Atomic Structure 1

Name: _____

Class: _____

Date: _____

Time: **79 minutes**

Marks: **75 marks**

Comments:

1. Some street lamps contain sodium.

Below are two isotopes of sodium.

$^{23}_{11}Na$ $^{24}_{11}Na$

(a) What are isotopes?

_____

_____

_____

_____

(2)

(b) How many protons and neutrons are in a nucleus of $^{23}_{11}Na$?

Number of protons = _____

Number of neutrons = _____

(2)

(c) The sodium atoms emit light.

What would cause light to be emitted from a sodium atom?

Tick **one** box.

Electrons being emitted from the nucleus.	☐
Electrons falling to a lower energy level.	☐
Electrons leaving the atom when it is ionised.	☐
Electrons moving to a higher energy level.	☐

(1)

(d) In a street lamp, solid sodium is melted and vaporised.

Describe how the arrangement of the sodium atoms changes as the sodium goes from solid to liquid to gas.

(4)

The table shows the power ratings of some types of sodium lamp.

Type of sodium lamp	Power in Watts
A	35
B	50
C	70
D	100
E	150

(e) Some main roads are lit by type **E** sodium lamps.

Calculate the energy transferred by one type **E** sodium lamp in 1 hour.

Energy transferred = _____ J

(3)

(f) Many housing estates are lit by type **A** sodium lamps.

Suggest **two** advantages of using type **A** sodium lamps on housing estates.

1. _____

2. _____

(2)

(Total 14 marks)

2. The nuclei of some isotopes are radioactive.

(a) Which of the following statements could apply to a radioactive nucleus?

Tick **one** box.

The nucleus will emit an atom. ☐

The nucleus will emit light. ☐

The nucleus will emit a neutron. ☐

The nucleus will emit sound. ☐

(1)

(b) Potassium-40 is a radioactive isotope present in food, such as bananas.

The following equation shows how potassium-40 will decay into calcium-40

$$^{40}_{19}\text{potassium} \longrightarrow {}^{40}_{20}\text{calcium} + {}^{0}_{-1}\text{e}$$

Give one similarity and one difference between nuclei of potassium-40 and calcium-40

Similarity _____

Difference _____

(2)

(c) The activity of a sample of potassium-40 is measured 3 times.

The measurements are given below.

4906 Bq **4956 Bq** **4889 Bq**

Which of the following statements explains why the readings are different?

Tick **one** box.

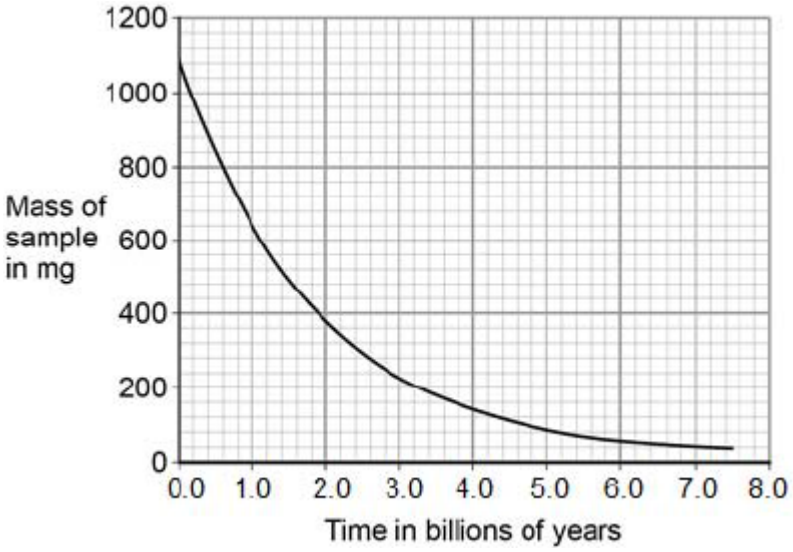
Radioactive decay is constant. ☐

Radioactive decay is hazardous. ☐

Radioactive decay is random. ☐

(1)

(d) The figure below shows how the activity of a sample of potassium-40 changes over time.



Use the figure above to determine the half-life of potassium-40.

_____

_____

Half-life = _____ billion years

(2)

(e) When food is eaten, some of the radiation the food emits is detectable outside the body.

Which type of radiation would not be detectable outside the body?

