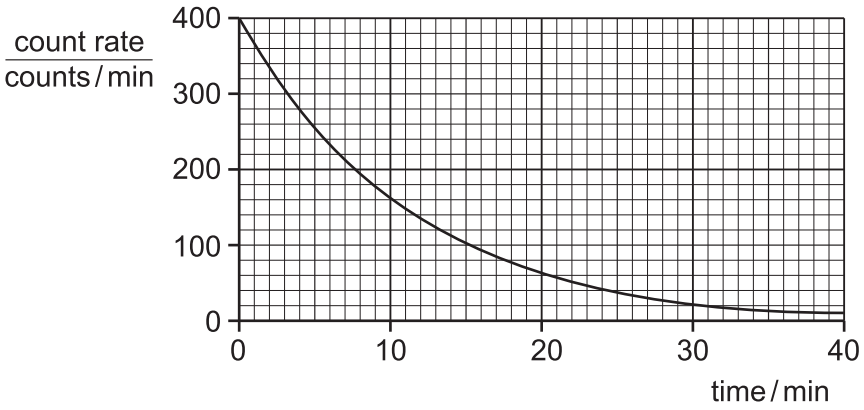


Fig. 12.1

(i) Determine the half-life of the radioactive isotope. Use information from Fig. 12.1.

Show on Fig. 12.1 how you obtained your value.

half-life = ... minutes
[3]

(ii) The radioactive isotope emits γ-radiation.

Describe **one** method of safely storing the radioactive isotope.

.....

..... [1]

[Total: 5]

Half-life Click for more variations

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2(a)	rocks, buildings, (natural) radon, air, cosmic rays, sun, food, drink	**B1**
2(b)(i)	evidence of using graph	**C1**
	TWO pairs of coordinates seen	**C1**
	7.5 (min)	**A1**
2(b)(ii)	Use a lead(-lined) box / container	**B1**

3 Radioactive decay may include the emission of:

α-radiation
β-radiation
γ-radiation

(a) (i) From the list, state the type of radiation which has the **greatest** ionising effect.

.....[1]

(ii) From the list, state the type of radiation which has the **lowest** penetrating ability.

.....[1]

(b) In a factory, rollers press aluminium metal to make thin foil sheets. An automatic system for controlling the thickness of the foil uses a radioactive source. The automatic system changes the gap between the top and bottom roller. Fig. 12.1 shows the equipment.

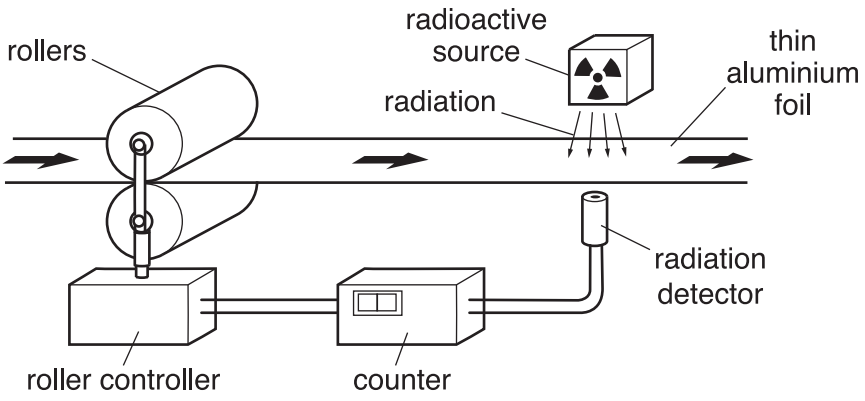


Fig. 12.1

(i) Use your ideas about the properties of radiation to suggest and explain the type of radiation used.

type of radiation .....

explanation .....

.....

.....

.....

[2]

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(ii) The aluminium foil passing the radiation detector is too thin. Describe how this fault affects the reading on the counter.

.....[1]

(iii) Suggest how the fault in **(b)(ii)** is corrected. State what happens to the rollers.

