Atomic Structure 4

Name: ______________________

Class: ______________________

Date: ______________________

Time: **84 minutes**

Marks: **77 marks**

Comments:

1. A scientist investigated a sample of a radioactive material to determine if it would be suitable for medical use.

(a) The method, results and conclusions of the scientist will need to be checked by other scientists before the results of the investigation are published.

What name is given to this checking process?

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(1)

(b) There is an increased risk of cancer if the scientist is irradiated by nuclear radiation.

What property of nuclear radiation causes the increased risk of cancer?

____

____

(1)

(c) The activity of a radioactive source is the rate at which the nuclei of the source decay.

What is the unit for the activity of a radioactive source?

____

(1)

(d) The scientist placed a radiation detector near the sample and measured the count-rate.

Explain why the count-rate is less than the activity of the sample.

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(2)

(e) The scientist recorded the count-rate from the sample with the radiation detector at different distances from the sample.

Table 1 shows the results.

Table 1

Distance between the sample and the detector in centimetres	**Count-rate in counts/second**
2.0	300
5.0	24
10.0	0

Explain which type of radiation was emitted by the sample.

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(2)

(f) The scientist moved the detector closer to the sample and started a stopwatch.

The scientist measured the count-rate from the sample at different times.

Table 2 shows some of the results.

Table 2

Time in minutes	**Count-rate in counts/second**
0	1568
30	**X**
60	98

The scientist realised that 30 minutes is a whole number of half-lives.

Calculate the value of **X** in **Table 2**.

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X = ________________ counts/second

(3)

(g) The scientist had a second sample of the radioactive material.

The scientist made appropriate measurements, then calculated the half-life of each sample.

Why was the half-life calculated from the second sample slightly different from the half-life calculated from the first sample?

Tick (✓) **one** box.

Radioactive decay is a random process. ☐

The count-rate from a radioactive sample is predictable. ☐

The samples were at different temperatures. ☐

The size of each sample was different. ☐

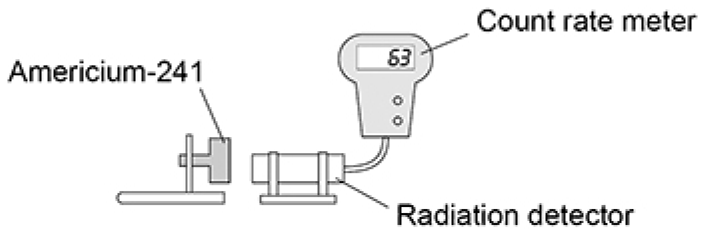
(1)

(Total 11 marks)

2. A teacher demonstrated that the radioactive isotope americium-241 emits alpha particles.

Figure 1 shows the equipment used.

Figure 1



(a) An americium-241 nucleus (Am) emits an alpha particle and turns into a neptunium nucleus (Np).

Which is the correct nuclear equation for this decay?

Tick (✓) **one** box.

$^{241}_{95}Am \longrightarrow ^{237}_{93}Np + ^{4}_{2}He$ ☐

$^{241}_{95}Am \longrightarrow ^{245}_{93}Np + ^{4}_{2}He$ ☐

$^{241}_{95}Am \longrightarrow ^{237}_{97}Np + ^{4}_{2}He$ ☐

(1)

(b) What is the furthest distance that alpha radiation can travel in air?

Tick (✓) **one** box.

A few millimetres ☐

A few centimetres ☐

A few metres ☐

(1)

(c) The teacher placed a piece of paper between the americium-241 and the radiation detector.

The reading on the count rate meter decreased by a large amount.

Why does the decreased reading show that americium-241 emits alpha radiation?

Tick (✓) **one** box.

Paper stops alpha radiation.	☐
Paper stops all types of radiation.	☐
Paper stops beta and gamma radiation.	☐

(1)

The teacher replaced the americium-241 with a source of beta radiation.

(d) Which symbol represents a beta particle?

Tick (✓) **one** box.

${}^{0}_{-1}e$	☐
${}^{0}_{0}e$	☐
${}^{-1}_{-1}e$	☐
${}^{-1}_{0}e$	☐

(1)

(e) The count rate from the source was 119 ± 7 counts per second.

Calculate the smallest count rate this could have been.

____

____

Smallest count rate = _______________ counts per second

(1)

A teacher investigated how the distance between a different radioactive source and the detector affects the count rate.

