Atomic Structure 3

Name: _____

Class: _____

Date: _____

Time: **67 minutes**

Marks: **61 marks**

Comments:

1. There are different isotopes of the element lead.

(a) What is the difference between the atoms of different isotopes of lead?

Tick (✓) **one** box.

- The number of electrons ☐
- The number of neutrons ☐
- The number of protons ☐

(1)

(b) The isotope lead-210 is radioactive.

What is meant by 'lead-210 is radioactive'?

Tick (✓) **one** box.

- Lead-210 forms many different compounds. ☐
- Lead-210 has unstable nuclei. ☐
- Lead-210 melts at a low temperature. ☐

(1)

(c) The isotope lead-210 emits beta radiation.

What is beta radiation?

Tick (✓) **one** box.

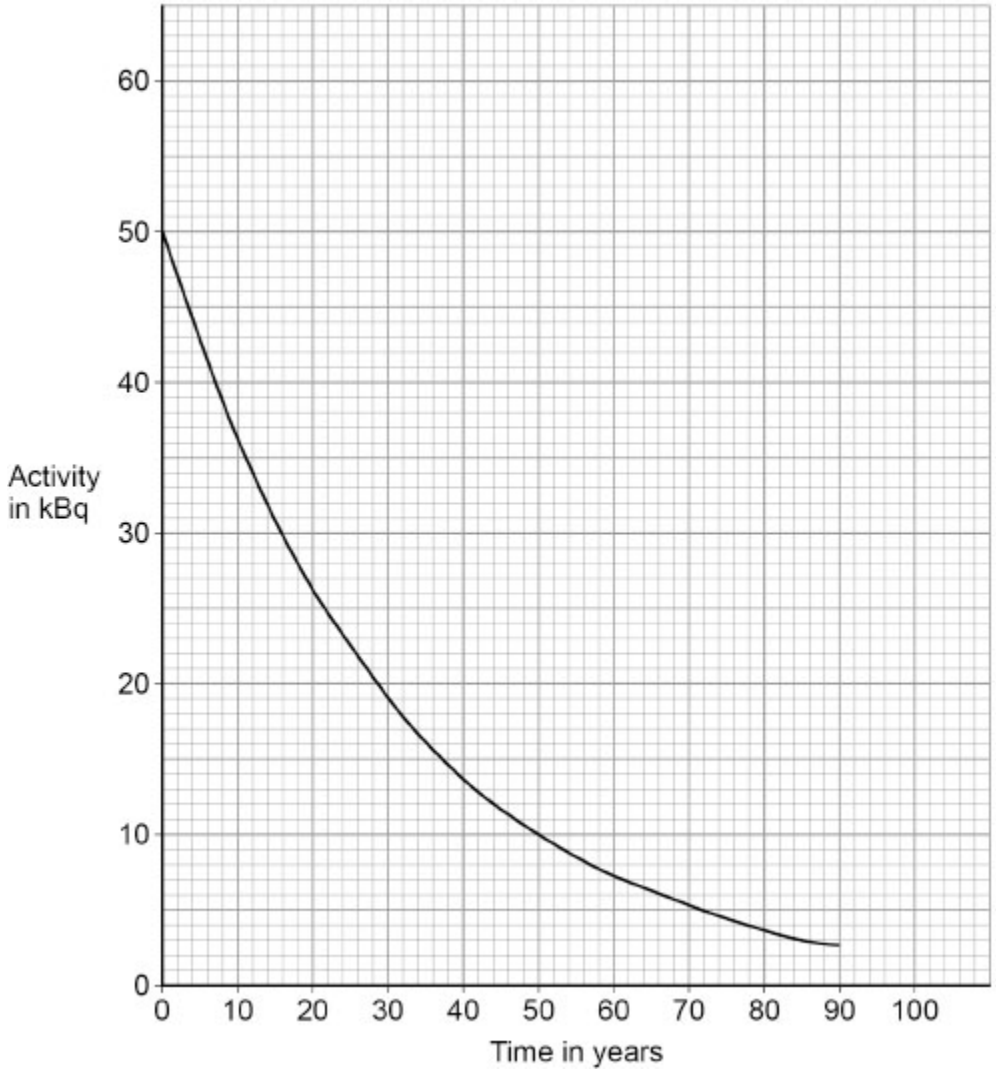
- Electromagnetic radiation emitted from nuclei ☐
- High speed electrons ejected from nuclei ☐
- Particles that consist of two neutrons and two protons ☐

(1)

The paint in an old painting contains the isotope lead-210.

