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

Surname	Other names

Centre number | | | | | |

Candidate number | | | | |

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Half-life

Time allowed: 55 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

/ 58

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 9 questions worth 58 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 radioactive nuclide has a half-life of 4.0 days. A sample contains 9.6×10^8 atoms of the nuclide.

(a) Calculate the number of atoms of the nuclide remaining after 12 days.

number = ... [2]

(b) The count rate from the sample is measured in a laboratory where the background count rate is 16 counts/minute.

A detector is placed at a fixed distance from the sample. The initial count rate measured by the detector is 160 counts/minute.

Calculate the count rate measured by the detector after 12 days.

count rate = ... [2]

[Total: 4]

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Half-life Click for more variations

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1(a)	$9.6 \times 10^8 / 8$ 1.2×10^8 (atoms)	**C1** **A1**
1(b)	160 – 16 OR 144 (144/8 + 16 = 18 + 16 =) 34 counts/minute	**C1** **A1**

2 Fig. 12.1 shows the graph of the count rate from a radioactive source over a period of time. The readings have already had the background count rate subtracted.

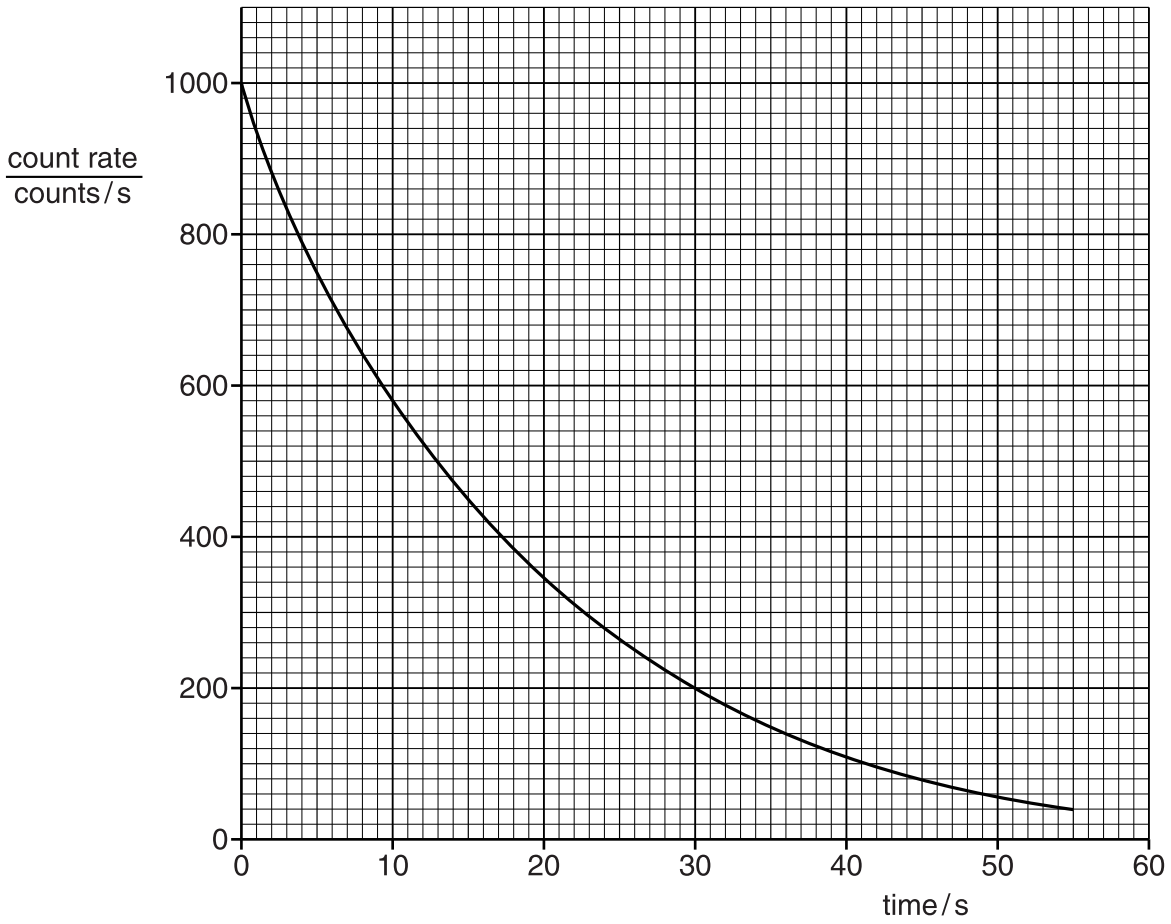


Fig. 12.1

(a) From Fig. 12.1, find the time taken for the count rate to decrease from 1000 counts/s to 125 counts/s.