Tick **one** box.

alpha ☐

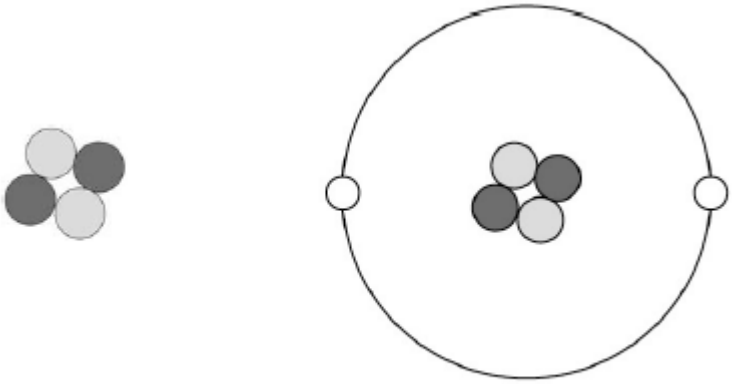
beta ☐

gamma ☐

(1)

(Total 7 marks)

3. The figure below is a diagram of an alpha particle and a helium atom.



Alpha particle Helium atom

(a) What is the approximate size of a helium atom?

Tick **one** box.

1×10^{-5} m ☐

1×10^{-10} m ☐

1×10^{-15} m ☐

1×10^{-20} m ☐

(1)

(b) A helium atom is much larger than an alpha particle.

Give **one** other difference between a helium atom and an alpha particle.

_____

_____

(1)

(c) What is the atomic number of the helium atom in the figure above?

Tick **one** box.

2 ☐

4 ☐

6 ☐

8 ☐

(1)

(d) What is the charge on the helium atom in the figure above?

Explain your answer.

_____

_____

_____

_____

_____

(3)

(e) Helium is a gas that occurs naturally.

There is very little helium on Earth.

Helium has important uses in medicine and is also used to inflate party balloons.

Some scientists believe that helium should **not** be used to inflate party balloons.

Why?

_____

_____

_____

_____

(2)

(Total 8 marks)

4. Some small fractures do not show up on an X-ray image.

To see the fracture doctors inject the patient with a radioactive isotope.

The image is formed by detecting radiation as it leaves the body.

The figure below shows an image of a foot after the patient was injected with the radioactive isotope technetium-99.

© Ni Qin/ Getty Images

Technetium-99 emits gamma radiation.

(a) What is gamma radiation?

_____

_____

(1)

(b) Explain why a gamma emitter is used.

(2)

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

Give the meaning of the term **half-life**.

(1)

(d) After treatment, hospital equipment may become contaminated.

Describe the level of the hazard associated with contamination with technetium-99.

You should include in your answer a description of how the level of hazard changes over time.

(3)

(e) Some of the hospital equipment may also be irradiated during treatment.

Describe how equipment becomes irradiated.

(1)

(f) Why is irradiated equipment not hazardous?

_____

_____

(1)

(Total 9 marks)

5. Atoms are very small and most of their mass is concentrated in the nucleus.

Electrons orbit at different distances from the nucleus.

(a) A nucleus is much smaller than an atom.

Approximately how many times smaller is a nucleus than an atom?

Tick **one** box.

100 ☐

1000 ☐

10 000 ☐

100 000 ☐

(1)

(b) The electrons in an atom can only orbit at specific distances from the nucleus.

State what causes an electron's distance from the nucleus to increase or decrease.

Increase _____

_____

Decrease _____

_____

(2)

(c) Atoms have different atomic numbers and mass numbers.

In terms of sub-atomic particles, describe the difference between an atom's atomic number and its mass number.

(2)

(d) Transmutation is the name given to a process where one element changes into another.

Explain and compare how two different types of radioactive decay can cause transmutation.

(4)

(Total 9 marks)

6. Atoms are different sizes.

One of the heaviest naturally occurring stable elements is lead.

Two of its isotopes are lead-206 ($^{206}_{82}Pb$) and lead-208 ($^{208}_{82}Pb$).

(a) (i) What is meant by 'isotopes'?

(2)

(ii) How many protons are in the nucleus of a $^{206}_{82}Pb$ atom?

_____

(1)

(iii) How many neutrons are in the nucleus of a $^{206}_{82}Pb$ atom?