The lead-210 in the paint can be used to estimate the age of the painting.

The figure below shows how the activity of the lead-210 in the paint changes with time.



(d) What was the initial activity of the lead-210 in the paint?

Use the figure above.

Activity = _____ kBq

(1)

(e) Calculate the activity of the lead-210 in the paint after one half-life.

_____

Activity = _____ kBq

(1)

(f) What was the estimated age of the painting when the activity was 10 kBq?

Use the figure above.

Age = _____ years

(1)

The paint also contains other radioactive substances.

(g) A scientist removed the other radioactive substances before measuring the activity.

The activity would be greater if the other radioactive substances were **not** removed.

How would the estimate of the age of the painting be different if the activity was greater?

Use the figure above.

Tick (✓) **one** box.

The estimated age would be lower ☐

The estimated age would be the same ☐

The estimated age would be greater ☐

(1)

The other radioactive substances in the paint emit different types of radiation.

(h) Complete the sentence.

Choose the answer from the box.

alpha	**beta**	**gamma**

The type of radiation with the greatest range in air is _____.

(1)

(i) Complete the sentence.

Choose the answer from the box.

alpha	beta	gamma

The type of radiation that is the least penetrating is _____.

(1)

(Total 9 marks)

2. Three types of radiation emitted by unstable nuclei are:

- alpha particle
- beta particle
- gamma ray.

(a) Describe each type of radiation.

Alpha particle _____

_____

Beta particle _____

_____

Gamma ray _____

_____

(3)

(b) The radioactive isotope gold-198 (Au) decays to mercury (Hg) by emitting beta radiation.

Complete the nuclear equation for the decay of gold-198.

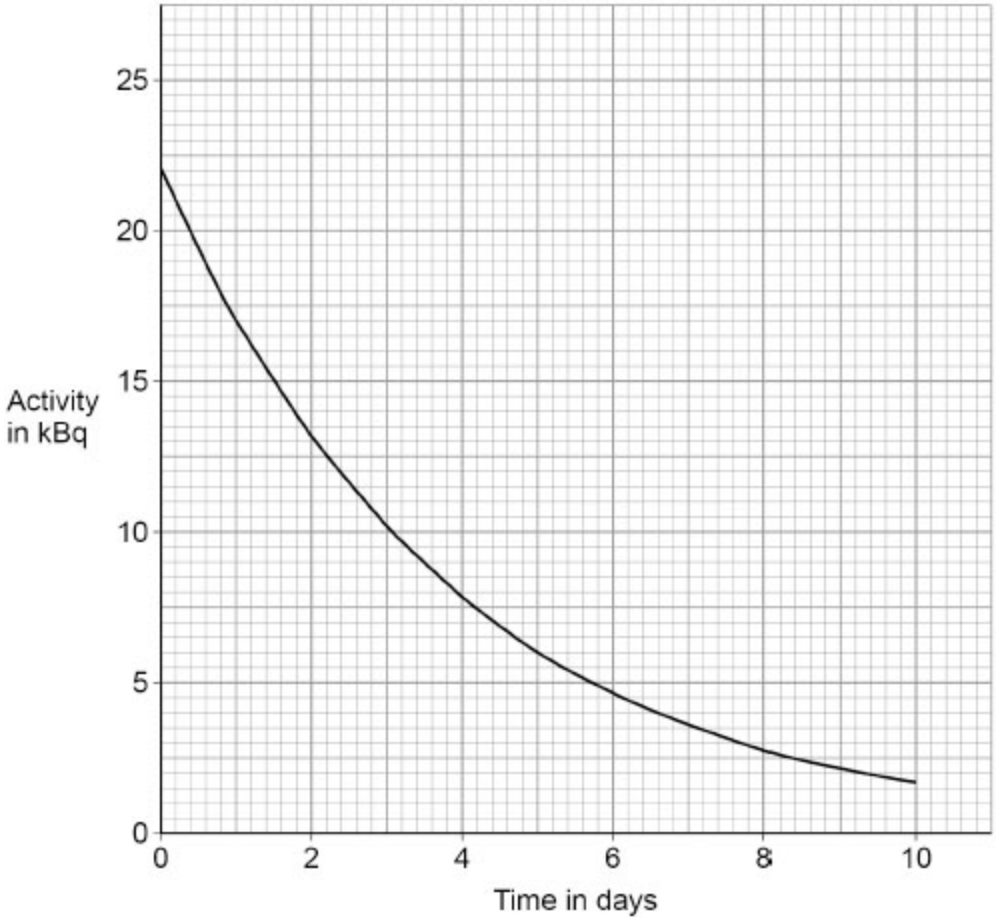
$$^{198}_{79}Au \rightarrow \_\_Hg + \_\_\beta$$