time = ... s [1]

(b) How many half-lives of the radioactive material were there during the time interval in **(a)**?

number of half lives = ...[1]

(c) From your answers to **(a)** and **(b)**, calculate the half-life of the material.

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half-life = ... s [2]

(d) On Fig. 12.1, sketch the curve that might have been plotted if the background count rate had **not** been subtracted. [1]

[Total: 5]

Half-life Click for more variations

2	**(a)**	37.5 ± 0.4 s	B1	
	(b)	3	B1	
	(c)	his(a) / his(b) in range 12 to 13 OR his value calculated correctly	C1 A1	
	(d)	curve above existing line at all points and roughly parallel	B1	[5]

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3 In a laboratory at a nuclear power station, a radiation detector is connected to a computer. The readings recorded are displayed on the computer screen.

The detector is switched on. Ten minutes later, at time t = 10 minutes, a small sample of radioactive material is removed from a nuclear reactor and placed near to the detector. Readings are recorded for a further 40 minutes. Fig. 11.1 shows the display.

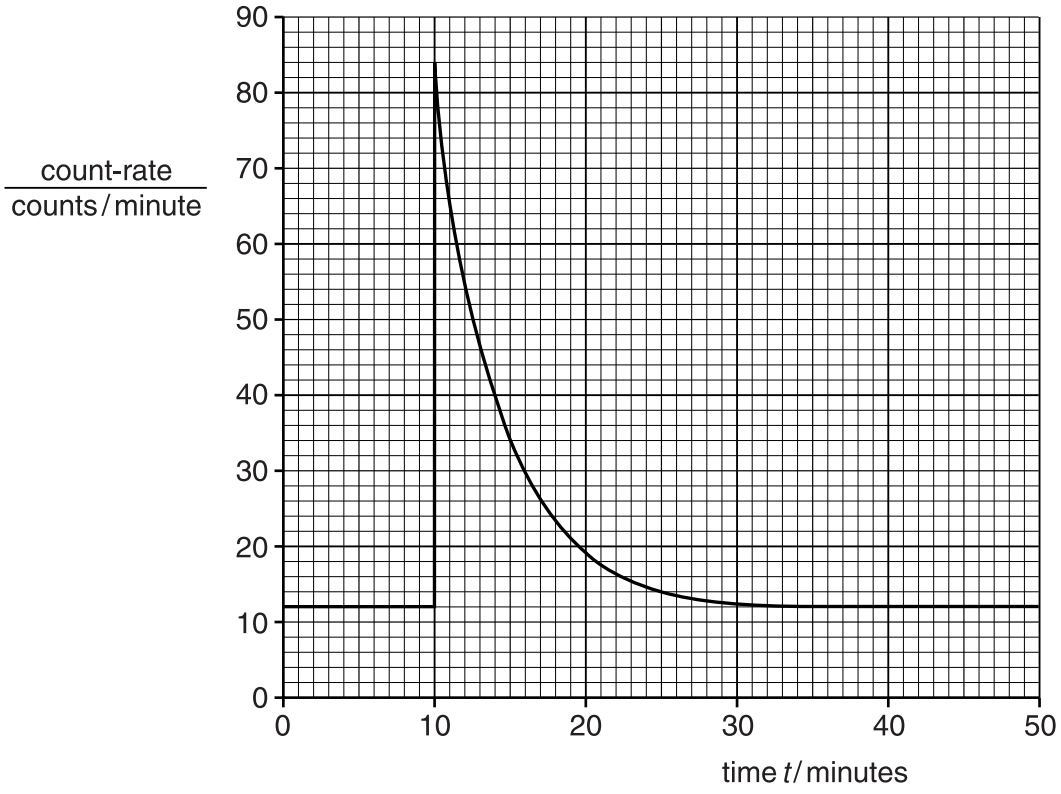


Fig. 11.1

(a) Use Fig. 11.1 to determine the background count-rate in the laboratory.

background count-rate = ... [1]

(b) Use Fig. 11.1 to determine the count-rate due to the radioactive sample

(i) at t = 10 minutes,

count-rate due to sample = ...