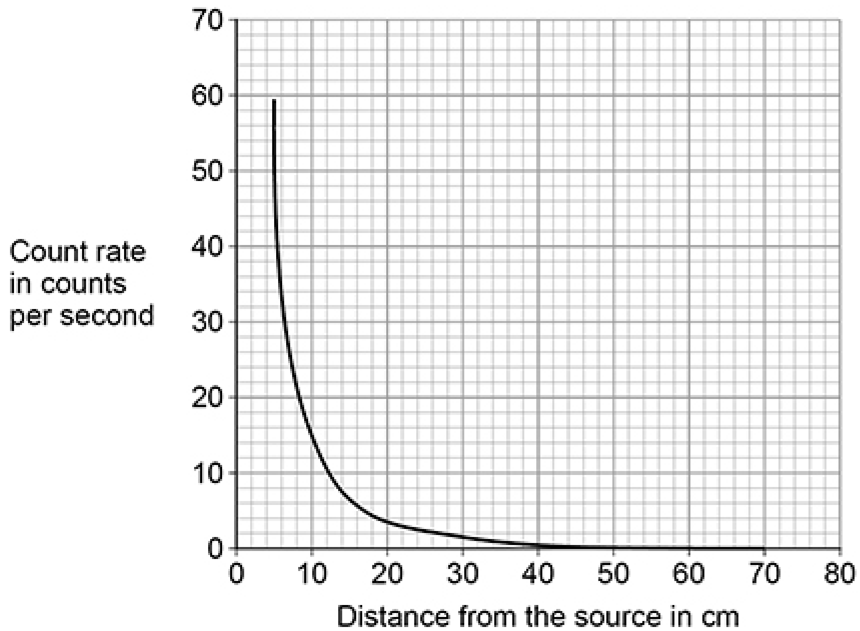
(f) Draw **one** line from each type of variable to the description.

Type of variable	**Description**
	Count rate
Control variable	
	Distance between the source and detector
Dependent variable	
	Radioactive source
Independent variable	
	Time

(3)

(g) **Figure 2** shows how the count rate from the different radioactive source changed with the distance from the source.

Figure 2



Describe the relationship between the distance from the source and the count rate.

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(2)

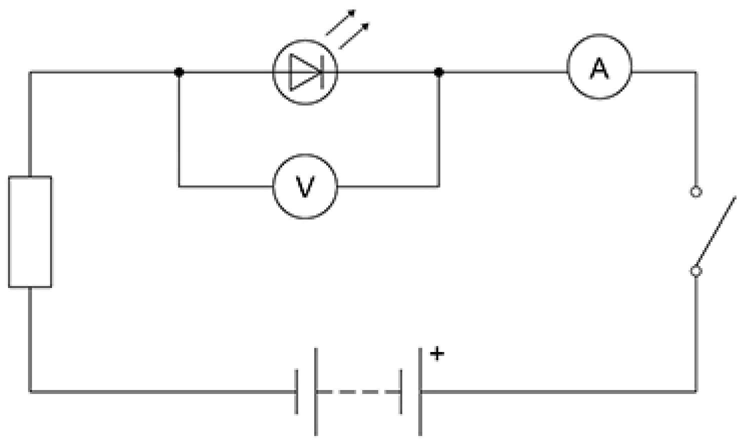
(Total 10 marks)

3. The camera in a mobile phone uses an LED to provide light when taking a photograph.

A student investigated how the potential difference across an LED varies with the current in it.

Figure 1 shows the circuit used.

Figure 1



(a) The student closed the switch. The voltmeter gave a reading of 5.0 V

The ammeter gave a reading of 0 mA

The LED did not emit any light.

Explain how the student should have changed the circuit to make the LED emit light.

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(2)

(b) The student changed the circuit so that the LED emitted light.

The current in the circuit was 290 mA

The power of the LED was 0.98 W

Calculate the potential difference across the LED.

Use the Physics Equations Sheet.

Give your answer to 2 significant figures.

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Potential difference (2 significant figures) = _______________ V

(5)

A traditional camera uses a flash unit to provide light.

Figure 2 shows a flash unit on a traditional camera.

Figure 2

(c) The flash unit emits light from xenon gas in a fluorescent tube.

What happens when a xenon atom emits light?

Tick (✓) **one** box.