.....[1]

(iv) The source used is strontium-90. A nucleus of strontium-90 can be described as $^{90}_{38}Sr$. State the number of protons in a nucleus of strontium-90.

.....[1]

[Total: 7]

Half-life Click for more variations

Reduced to 78% to fit the page (wider than A4).

3(a)(i)	α or alpha	1
3(a)(ii)	α or alpha	1
3(b)(i)	beta or β	1
	beta emission would be affected by the thickness of the metal owtte	1
3(b)(ii)	(counter) reading higher	1
3(b)(iii)	rollers move apart/provide less force/pressure owtte	1
3(b)(iv)	38	1

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4 Fig. 11.1 shows a beam of radiation that contains α-particles, β-particles and γ-rays. The beam enters a very strong electric field between charged plates in a vacuum.

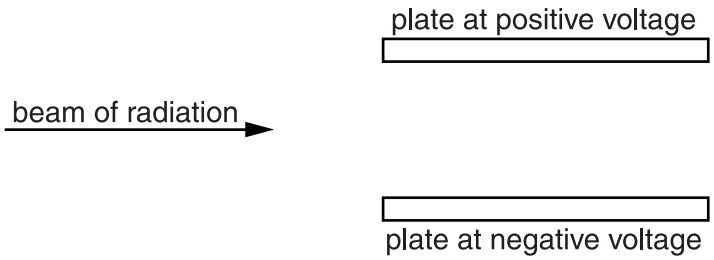


Fig. 11.1

(a) Indicate the deflection, if any, of the α-particles, β-particles and γ-rays, by placing **one** tick in **each** column of the table.

possible deflection	α-particles	β-particles	γ-rays
no deflection			
towards positive plate			
towards negative plate			
out of the paper			
into the paper			

[3]

(b) The radiation is said to be *ionising*. Explain what this means.

.....

.....[1]

(c) α-particles are more strongly ionising and have a shorter range in air than γ-rays.

Use your knowledge of the nature of these radiations to explain these differences.

.....

.....

.....

..... [3]

[Total: 7]

Alpha, beta and gamma radiation Click for more variations

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4 (a) γ not deflected — NOT extra(s) in γ column — B1

α towards –ve or +ve AND β opposite — NOT extra(s) in α or β column — B1

α towards –ve AND β towards +ve — NOT extra(s) in α or β column — B1

(b) atoms / molecules (condone particles) lose / gain electrons OR become charged
NOT α or β particles lose / gain electrons OR become charged — B1

(c) maximum three points (to include at least one explanation) from:
maximum two points from:

- α is charged / is a helium ion (is scored if 3rd explanation bullet point scored)
- γ is not charged
- α has mass
- γ does not have mass
- α has large size
- γ has negligible / no size
- γ is electromagnetic (wave) / photon
- α travels more slowly (than γ, but NOT more slowly than speed of light unless next bullet point is also scored)
- γ travels at the speed of light / faster (than α)

any explanation (maximum three) e.g.:

- α makes frequent collisions (with air molecules) so range short
- γ has few (successful) collisions (with electrons) so not very ionising / range long
- α more ionising because it has greater charge
- γ has no charge so less ionising
- α loses some energy with each collision so range short
- γ loses energy in single rare collision so takes longer distance before losing all energy
- γ faster so travels further before energy is lost
- different methods of ionisation make α more ionising

B3

[Total: 7]

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5 Strontium-90 is a radioactive isotope of strontium. The nuclide notation for strontium-90 is:

$$^{90}_{38}Sr$$

(a) (i) Explain what isotopes are.

.....

..... [1]

(ii) Complete Table 9.1 for strontium-90.

Table 9.1

particle	number in one atom	location
	38	outside nucleus
neutron		
	38	inside nucleus

[2]

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(b) Strontium-90 is used to measure the thickness of metal sheets in industry.
Strontium-90 decays by emitting beta (β) particles which pass through a metal sheet to a detector.

(i) One metal sheet is 0.75 mm thick. Suggest why strontium-90 is a suitable radioactive source to measure the thickness of the metal sheets.