(ii) at t = 19 minutes.

count-rate due to sample = ...
[2]

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(c) Use the values obtained in **(b)** to estimate the half-life of the radioactive sample.

half-life = ... [2]

[Total: 5]

Half-life Click for more variations

3 **(a)** 12 counts / min B1 [1]

(b) **(i)** 72 counts / min (e.c.f. from **11(a)**) B1

(ii) 9 counts / min (note: if background not subtracted, **(i)** 84 and **(ii)** 21 gains 1 compensatory mark) B1 [2]

(c) 9/72 **or** 1/8 **or** 3 (half-lives)
or (e.c.f.) 21/84 **or** 1/4 **or** 2 (half-lives) C1
3.0 minutes **or** 4.5 minutes (i.e. background not subtracted but otherwise correct) A1 [2]

[Total: 5]

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4 **(a)** Four students attempt to define the *half-life* of a sample of radioactive substance.

Student A Half-life is half the time for the activity of the sample to decrease to zero.

Student B Half-life is half the time taken for the activity of the sample to decrease to half its original value.

Student C Half-life is the time taken for the activity of the sample to decrease to half its original value.

Which student has given a correct definition? ..... [1]

(b) Fig. 12.1 shows two samples of the same radioactive substance. The substance emits β-particles.

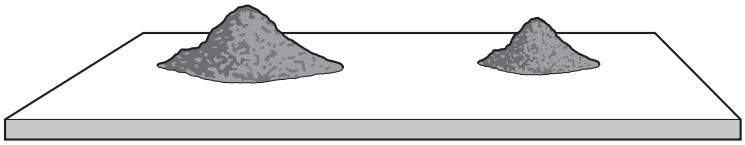


Fig. 12.1

Put a tick alongside any of the following quantities which is the same for both samples.

the half-life of the samples	☐
the mass of the samples	☐
the number of atoms decaying each second	☐
the number of β-particles emitted per second	☐

[1]

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(c) A quantity of radioactive material has to be taken from a nuclear reactor to a factory some distance away. Fig. 12.2 shows the decay curve for the quantity of radioactive material.