Electrons in the atom fall to a lower energy level. ☐

Electrons in the atom move to a higher energy level. ☐

Electrons leave the atom, causing ionisation. ☐

Electrons transfer to the atom from the electrical circuit. ☐

(1)

(d) When the flash unit is used there is a mean potential difference of 200 V across the fluorescent tube.

The flash of light lasts for 2.8×10^{-4} s

1.4 J of energy is transferred.

Calculate the mean current.

Use the Physics Equations Sheet.

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Mean current = ________________ A

(6)

(Total 14 marks)

4. A smoke detector contains a source of alpha radiation in a plastic case.

(a) A source of beta radiation in a smoke detector would be more hazardous than a source of alpha radiation.

Explain why.

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(2)

(b) Actinium (Ac) is one source of alpha radiation.

An actinium (Ac) nucleus emits an alpha particle (α) and turns into a francium (Fr) nucleus.

This can be represented as:

$$^{A}_{Z}Ac \longrightarrow {}^{223}_{87}Fr + \alpha$$

Determine the values of **A** and **Z**.

____

____

A = _______________

Z = _______________

(2)

(c) A teacher wanted to find out what nuclear radiation is emitted from a source.

The teacher placed different barriers between the source and a detector.

The teacher recorded the count for 30 seconds after each barrier was put in place.

The table below shows the results.

Barrier	**Thickness in millimetres**	**Count after 30 seconds**
None		985
Paper	0.1	149
Aluminium	5.0	0
Lead	20.0	0

Explain what nuclear radiation was emitted by the source.

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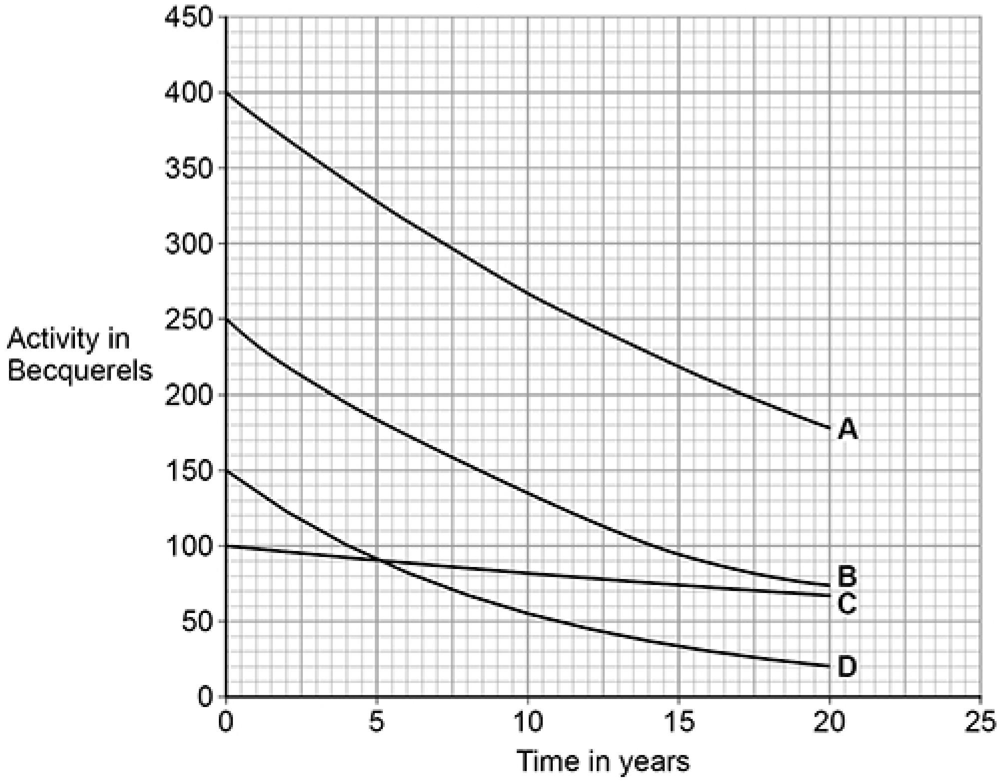
(4)

(d) The graph below shows how the activity of four different radioactive isotopes, **A**, **B**, **C** and **D**, changes over time.



Write the isotopes **A**, **B**, **C** and **D** in order of increasing stability of their nuclei.

Explain your answer.