(2)

Gold-198 is used in the treatment of cancer.

A small sample containing gold-198 is surgically implanted into a patient, very near to the cancer cells.

The figure below shows how the activity of the sample changes after it has been implanted.



(c) Determine the half-life of gold-198.

_____

_____

_____

Half-life = _____ days

(2)

(d) Determine the percentage decrease in the activity at 5 days.

Give your answer to 2 significant figures.

Percentage decrease (2 significant figures) = _____ %

(4)

(e) The sample containing gold-198 is implanted very near to the cancer cells.

Give **two** reasons why.

1 _____

2 _____

(2)

(f) After treatment, the sample containing gold-198 is **not** removed from the patient.

Suggest why the sample is left in the patient and **not** removed.

(1)

(Total 14 marks)

3. Some people used to think that radioactive substances had health benefits.

100 years ago, a company made toothpaste containing the radioactive isotopes radium-228 and radium-226.

Figure 1 shows the symbols for these isotopes.

Figure 1

$^{228}_{88}Ra$ $^{226}_{88}Ra$

(a) How are atoms of radium-228 different from atoms of radium-226?

Tick (✓) **one** box.

Radium-228 atoms have one more neutron and one more proton. ☐

Radium-228 atoms have two more neutrons and two more protons. ☐

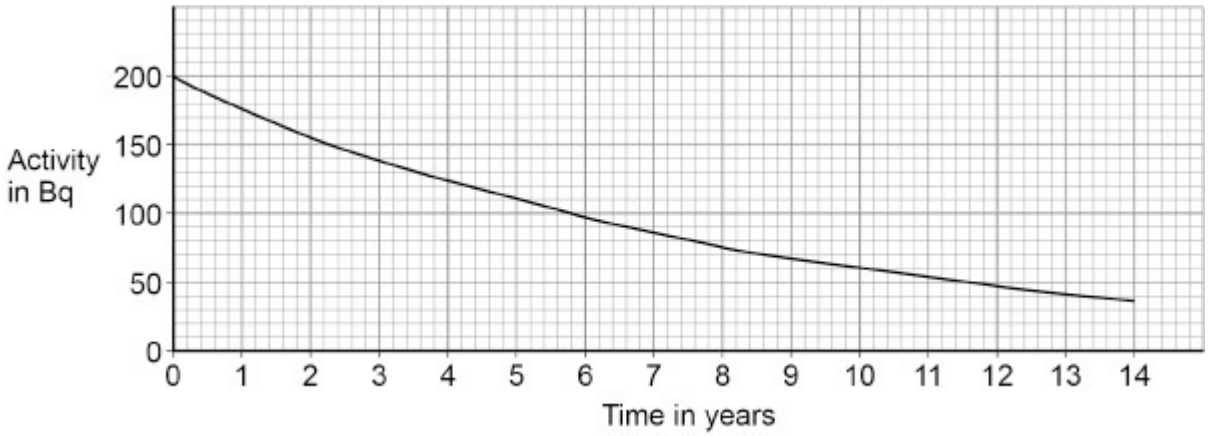
Radium-228 atoms have two more neutrons. ☐

Radium-228 atoms have two more protons. ☐

(1)

(b) **Figure 2** shows how the activity of a sample of radium-228 changed over time.