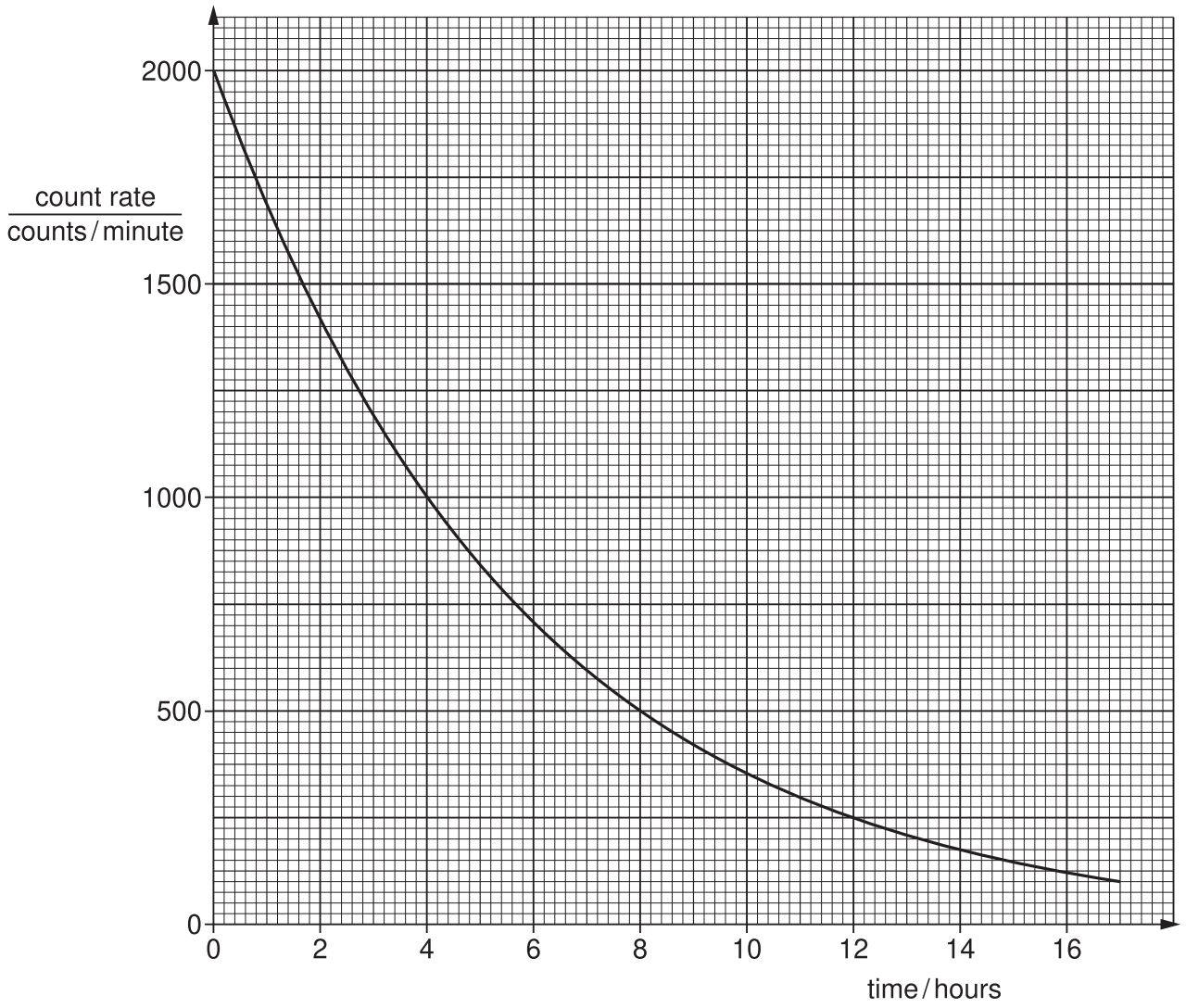


Fig. 12.2

Just before it leaves the nuclear reactor, the count-rate from the material is 2000 counts / minute. When it arrives at the factory, the count-rate is 1000 counts / minute.

(i) How long did the journey take? ..... hours [1]

(ii) How many half-lives elapsed during the journey? ..... [1]

(iii) The material is only useful to the factory if the activity is at least 100 counts / minute. Use Fig. 12.2 to determine how many hours of useful life the factory has from the radioactive material.

useful life = ... hours [2]

[Total: 6]

Half-life Click for more variations

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4 **(a)** student C OR the last one B1

(b) half-life ticked B1

(c) **(i)** 4 (hours) B1

(ii) 1 B1

(iii) 17 hours (gives 100 cpm) C1
13 (hours) A1 [6]

5 **(a)** Complete the following definition of radioactive half-life.

The half-life of a radioactive substance is the time taken for .....

.....

.....

.....[2]

(b) Fig. 12.1 shows how the count rate from a sample of radioactive material changes with time.