Least stable **Most stable**

__________ __________ __________ __________

Explanation ____

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(3)
(Total 11 marks)

5. A radioactive source emits alpha, beta and gamma radiation.

(a) An alpha particle is the same as a helium nucleus.

How many times bigger is the radius of a helium atom than the radius of an alpha particle?

Tick (✓) **one** box.

Less than 100 times bigger	☐
Exactly 5000 times bigger	☐
More than 10 000 times bigger	☐

(1)

(b) Alpha particles can ionise atoms in the air.

What happens to an atom when it is ionised by an alpha particle?

Tick (✓) **two** boxes.

A neutron in the atom becomes a proton.	☐
The atom becomes a positive ion.	☐
The atom gains a neutron.	☐
The atom gains a proton.	☐
The atom loses an electron.	☐

(2)

(c) A spark detector is a device that can be used to detect alpha radiation.

A spark detector works by alpha particles ionising atoms in the air near a wire mesh.

A large potential difference creates a spark when the air near the wire mesh is ionised.

Suggest why a spark detector **cannot** detect beta radiation.

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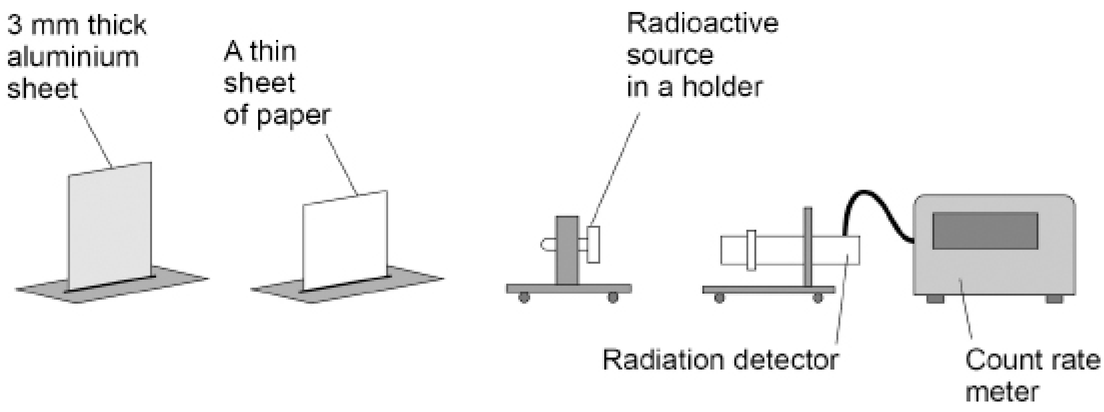
(1)

(d) A teacher wants to demonstrate that the radioactive source emits alpha, beta and gamma radiation.

The figure below shows the equipment the teacher has.



Describe a method the teacher could use.

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(6)

(Total 10 marks)

6. Between 1951 and 1992 the USA tested nuclear weapons in a desert.

(a) Complete the sentence.

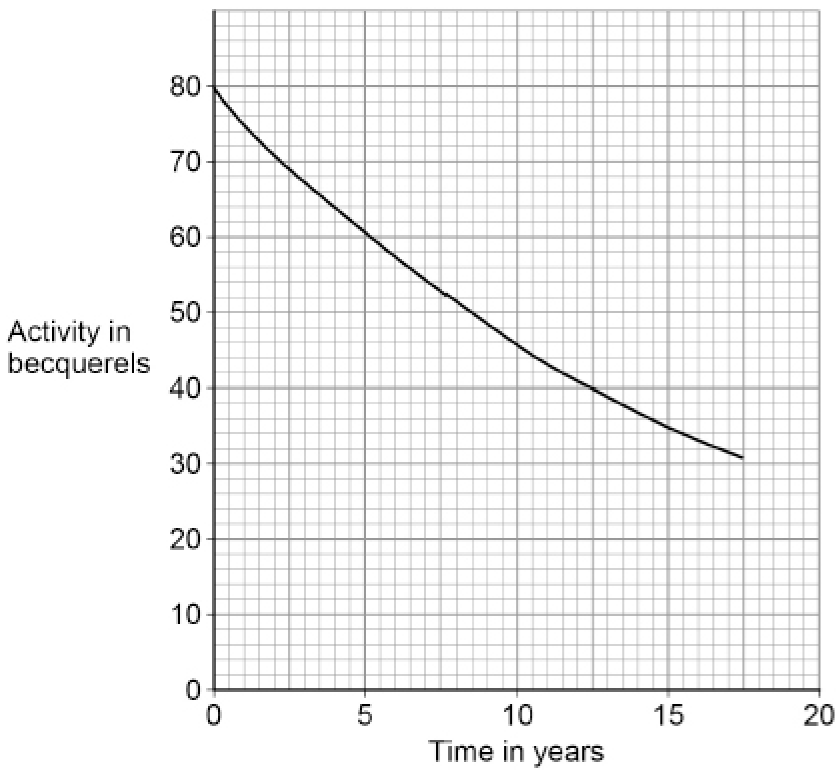
Choose the answer from the box.