Figure 2



What is the approximate half-life of radium-228?

Tick (✓) **one** box.

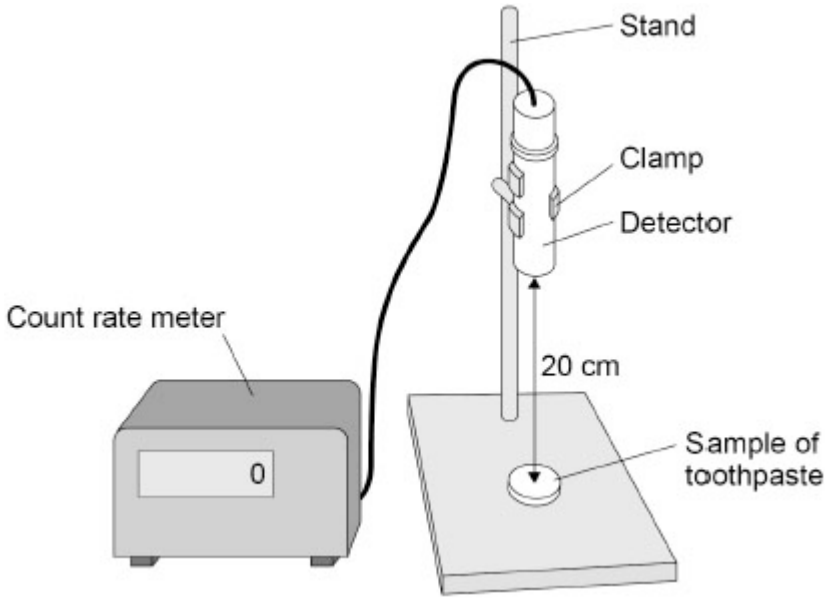
6 years	☐
7 years	☐
14 years	☐
100 years	☐

(1)

A scientist investigated whether the toothpaste in four tubes of the 100-year-old toothpaste is equally radioactive.

Figure 3 shows the equipment used.

Figure 3



(c) When the equipment was arranged as shown in **Figure 3**, it was **not** possible to detect alpha particles from the toothpaste.

Suggest how the scientist adjusted the equipment to detect alpha particles from the toothpaste.

_____

_____

(1)

(d) The scientist adjusted the equipment and determined the activity of the toothpaste from each tube.

The table below shows the results.

Tube	**Activity in Bq**
A	3150
B	2940
C	3180
D	3050

What was the range of activities shown in above table?

From _____ Bq to _____ Bq

(1)

(e) What was the independent variable in the investigation?

Tick (✓) **one** box.

The activity of the toothpaste ☐

The mass of toothpaste used ☐

The temperature of the toothpaste ☐

The tube of toothpaste used ☐

(1)

(f) What was the dependent variable in the investigation?

Tick (✓) **one** box.

- The activity of the toothpaste ☐
- The mass of toothpaste used ☐
- The temperature of the toothpaste ☐
- The tube of toothpaste used ☐

(1)

(g) When the toothpaste was new, it caused a risk to health because of the nuclear radiation emitted.

What happened to the risk to health from the toothpaste after 100 years?

_____

_____

(1)

(h) Which property makes nuclear radiation hazardous?

Tick (✓) **one** box.

- Nuclear radiation is ionising. ☐
- Nuclear radiation is penetrating. ☐
- Nuclear radiation is too small to see. ☐
- Nuclear radiation makes objects radioactive. ☐

(1)

(Total 8 marks)

4. Last century, scientists used evidence from the alpha particle scattering experiment to develop a new model of the atom.

In the experiment, alpha particles were directed towards a piece of gold foil.

(a) What does an alpha particle consist of?

_____

_____

(1)

(b) A gold atom has the symbol $^{197}_{79}Au$.

How many neutrons are there in this gold atom?