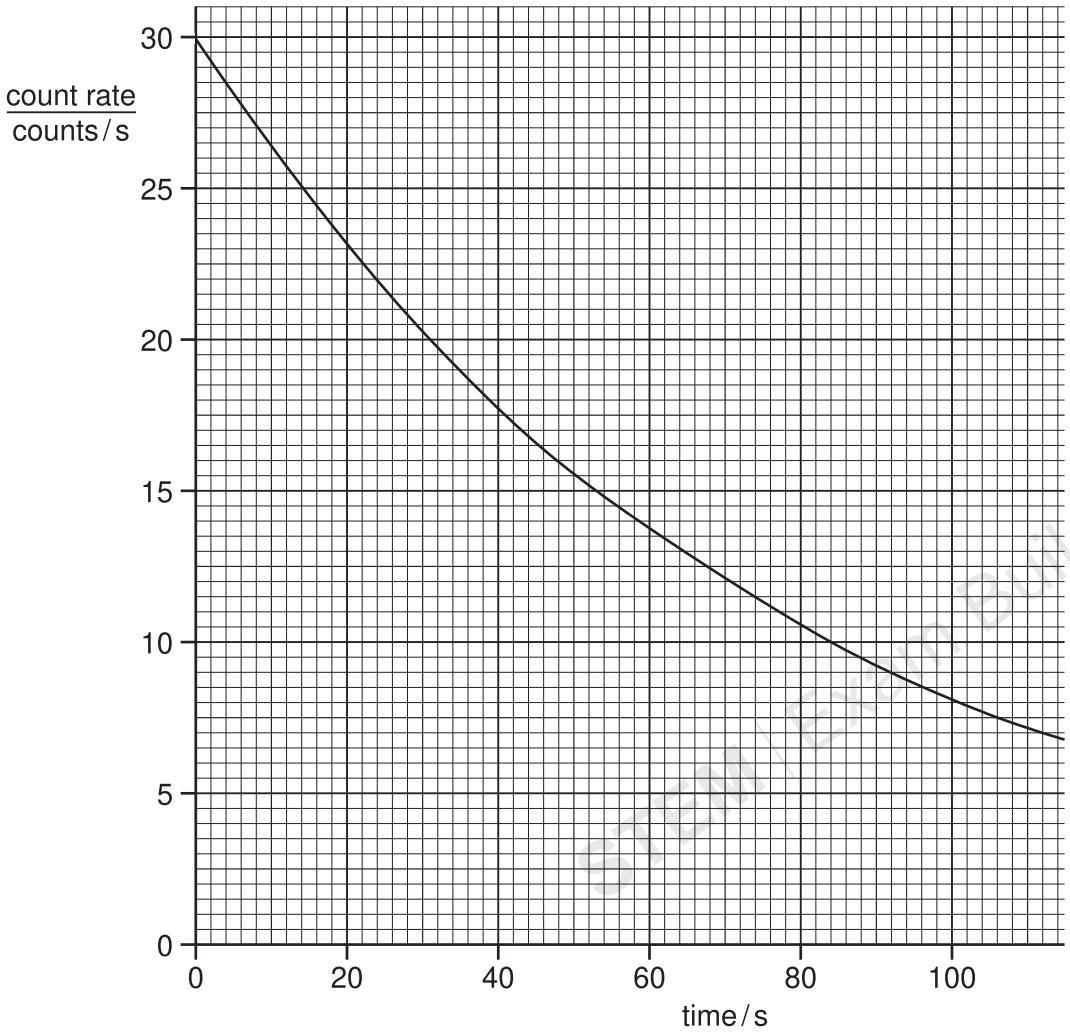


Fig. 12.1

(i) Use Fig. 12.1 to find the half-life of the radioactive material.

half-life = ... s [1]

(ii) Use the graph to find how long it takes for the count rate to decrease from 30 counts/s to 10 counts/s.

time taken = ... s [1]

(iii) Use your answers to **(i)** and **(ii)** to find how long it takes for the count rate to decrease from 30 counts/s to 5 counts/s.

time taken = ... s [2]

[Total: 6]

Half-life Click for more variations

5 **(a)** (radio)activity OR count rate OR counts/s OR particles emitted/s
OR rate of decay OR number of undecayed atoms/nuclei
OR radiation OR original number of atoms/nuclei B1
NOT mass/substance/material, unless clearly specified
to decrease to half (original value) NOT half the time B1

(b) **(i)** 53 ± 1 (s) B1

(ii) 84 ± 1 (s) B1

(iii) candidate's **(ii)** + candidate's **(i)** C1
correct evaluation of candidate's **(ii)** + candidate's **(i)** A1 [6]

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6 Iodine-131 is a radioactive isotope of iodine. Iodine-131 decays by the emission of a β-particle and a γ-ray.