contamination	**irradiation**	**ionisation**	**decay**

Radioactive dust from the nuclear weapons testing settled on the desert. This is called radioactive ____________________.

The desert now contains radioactive tritium.

The graph below shows how the activity of the tritium in a sample taken from the desert changed with time.



(1)

(b) The sample was collected from the desert in 1992.

Determine the activity of the tritium in the sample in 2007.

____

____

Activity = _______________ Bq

(2)

(c) How much time did it take for the activity of the tritium in the sample to decrease from 80 Bq to 40 Bq?

____

____

Time = _______________ years

(1)

(d) What is the half-life of tritium?

Half-life = _______________ years

(1)

(e) The sample started with 45 billion atoms of tritium.

After 4 years the sample had 36 billion atoms of tritium.

Calculate the percentage of the tritium in the sample that remained after 4 years.

____

____

____

____

Percentage of tritium remaining = _______________ %

(2)

(f) A scientist determined the activity of a sample of tritium every minute for 3 minutes.

The table below shows the results.

Time in minutes	**Activity in Bq**
0	149
1	151
2	148
3	152

Why do the activity readings in table vary?

Tick (✓) **one** box.

Radioactive decay is a random process. ☐

Temperature changes affect the radioactive decay. ☐

The number of radioactive nuclei keeps increasing and decreasing. ☐

(1)

(g) What safety precaution should scientists take when working with radioactive materials in a laboratory?

Tick (✓) **one** box.

Tie long hair back before handling the materials. ☐

Use long tongs to handle the materials. ☐

Wear safety goggles when handling the materials. ☐

(1)

(h) Studies show that children born near the area of the desert containing tritium were more likely to develop cancer.

It is important that the results from these studies are checked by other scientists.

What is this process called?

Tick (✓) **one** box.

Experiment review ☐

Peer review ☐

Results review ☐

Test review ☐

(1)
(Total 10 marks)

7. Different radioactive isotopes emit different types of nuclear radiation.

A polonium-210 (Po) nucleus emits an alpha particle (α) and turns into a lead (Pb) nucleus.

This can be represented by the equation:

$$^{210}_{84}\text{Po} \longrightarrow {}^{A}_{Z}\text{Pb} + \alpha$$

(a) What is the value of A in the equation?

Tick (✓) **one** box.

A = 206 ☐ A = 208 ☐ A = 210 ☐ A = 211 ☐

(1)

(b) What is the value of Z in the equation?

Tick (✓) **one** box.

Z = 80 ☐ Z = 82 ☐ Z = 85 ☐ Z = 86 ☐

(1)

(c) A strontium-89 nucleus (Sr) emits a beta particle (β) and turns into an yttrium nucleus (Y).

This can be represented by the equation:

$$^{89}_{38}Sr \longrightarrow \, ^{A}_{Z}Y + \beta$$

What are the values of A and Z in the equation?

A = ____________________________

Z = ____________________________

(2)

(d) Gamma radiation is another type of nuclear radiation.

What does gamma radiation consist of?

Tick (✓) **one** box.

High energy neutrons ☐

Electromagnetic waves ☐

Particles with no charge ☐

Positively charged ions ☐

(1)

(e) Explain the differences between the properties of alpha, beta and gamma radiations.