.....

.....

..... [2]

(ii) The half-life of strontium-90 is approximately 27 years. Fig. 9.1 shows the shape of a decay curve.

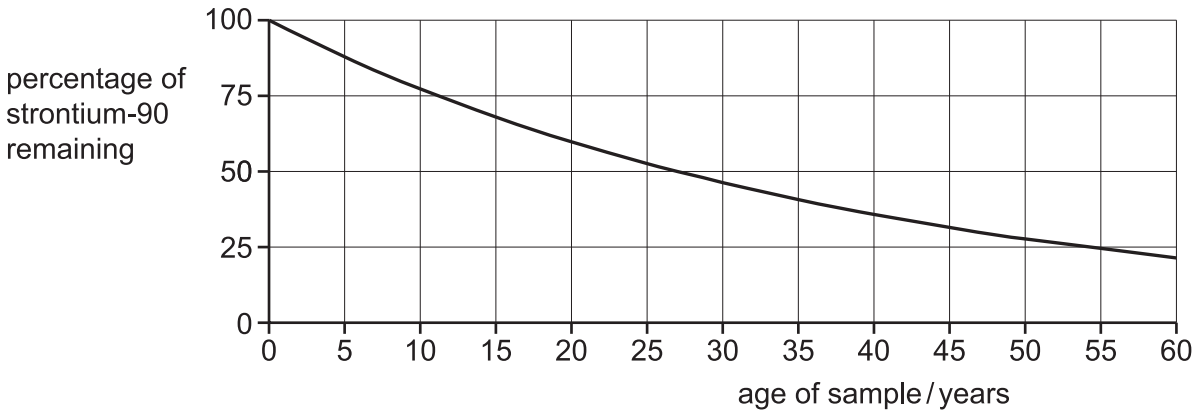


Fig. 9.1

The strontium-90 source is replaced with a new source after 15 years. Using Fig. 9.1, suggest why a strontium-90 source that is more than 15 years old needs to be replaced with a new source.

.....

..... [2]

[Total: 7]

Half-life Click for more variations

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<table>
<tr><td>5(a)(i)</td><td>(isotopes are) forms of an element with the same number of protons but a different number of neutrons (in the nucleus) OR
(isotopes are) the same element with a different number of neutrons</td><td>B1</td></tr>
<tr><td>5(a)(ii)</td><td>
<table>
<tr><td>particle</td><td>number in each atom of strontium</td><td>location</td></tr>
<tr><td>electron</td><td>38</td><td>outside nucleus</td></tr>
<tr><td>neutron</td><td></td><td></td></tr>
<tr><td>proton</td><td>38</td><td>Inside nucleus</td></tr>
</table>
</td><td>B1</td></tr>
<tr><td></td><td>
<table>
<tr><td>particle</td><td>number in each atom of strontium</td><td>location</td></tr>
<tr><td></td><td>38</td><td>outside nucleus</td></tr>
<tr><td>neutron</td><td>52</td><td>Inside nucleus</td></tr>
<tr><td></td><td>38</td><td>Inside nucleus</td></tr>
</table>
</td><td>B1</td></tr>
<tr><td>5(b)(i)</td><td>(there is a) different count rate with different thicknesses of metal OR number of β-particles detected varies with thickness</td><td>A2</td></tr>
<tr><td></td><td>(beta (β) particles) can penetrate thin / 0.75mm metal OR (beta (β) particles) are stopped by thick metal</td><td>C1</td></tr>
<tr><td>5(b)(ii)</td><td>(approximate) percentage of source remaining (after 15 years) stated AND in range 63–70%
(approximate) percentage of sample lost (after 15 years) stated AND in range 30–37%</td><td>B1</td></tr>
<tr><td></td><td>Any one from:
• count rate / activity (too) low (to detect differences in thickness) owtte
• detector needs high activity (to detect differences in thickness) owtte
• count rate / activity too close to background owtte
• less difference in activity for different thicknesses owtte</td><td>B1</td></tr>
</table>

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6 A radiation detector is placed on the bench in a laboratory. It detects a background count rate of 40 counts / minute.