(a) A nucleus of iodine-131 can be represented as

$$^{131}_{53}\mathrm{I}$$

Determine the number of neutrons in a nucleus of iodine-131.

number of neutrons ..... [1]

(b) β-particles and γ-rays are ionising radiations.

Explain the meaning of *ionising* radiations.

.....

..... [1]

(c) Fig. 8.1 shows a decay curve for iodine-131.

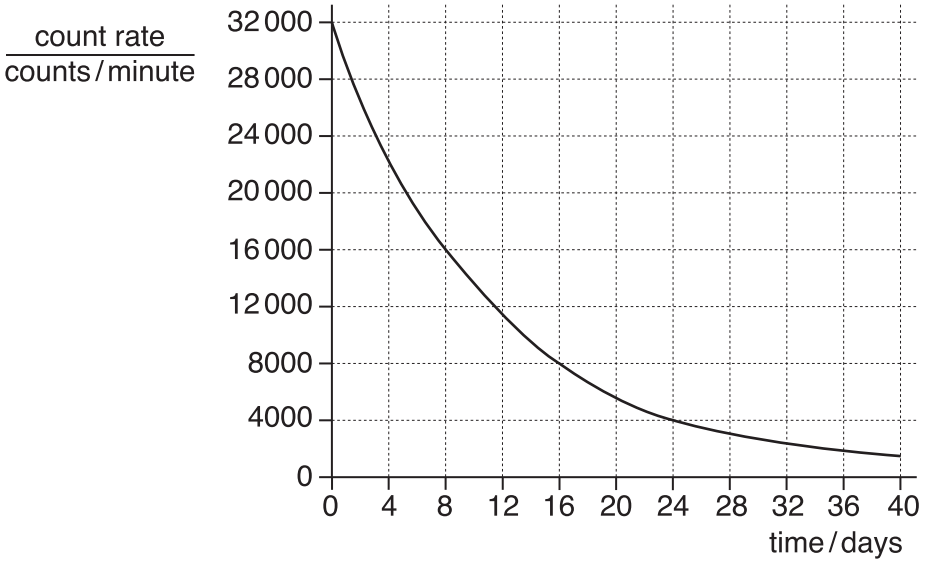


Fig. 8.1

Use information from Fig. 8.1 to determine the half-life of iodine-131. Show clearly how you used the graph.

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half-life = ... days [3]

(d) A different radioactive substance has a half-life of 120 hours.

Calculate the time for it to decay to 25% of its original amount.

time = ... hours [2]

[Total: 7]

Half-life Click for more variations

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6(a)	78	**B1**
6(b)	(radiations that) remove electrons OR break molecules	**B1**
6(c)	pair of count-rate values used	**C1**
	clear indication of use of graph, expect two vertical lines or two clear indications on axes using their values	**C1**
	8 days (± 1 day)	**A1**
6(d)	2 half-lives	**C1**
	240 hours	**A1**
	Total:	**7**

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7 **(a)** The nuclide notation ${}^{A}_{Z}X$ describes the nucleus of an atom.

Draw a line from each symbol to the correct description of the symbol.

symbol	**description**
	half-life value
A	neutron number
	nucleon number
Z	type of radiation
	proton number

[2]

(b) The activity of a sample of a radioactive nuclide is measured in June of each year.
In June 2004 the activity was 80 000 counts / s.
In June 2014 the activity was 20 000 counts / s.

(i) Show that the half-life of the nuclide is 5 years.

[3]

(ii) Determine the year when the activity of the sample was 10 000 counts / s.

year = ... [2]

[Total: 7]

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Half-life Click for more variations

7(a)	line from A to middle box: nucleon number	**B1**
	line from Z to bottom box: proton number	**B1**
7(b)(i)	(from June 2004 to June 2014 =) 10 (years)	**B1**
	(decrease in activity from) 80 000 (Bq) to 20 000 (Bq) takes 2 half-lives	**B1**
	10 ÷ 2 = (5 years)	**B1**
7(b)(ii)	(decrease in activity from) 20 000 (Bq) to 10 000 (Bq) is one half-life	**C1**
	so half the time difference = 5 years OR 2019	**A1**

8 350 dice are made from small cubes of wood with one face painted blue, as shown in Fig. 12.1.