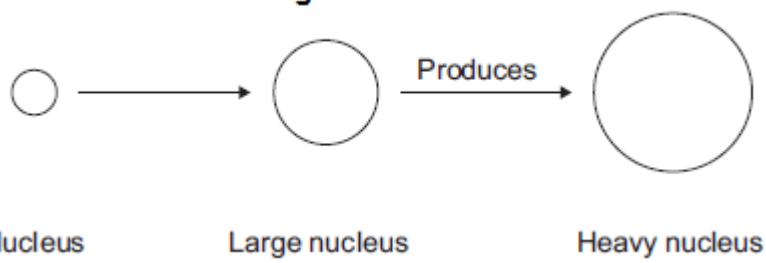
_____

(1)

(b) A nucleus can be accelerated in a particle accelerator and directed at a large nucleus. This produces a heavy nucleus that will decay after a short time.

This is shown in **Figure 1**.

Figure 1



(i) In 1984, nuclei of iron (Fe) were directed at nuclei of lead (Pb). This produced nuclei of hassium (Hs).

Complete the equation for this reaction by writing numbers in the empty boxes.

$$\square^{58}Fe + \frac{\square}{\square}Pb = {}^{265}_{108}Hs + {}^{1}_{0}X$$

(3)

(ii) Use the correct answer from the box to complete the sentence.

an electron	**a proton**	**a neutron**

The particle **X** in part (b)(i) is _____ .

(1)

(iii) After acceleration the iron nuclei travel at a steady speed of one-tenth of the speed of light.

The speed of light is 3.00×10^8 m/s.

Calculate the time taken for the iron nuclei to travel a distance of 12 000 m.

_____

_____

Time taken = _____ s

(2)

(iv) Linear accelerators, in which particles are accelerated in a straight line, are **not** used for these experiments. Circular particle accelerators are used.

Suggest why.

_____

_____

_____

_____

_____

_____

(3)

(c) Hassium-265 ($^{265}_{108}Hs$) decays by alpha emission with a half-life of 0.002 seconds.

(i) What is meant by 'half-life'?

Tick (✓) **two** boxes.

	Tick (✓)
The average time for the number of nuclei to halve	
The time for count rate to be equal to background count	
The time for background count to halve	
The time for count rate to halve	

(2)

(ii) Complete the equation for the decay of Hs-265 by writing numbers in the empty boxes.

$$^{265}_{108}Hs = \frac{\square}{\square}Sg + \frac{\square}{\square}\alpha$$

(2)

(d) The table below shows how the atomic radius of some atoms varies with atomic number.