_____

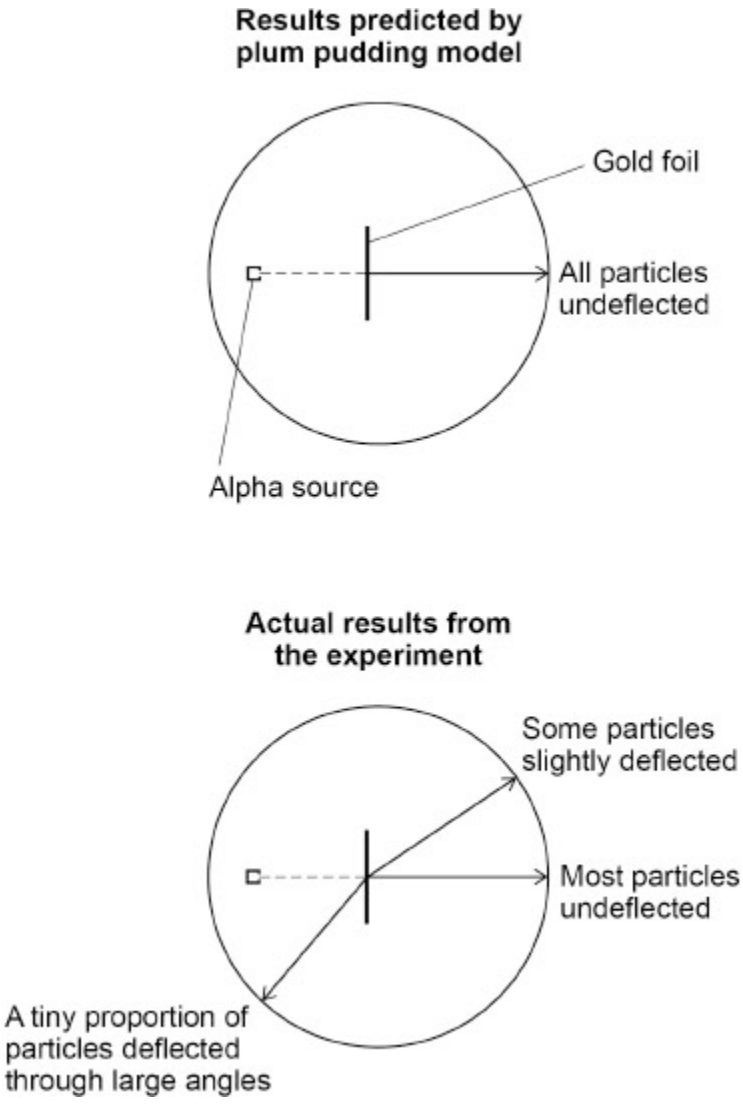
_____

Number of neutrons = _____

(1)

(c) The alpha particle scattering experiment led to the plum pudding model of the atom being replaced by the nuclear model.

The figure below shows the results predicted by the plum pudding model and the actual results from the alpha particle scattering experiment.



Describe how the actual results led to the plum pudding model of the atom being replaced by the nuclear model.

You should include details of the plum pudding model and the nuclear model of the atom.

(6)

(d) Scientists did not know that neutrons existed when they first did alpha particle scattering experiments.

Which scientist did the experiments that provided evidence that neutrons exist?

Tick (✓) **one** box.

Isaac Newton ☐

James Chadwick ☐

Niels Bohr ☐

(1)

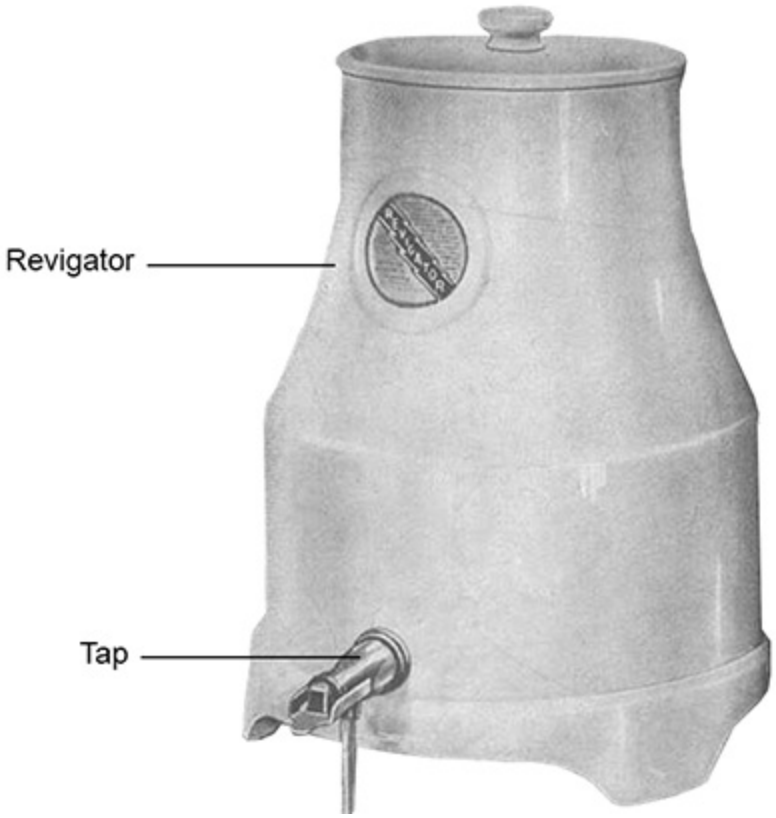
(Total 9 marks)