(a) State what is meant by background radiation. Suggest one source for it.

.....

.....

..... [2]

(b) A sample containing atoms of the radioactive isotope polonium-208 is removed from a lead container and brought close to the detector. The average count rate increases to 890 counts / minute.

When two sheets of paper are inserted between the sample and the detector, the average count rate returns to 40 counts / minute.

Polonium-208 is represented by the symbol $^{208}_{84}$Po. It decays to an isotope of lead (Pb).

(i) Deduce the type of radiation emitted by polonium-208. Explain your answer.

.....

.....

.....

..... [2]

(ii) Write down the nuclide equation for the decay of polonium-208.

[3]

[Total: 7]

Alpha, beta and gamma radiation Click for more variations

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6(a)	radiation that is always present **or** due to environment **or** in everyday life	**B1**
	soil / rocks / earth / cosmic rays / space / Sun / weapons testing / radon / nuclear waste	**B1**
6(b)(i)	alpha-emission (only)	**B1**
	alpha-particles do not penetrate (two sheets of) paper **or** β-particles **and** γ-rays pass through (two sheets of) paper	**B1**
6(b)(ii)	$^{208}_{84}Po \rightarrow {}^{4}_{2}\alpha$ / $^{4}_{2}He$	**B1**
	^{204}Pb... **or** $_{82}Pb$	**C1**
	$^{204}_{82}Pb$	**A1**

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7 Fig. 10.1 represents a neutral atom of an isotope of element X.

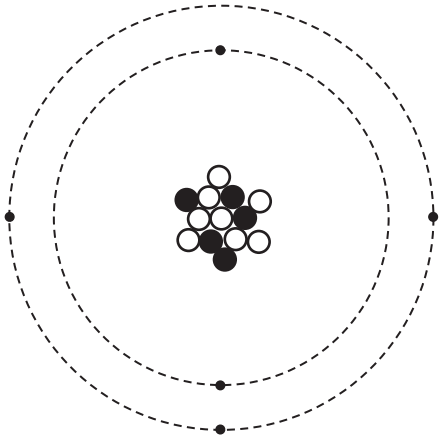


Fig. 10.1

(a) State **one** similarity between this atom and a neutral atom of a different isotope of element X.

.....

..... [1]

(b) The isotope of element X is radioactive. It decays to form an isotope of element Y by emitting a β-particle.

(i) Using Fig. 10.1 deduce the nuclide notation for the isotope of Y produced by this decay.

nuclide notation: .....Y..... [3]

(ii) β-particles ionise the air they pass through less strongly than the same number of α-particles.

Suggest why this is so.

.....

.....

..... [3]

[Total: 7]

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Alpha, beta and gamma radiation Click for more variations

7(a)	equal number of electrons OR equal number of protons	**B1**
7(b)(i)	$^{13}_{5}X$	**C1**
	$^{0}_{-1}\beta$	**C1**
	$^{13}_{6}Y$	**A1**
7(b)(ii)	any **three** from: • β-particles have charge of smaller size • β-particles have smaller mass • β-particles have less energy • β-particles travel faster / less time near to air molecule • effect / force on electrons in air molecules less	**B3**

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8 The isotope thallium-208 ($^{208}_{81}Tl$) is radioactive. It decays by β-decay.

(a) Thallium-208 decays to an isotope of lead (Pb).

(i) Complete the equation for this decay.

$$^{208}_{81}Tl \longrightarrow \text{.....}^{\text{.....}}\text{Pb} + \text{.....}^{\text{.....}}\beta$$

[3]

(ii) The β-emission of thallium-208 is accompanied by γ-emission from the nucleus.

Explain why this γ-emission does **not** affect the numbers in the equation in **(a)(i)**.

.....

..... [1]

(iii) Suggest **one** reason why a nucleus of thallium-208 is unstable.

.....

..... [1]

(b) A sample of thallium-208 is placed in a thick lead container. Fig. 8.1 shows a narrow beam of β-particles and γ-radiation emerging from a small hole in one side of the container.