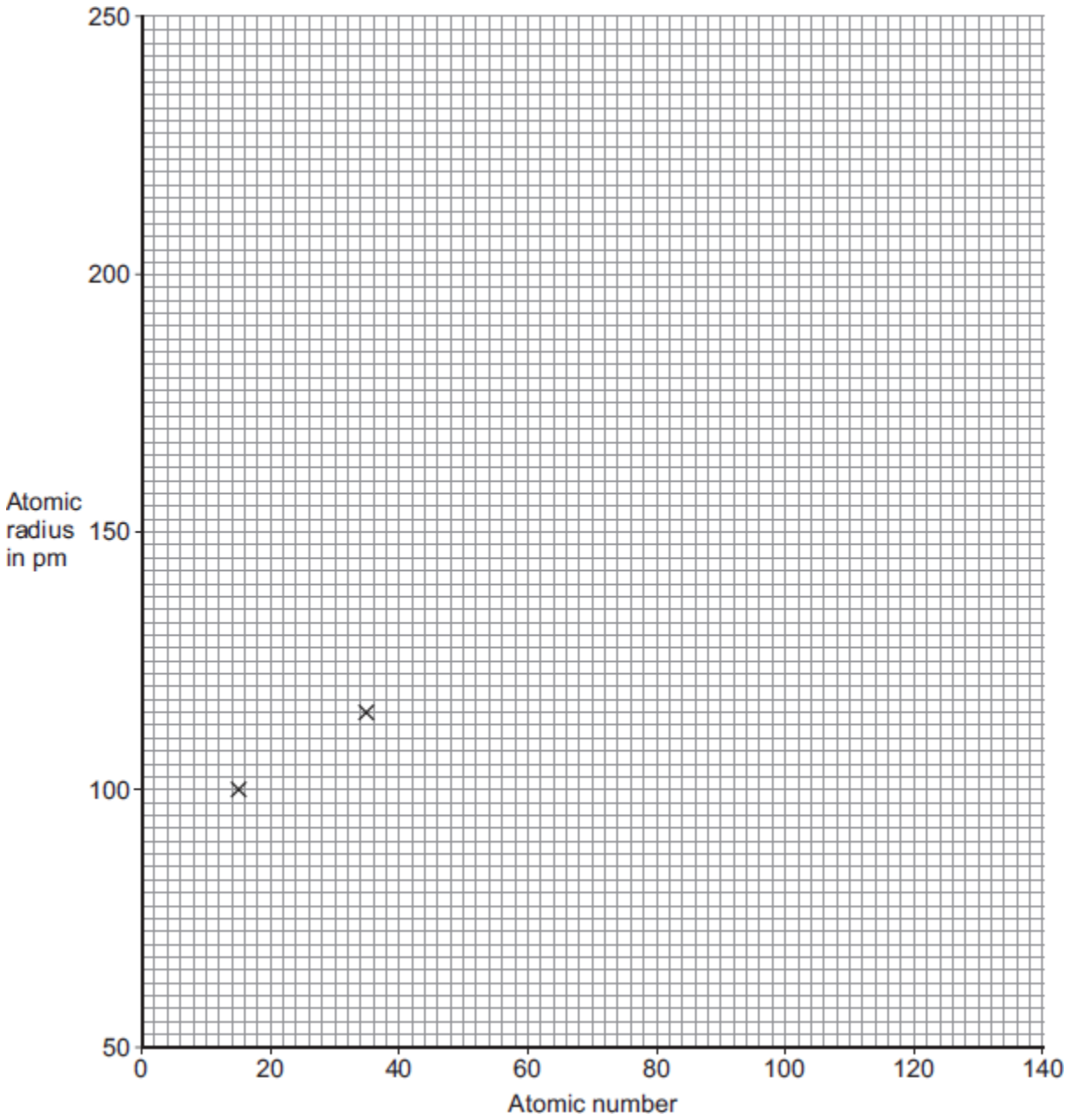
Atomic number	**Atomic radius in picometres (pm)**
15	100
35	115
50	130
70	150
95	170

1 pm = 10^{-12} m

(i) On **Figure 2**, use the data from the table above to plot a graph of atomic radius against atomic number and draw a line of best fit.

Two points have been plotted for you.

Figure 2



(2)

(ii) Scientists believe that the element with atomic number 126 can be produced and that it will be stable.

Use your graph in **Figure 2** to predict the atomic radius of an atom with atomic number 126.

Atomic radius = _____ pm

(1)

(Total 20 marks)

7. (a) Radioactive sources that emit alpha, beta or gamma radiation can be dangerous.

What is a possible risk to health caused by using a radioactive source?

_____

_____

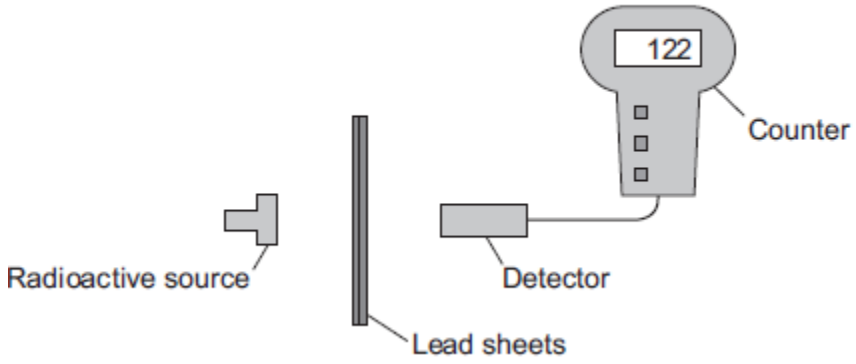
(1)

(b) In an experiment, a teacher put a 2 mm thick lead sheet in front of a radioactive source. She used a detector and counter to measure the radiation passing through the lead sheet in one minute.

She then put different numbers of lead sheets, each 2 mm thick, in front of the radioactive source and measured the radiation passing through in one minute.

The apparatus the teacher used is shown in **Figure 1**.

Figure 1



(i) When using a radioactive source in an experiment, how could the teacher reduce the risk to her health?

Suggest **one** way.

_____

_____

(1)

(ii) The number recorded on the counter is actually higher than the amount of radiation detected from the source.