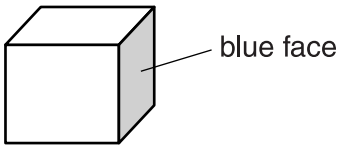


Fig. 12.1

Throwing large numbers of dice represents radioactive decay.

The 350 dice are thrown on a bench. All those dice that land with the blue face uppermost are removed. They are regarded as having "decayed".

The remaining dice are then thrown again, and the "blue-uppermost" dice are removed. This process is repeated until the number of dice remaining is quite small.

The table below shows the number of dice remaining after each throw.

throw	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
number of dice remaining	350	289	237	201	168	138	115	94	79	67	59	50	41	39	35

On Fig. 12.2, points have been plotted for some of the readings in the table.

(a) On Fig. 12.2, plot the first five points and draw the best smooth curve for all the points. [3]

(b) **(i)** Complete the sentence below.

The half-life of a radioactive substance is the time taken to reduce the number of nuclei of the original sort to ..... its original value. [1]

(ii) Throwing dice obeys the same laws as radioactive decay.

From your graph in Fig. 12.2, find the "half-life" of dice, showing clearly on Fig. 12.2 how you obtained your answer.

"half-life" of dice = ... throws [3]

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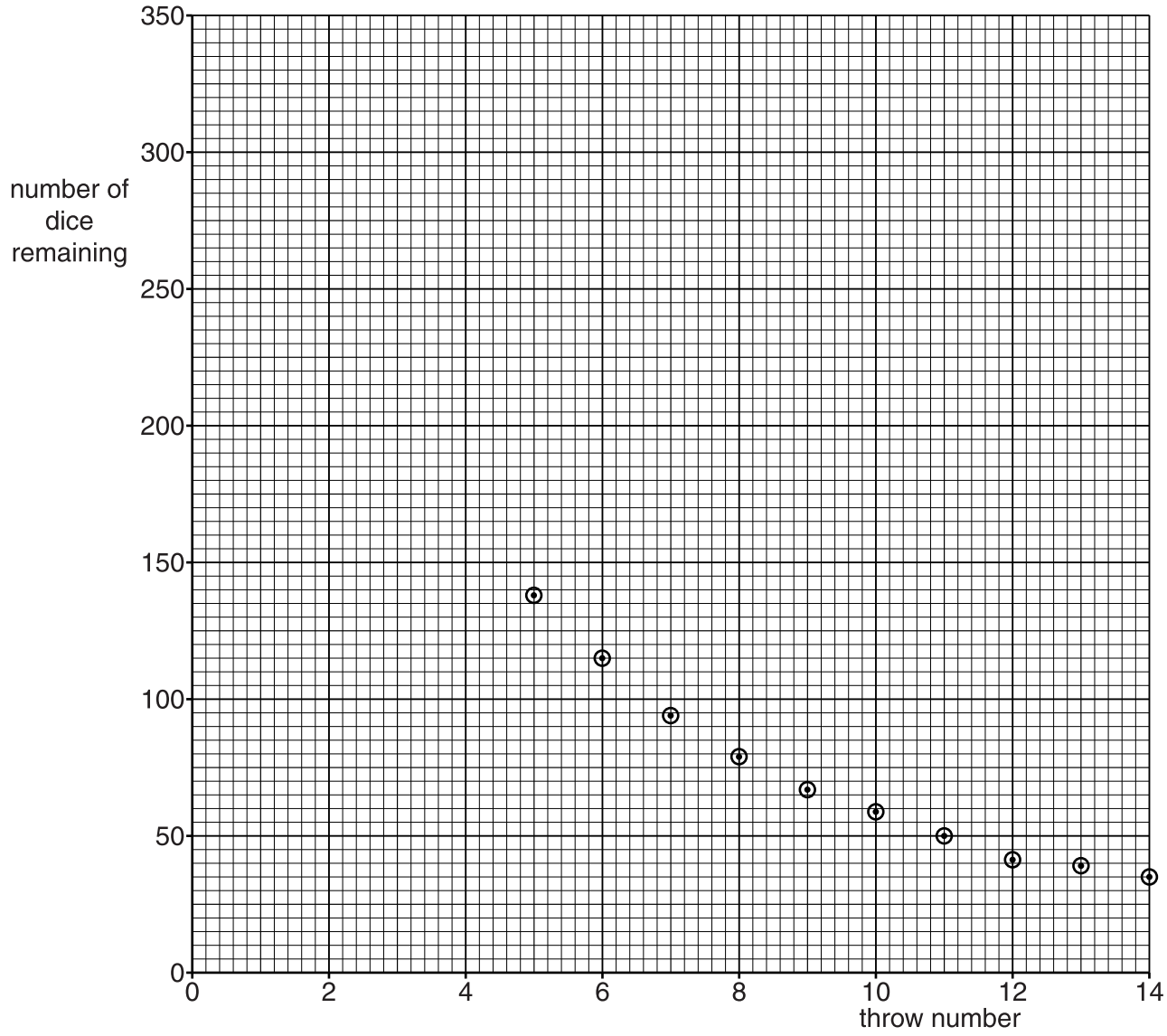