(6)

(Total 11 marks)

Mark schemes

1. (a) <u>peer review</u>

1

(b) it is ionising

ignore references to penetrating ability

1

(c) becquerel / Bq

1

(d) not all the radiation emitted (by the sample) is detected

1

(because) the radiation spreads out
or
(because) some radiation is absorbed before reaching the detector
or
(because) some of the radiation entering the detector is **not** detected

allow because the radiation is emitted in all directions

1

(e) alpha radiation

1

because the radiation is not detected beyond 5 cm
or
because alpha radiation cannot travel 10 cm (in air)
or
because beta **and** gamma radiation would be detected at 10 cm

dependent on MP1

allow because alpha radiation cannot travel more than a few cm (in air)

1

(f) 60 minutes is 4 half-lives

allow 15 minutes is 1 half-life

allow 1568 → 784 → 392 → 196 → 98

allow $\frac{1568}{98} = 2^4$

allow $\frac{98}{1568} = \frac{1}{2^4}$

1

30 minutes is 2 half-lives

1

X = 392

1

(g) radioactive decay is a random process

1

[11]

2. (a) $^{241}_{95}\text{Am} \longrightarrow {}^{237}_{93}\text{Np} + {}^{4}_{2}\text{He}$

first box ticked

1

(b) a few centimetres

1

(c) paper stops alpha radiation

1

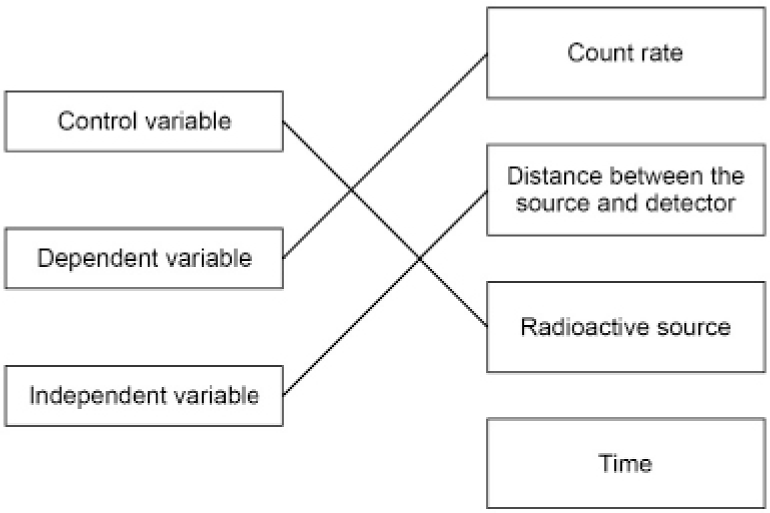
(d) $^{0}_{-1}\text{e}$

1

(e) 112

1

(f)



*do **not** accept more than one line from a box on the left*

3

(g) as distance increased the count rate decreased

1

(between 40 cm and 50 cm) the count rate becomes zero

1

[10]

3. (a) reverse the connections to the LED / battery

allow reverse the potential difference across the LED / diode

1

because an LED / diode only allows current through in one direction

allow LED / diode has a large resistance in the reverse direction

1

(b) 290 mA = 0.29 A

1

0.98 = $V \times 0.29$

allow a correct substitution of an incorrectly / not converted current

1

or

$R = \frac{0.98}{0.29^2}$

allow R = 11.652…

ignore 0.98 = $(0.29)^2 \times R$

allow a correct substitution of an incorrectly / not converted current

$V = \frac{0.98}{0.29}$

allow V = 11.65 × 0.29

1

V = 3.379…

allow a correct rearrangement using an incorrectly / not converted current

1

V = 3.4 (V)

allow a correct calculation using an incorrectly / not converted current

allow a correctly rounded answer to 2 sig figs consistent with their calculated value of V using numbers from the question

1

(c) electrons in the atom fall to a lower energy level

1

(d) $1.4 = Q \times 200$

1

$Q = \frac{1.4}{200}$

1

$Q = 0.0070$ (C)

1

$0.0070 = I \times 2.8 \times 10^{-4}$

allow a correct substitution of their calculated value of Q

1

$I = \frac{0.0070}{2.8 \times 10^{-4}}$

allow a correct re-arrangement using their value of Q

1

$I = 25$ (A)

allow an answer consistent with their value of Q

1

OR

$1.4 = P \times 2.8 \times 10^{-4}$ (1)

$P = \frac{1.4}{2.8 \times 10^{-4}}$ (1)

$P = 5000$ (W) (1)

$5000 = 200 \times I$ (1)

allow a correct substitution of their calculated value of P

$I = \frac{5000}{200}$ (1)

allow a correct re-arrangement using their value of P

$I = 25$ (A) (1)

allow an answer consistent with their value of P

[14]