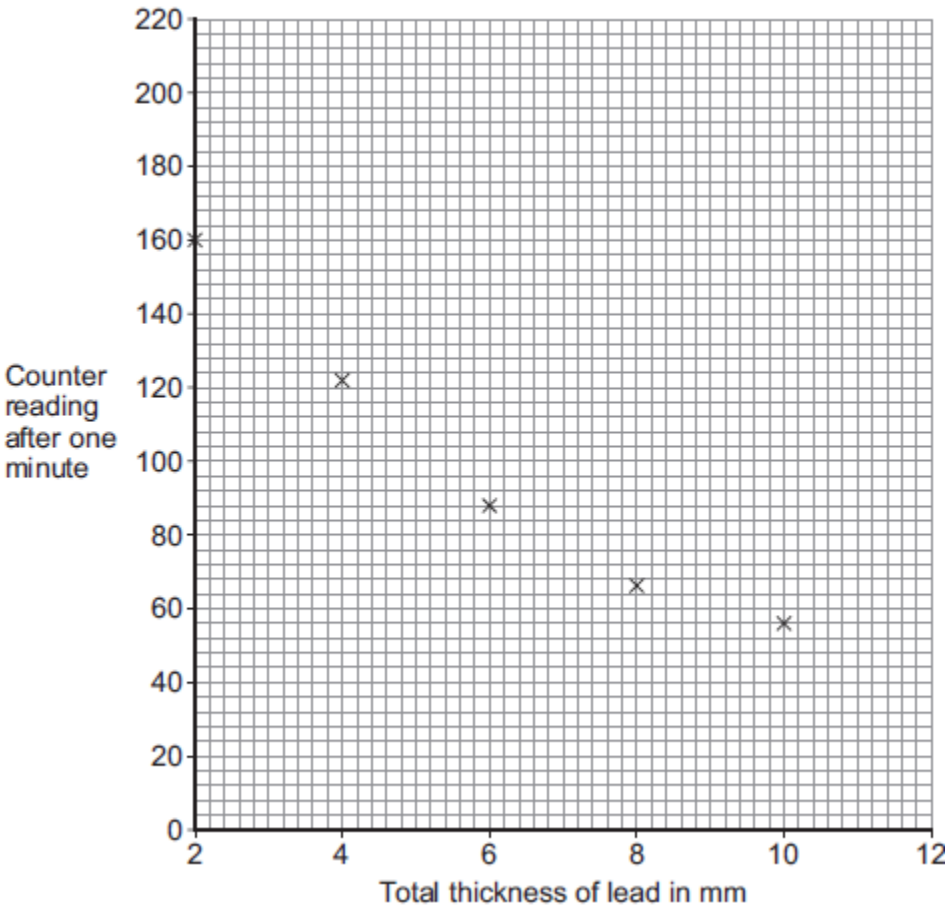
Complete the following word equation.

The number recorded on the counter	=	The amount of radiation detected from the source	+	_____ radiation

(1)

(c) The readings taken by the teacher are plotted in **Figure 2**.

Figure 2



(i) Draw a line of best fit to complete **Figure 2**.

(1)

(ii) How does the amount of radiation **absorbed** by the lead change as the total thickness of the lead is increased?

_____

_____

(1)

(iii) Use **Figure 2** to estimate the reading on the counter when the total thickness of the lead is increased to 12 mm.

Estimated counter reading = _____

(1)

(d) What type of radiation was emitted from the radioactive source?

Draw a ring around the correct answer.

alpha **beta** **gamma**

Give a reason for your answer.

_____

_____

(2)

(Total 8 marks)

1.

(a) atoms with the same number of protons

allow atoms of the same element

1

but with a different number of neutrons

1

(b) protons = 11

1

neutrons = 12

1

(c) electrons falling to a lower energy level

1

(d)

Level 2: Scientifically relevant facts, events or processes are identified and given in detail to form an accurate account.	3-4
Level 1: Facts, events or processes are identified and simply stated but their relevance is not clear.	1-2
No relevant content	0
Indicative content **solid** • atoms closely packed • atoms in a regular arrangement • atoms vibrate about a fixed position **liquid** • atoms are close together • atoms are not in regular arrangement • atoms can move past each other **gas** • atoms are well separated • atoms are not in regular arrangement • atoms move randomly at high speeds	

4

(e) 60 × 60

1

E = 150 × 3600

1

E = 540 000 (J)

*an answer of 540 000 (J) scores **3** marks*

1

(f) less energy transferred

1

not as bright

1

[14]

2. (a) The nucleus will emit a neutron.