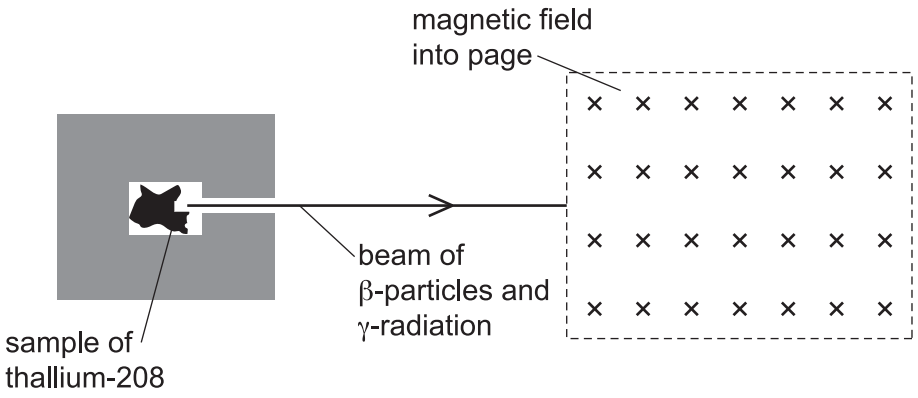


Fig. 8.1

The narrow beam enters a region where there is a magnetic field that is directed into the page.

On Fig. 8.1:

- draw a line **labelled β** to indicate the path of the β-particles in the magnetic field
- draw a line **labelled γ** to indicate the path of the γ-radiation in the magnetic field.

[3]

[Total: 8]

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Alpha, beta and gamma radiation Click for more variations

8(a)(i)	$^{0}_{-1}\beta$	**B1**
	$^{208}_{\cdots}Pb$	**B1**
	$^{\cdots}_{82}Pb$	**B1**
8(a)(ii)	γ-emission / it consists of waves / rays **OR** γ-emission has no mass / charge	**B1**
8(a)(iii)	(it contains) too many / excess of neutrons **OR** (nucleus is) too heavy	**B1**
8(b)	smooth curve (through magnetic field) **AND** labelled β	**B1**
	path towards bottom of page **AND** no upward component **AND** labelled β	**B1**
	(continuation of beam along) horizontal line through magnetic field **AND** labelled γ	**B1**

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9 In a research laboratory, a radioactive sample is placed close to a radiation detector. The graph in Fig. 11.1 shows the decay of the sample.

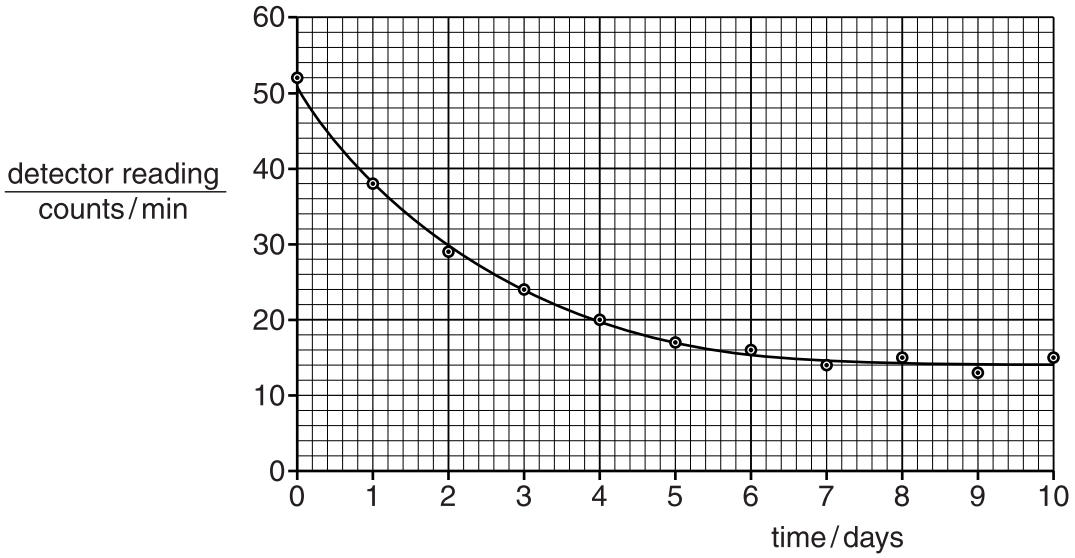


Fig. 11.1

(a) After 6 days the count rate hardly decreases and, in fact, increases a little at times. Explain these observations.