Fig. 12.2

(iii) The experiment is repeated with 800 dice.

1. Suggest how many throws it takes to reduce the number of dice to 400.

.....

2. Explain your answer.

.....

.....

[2]

[Total: 9]

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Half-life Click for more variations

8 **(a)** all 5 points plotted ± ½ small square -1 e.e.o.o. B2

smooth best-fit single line curve through most of the points, not joining points dot to dot B1

(b) **(i)** half / 50% / 0.5 / ½ B1

(ii) indication of correct use of graph B1

idea of halving, e.g. 175 or mark at 175 on graph, **NOT** halving number of days, i.e. 7 C1

3.4 – 4.0, accept nearest integer from candidate's graph A1

(iii) **1.** candidate's **(ii)** **OR** integer either side of candidate's **(ii)** M1

2. half-life not affected by sample size / starting point
accept idea that half-life does not change. A1

[Total: 9]

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9 Carbon-14 ($^{14}_{6}C$) is a radioactive isotope of carbon. Carbon-12 ($^{12}_{6}C$) is not radioactive.

(a) Explain how an atom of carbon-14 ($^{14}_{6}C$) differs from an atom of carbon-12 ($^{12}_{6}C$).

.....

..... [2]

(b) All living organisms contain both carbon-12 atoms and carbon-14 atoms. The ratio of carbon-14 to carbon-12 is $1 : 1 \times 10^{12}$.

Carbon-14 has a half-life of 5700 years.

(i) When an organism dies no new carbon is absorbed. The amount of carbon-12 in the dead organism remains fixed.

Describe how the amount of carbon-14 in the dead organism decreases with time.

.....

.....

..... [2]

(ii) A sample of wood contains carbon-14 to carbon-12 atoms in the ratio $1 : 4 \times 10^{12}$.

Calculate how many years ago the tree died.

..... years ago [3]

(c) Other radioactive isotopes have different half-lives.

Suggest a use of a radioactive isotope with a half-life of one hour.

Explain why a short half-life is suitable for this use.

use .....

explanation .....

.....

[2]

[Total: 9]

Half-life Click for more variations

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9(a)	(nucleus of carbon-14 contains) more neutrons **OR** (nucleus of) carbon-12 has fewer neutrons	**B1**
	*any **one** from:* • (atom / nucleus of carbon-14) is heavier • (atom / nucleus of carbon-14 is) not stable • (nucleus of carbon-14 contains) two more neutrons	**B1**
9(b)(i)	Every 5700 years the (remaining) carbon-14 decreases by half **OR** amount of C-14 halved every half life	**A2**
	amount of carbon-14 halves in 5700 years **OR** amount of carbon-14 decreases at a decreasing rate (with time)	C1
9(b)(ii)	11 000 (years ago)	**A3**
	2 × half-life have elapsed	C1
	25% of C-14 at time of death is still present in tree OR 75% of C-14 has decayed.	C1
9(c)	medical tracers **OR** medical imaging **OR** medical diagnosis	**B1**
	*any **one** from:* • keep dose low • doesn't stay in body too long • less damage (to body) OR less harmful (to humans)	**B1**

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