1

(b) **Similarity**

same mass number

allow same number of nucleons (protons + neutrons)

1

difference

different atomic number

allow different number of protons

1

(c) Radioactive decay is random.

1

(d) 1.3 (billion years)

allow 1.2-1.4 (billion years)

2

*allow **1** mark for horizontal line drawn from ~ 550*

(e) alpha

1

[7]

3. (a) 1×10^{-10} m

1

(b) (a helium atom) has 2 electrons

accept it has more mass

allow it is not charged

1

(c) 2

1

(d) neutral

accept 0 or 'no charge'

1

(because) protons have positive charge and electrons have negative charge

1

(and) there are equal numbers of protons and electrons

1

(e) helium will one day run out

1

there will be none left for medical uses so balloons waste helium

1

[8]

4. (a) electromagnetic radiation from the nucleus

'electromagnetic radiation' is insufficient

1

(b) (Gamma is the most penetrating) so a large proportion of the emitted radiation will leave the body

1

more easily detected outside the body

1

(c) (average) time it takes for the number of nuclei of the isotope in a sample to halve

or

(average) time it takes for the count rate from a sample containing the isotope to fall to half its initial level

1

(d) initially there is a high level of hazard.

1

level of hazard drops to a low level quickly

1

answer must imply short period of time

(activity initially high) due to short half-life

or

(drops to safe level quickly) due to short half-life

1

(e) it is exposed to ionising radiation

1

(f) does not become radioactive

1

[9]

5. (a) 10 000

1

(b) **Increase**

absorb electromagnetic radiation

1

Decrease

emit electromagnetic radiation

1

(c) atomic number is the number of protons

1

mass number is the number of protons and neutrons

1

(d) **Level 2 (3–4 marks):**
A clear comparison, with logical structure.

Level 1 (1–2 marks):
Fragmented points, with no logical structure.

0 marks:
No relevant content

Indicative content

Beta decay
- Atomic number increases by one
- When a neutron decays into a proton

Alpha decay
- Atomic number decreases by two
- When an alpha particle is emitted

Comparison

Both change number of protons (hence new element / transmutation)
Beta decay increases atomic number and alpha decay decreases (explicit)

NB No credit is given for different number of protons = new element.

4

[9]

6.

(a) (i) (atoms with the) same number of protons

allow same atomic number

or *same proton number*

1

(atoms with) different number of neutrons

allow different mass number

1

(ii) 82

1

(iii) 124

1

(b) (i) $^{58}_{26}Fe + {}^{208}_{82}Pb$

1 *mark for each correct box*

3

(ii) (a) neutron

1

(iii) 4.0×10^{-4} (s)

or

0.0004

$3.00 \times 10^{8} \times 0.1 = 12\,000 / t$

gains ***1*** *mark*

2

(iv) particles need to travel a large distance

1

equipment would have to be very long

1

with circular paths long distances can be accommodated in a smaller space

1

(c) (i) the average time for the number of nuclei to halve

1

the time for count rate to halve

1

(ii) $^{261}_{106}Sg + {}^{4}_{2}\alpha$

1 *mark if top boxes total = 265*

and *bottom boxes total = 108*

1 *mark for 4 and 2 for alpha*

2

(d) (i) 3 plotted points

± ½ small square

1

best line through points

1

(ii) 190−205 (pm)

or correct from student's line

1

[20]

7. (a) cell damage or cancer

accept kills / mutates cells

radiation poisoning is insufficient

ionising is insufficient

1

(b) (i) any **one** from:

- use tongs to pick up source
- wear gloves
- use (lead) shielding
- minimise time (of exposure)
- maximise distance (between source and teacher).

accept any other sensible and practical suggestion

ignore reference to increasing / decreasing the number / thickness of lead sheets

1

(ii) <u>background</u>

1

(c) (i) curve drawn *from point 2,160*

*do **not** accept straight lines drawn from dot to dot*

1

(ii) (also) increases

less radiation passes through is insufficient

1

(iii) 50

accept any value from 40 to 56 inclusive

1

(d) gamma

1

only gamma (radiation) can pass through lead

*accept alpha **and** beta cannot pass through lead*
a general property of gamma radiation is insufficient

1

[8]