4. (a) beta radiation is more penetrating (than alpha radiation)

allow beta radiation can pass through the case (but alpha radiation cannot)

allow beta radiation can travel further (in air than alpha radiation)

*do **not** allow beta radiation is more ionising*

1

so beta could irradiate people passing near the smoke detector

allow beta radiation can pass through skin

1

(b) A = 227

1

Z = 89

1

(c) (some) radiation is stopped by paper

1

so the source emits alpha radiation

MP2 dependent on MP1

1

and (some) radiation passes through paper but is stopped by aluminium

1

so the source emits beta radiation (but does not emit gamma)

MP4 dependent on MP3

1

(d) D B A C

all four letters must be in the correct order

explanation only scores if correct order given

1

explanation

a substance with a longer half-life has more stable nuclei

allow the more stable a nucleus, the less likely it is to decay (in a given time)

1

so answers are in order of increasing half-life

1

[11]

5. (a) more than 10 000 times bigger

1

(b) the atom becomes a positive ion

1

the atom loses an electron

1

(c) beta radiation is only weakly ionising

1

(d) **Level 3:** The method would lead to the production of a valid outcome. The key steps are identified and logically sequenced.

5–6

Level 2: The method would not necessarily lead to a valid outcome. Most steps are identified, but the method is not fully logically sequenced.

3–4

Level 1: The method would not lead to a valid outcome. Some relevant steps are identified, but links are not made clear.

1–2

No relevant content

0

Indicative content

- move the detector very close to the source
- record the count rate

- position the paper between the source and the detector
- record the new count rate
- alpha radiation will not penetrate through paper
- if the count rate with the paper is (significantly) less than without then the source emits alpha radiation

- remove the paper and position the aluminium between the source and the detector
- record the new count rate
- (alpha and) beta radiation will not penetrate through the aluminium
- if the count rate has (significantly) reduced compared with using paper then beta radiation is present
- if radiation penetrates through the aluminium then gamma radiation is present

- the experiment should be repeated and mean results calculated because radioactivity is a random process

To access level 3, the candidate must use the paper sheet, the aluminium sheet and no sheet, and describe how the results would indicate the presence of alpha, beta or gamma radiation.

[10]

6. (a) contamination

1

(b) 2007-1992 = 15

allow an indication of the student reading from 15 years on the graph

1

35 (Bq)

allow an answer between 34 and 36 (Bq)

1

(c) 12.5 (years)

1

(d) 12.5 (years)

allow the same value as their answer to (c)

1

(e)

$\frac{36\ 000\ 000\ 000}{45\ 000\ 000\ 000}$ (× 100)

allow $\frac{36}{45}$ *(× 100)*

1

80 (%)

1

(f) radioactive decay is a random process

1

(g) use long tongs to handle the materials

1

(h) peer review

1

[10]

7. (a) A = 206

1

(b) Z = 82

1

(c)

numbers must be in this order

89

1

39

1

(d) electromagnetic waves

1

(e) **Level 3:** Relevant points (reasons/causes) are identified, given in detail and logically linked to form a clear account.

5–6

Level 2: Relevant points (reasons/causes) are identified, and there are attempts at logical linking. The resulting account is not fully clear.

3–4

Level 1: Points are identified and stated simply, but their relevance is not clear and there is no attempt at logical linking.

1–2

No relevant content

0

Indicative content

alpha radiation

- an alpha particle is the same as a helium nucleus
- alpha is the least penetrating
- alpha is stopped by paper or skin
- alpha has the shortest range in air
- alpha will travel a few cm in air
- because alpha is most ionising
- because alpha has a charge of +2

beta radiation

- a beta particle is an electron (emitted from the nucleus)
- beta penetrates less than gamma and more than alpha
- beta is stopped by a thin sheet of aluminium
- beta has a shorter range than gamma
- beta will travel up to 1m in air
- because beta is more ionising that gamma and less ionising than alpha
- because beta has a charge of -1

gamma radiation

- gamma radiation is an electromagnetic wave
- gamma is the most penetrating
- gamma is reduced/stopped by several cm of lead or thick concrete
- gamma has the largest range in air
- gamma will travel very large distances in air
- because gamma is least ionising
- because is uncharged

to access level 3 the answer should compare alpha, beta and gamma radiation and provide some explanation of their properties

[11]