.....

.....

.....

..... [2]

(b) Use the graph to determine the half-life of the sample. Explain your working carefully.

half-life = ... [4]

(c) Another radioactive sample is a strong emitter of α-particles and γ-rays. A junior researcher suggests that a sufficient safety precaution, when working with this sample, would be to hold the sample with long forceps. Explain why this suggestion, although helpful, may be insufficient.

.....

.....

.....

..... [2]

[Total: 8]

Half-life Click for more variations

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9	**(a)**	any mention background	B1	
		background/radiation varies randomly o.w.t.t.e. OR rate of decay very small OR sample nearly all decayed	B1	[2]
	(b)	correctly deducts correct background (13 – 15 /s)	B1	
		takes 2 detector readings, one twice the other	B1	
		correct working, with/without background subtraction, i.e. use of graph	B1	
		half life = 1.2 – 1.8 days OR follows from working	B1	[4]
	(c)	α (very) short range in air OR will not reach researcher NOT will not penetrate skin	B1	
		γ long range/very penetrating/heavy shielding needed OR will reach researcher	B1	[2]

[Total: 8]

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10 Many household smoke alarms contain a sample of the radioactive isotope americium-241 (Am).

(a) Americium-241 is the isotope of the element americium that has the nucleon number (mass number) 241.

(i) State how the composition of a nucleus of americium-241 differs from that of a nucleus of americium-242.

.....

..... [1]

(ii) An atom of a different element has a nucleon number of 241.

State **two** differences between the composition of a nucleus of this atom and a nucleus of americium-241.

1 .....

2 .....

[2]

(b) Americium-241 decays to an isotope of neptunium (Np) by alpha-particle (α-particle) emission.

(i) Complete the equation for this decay.

$$^{241}_{\ldots\ldots}\mathrm{Am} \longrightarrow {}^{\ldots\ldots}_{93}\mathrm{Np} + {}^{\ldots\ldots}_{\ldots\ldots}\alpha$$

[3]

(ii) One reason for using an isotope that emits α-particles in a smoke detector is that α-particles are more strongly ionising than beta-particles (β-particles).

Explain why α-particles are more strongly ionising than β-particles.

.....

.....

..... [2]

(iii) The isotope of neptunium produced by americium-241 is also radioactive.

The decay of this isotope of neptunium produces an isotope of protactinium which decays by β-emission. β-particles are more penetrating than α-particles.

The half-life of neptunium is longer than two million years.

Using this information, explain the advantage of this long half-life for the use and safe disposal of a household smoke alarm.

.....

.....

..... [2]

[Total: 10]

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Alpha, beta and gamma radiation Click for more variations

10(a)(i)	(americium-241 has) one neutron fewer (in the nucleus)	**B1**
10(a)(ii)	(different) number of protons (in nucleus)	**B1**
	(different) number of neutrons (in nucleus)	**B1**
10(b)(i)	$^{241}_{95}Am \rightarrow {}^{237}_{93}Np + {}^{4}_{2}a$	**A3**
	any two from: $_{95}Am$ ^{237}Np $^{4}_{2}a$	C2
10(b)(ii)	(α-particles have) more kinetic energy (than β-particles)	**B1**
	(α-particles have) more charge (than β-particles)	**B1**
10(b)(iii)	Low(er) (initial) activity OR Few emissions per unit time	**M1**
	so smoke detectors are not hazardous to humans **OR** so disposal of old detectors is cheap / easy	**A1**

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