5. Some people used to think that radioactive substances had health benefits.

In the 1920s, a water container called a revigator was sold.

The walls of a revigator contain radioactive isotopes.

The figure below shows a revigator.



The revigator was filled with water and left overnight.

People then drank the water from the revigator.

(a) The water was irradiated and contaminated by the radioactive isotopes in the walls of the revigator.

Explain how irradiating and contaminating the water affected the hazard caused by drinking the water.

Irradiating _____

_____

_____

_____

Contaminating _____

_____

_____

_____

(4)

A scientist tested some water that had been left in a revigator.

The water contained radon-222 and vanadium-52.

(b) Vanadium-52 (V) decays by emitting beta particles.

What is the correct nuclear equation for this process?

Tick (✓) **one** box.

$^{52}_{23}V - {}^{0}_{-1}\beta \rightarrow {}^{52}_{22}Ti$ ☐

$^{52}_{23}V - {}^{0}_{-1}\beta \rightarrow {}^{52}_{24}Cr$ ☐

$^{52}_{23}V \rightarrow {}^{52}_{22}Ti + {}^{0}_{-1}\beta$ ☐

$^{52}_{23}V \rightarrow {}^{52}_{24}Cr + {}^{0}_{-1}\beta$ ☐

(1)

(c) The table below shows the half-lives of radon-222 and vanadium-52.

Isotope	Half-life
Radon-222	3.8 days
Vanadium-52	3.7 minutes

The scientist measured the radiation emitted by a sample of radon-222 and the radiation emitted by a sample of vanadium-52.

The scientist repeated the measurements 7.4 minutes later.

Explain how the activity of the radon-222 and vanadium-52 had changed after 7.4 minutes.

Radon-222 _____

_____

_____

_____

Vanadium-52 _____

_____

_____

_____

(4)

(d) Scientists monitored the effects of drinking the water from a revigator.

Their methods and results were checked by other scientists.

What name is given to the process of other scientists checking work before it is published?

_____

(1)

(Total 10 marks)

6. A scientist investigated the radiation emitted by different radioactive isotopes.

The scientist had a sample of polonium-210.

The radiation emitted by polonium-210 can be represented by the symbol $^{4}_{2}\text{He}$.

(a) Which type of radiation can be represented by the symbol $^{4}_{2}\text{He}$?

Tick (✓) **one** box.

Alpha ☐

Beta ☐

Gamma ☐

(1)

(b) How many protons are there in a particle of radiation represented by $^{4}_{2}\text{He}$?

Tick (✓) **one** box.

2 ☐ 4 ☐ 6 ☐ 8 ☐

(1)

(c) A polonium-210 (Po) nucleus changes into a lead (Pb) nucleus by emitting a $^{4}_{2}\text{He}$ particle. This is shown by the following nuclear equation.

$$^{210}_{84}\text{Po} \rightarrow {}^{206}_{\mathbf{X}}\text{Pb} + {}^{4}_{2}\text{He}$$

What is the value of **X**?

Tick (✓) **one** box.

80 ☐ 82 ☐ 84 ☐ 86 ☐

(1)

(d) The sample of polonium-210 had an activity of 100 Bq.

Complete the sentence.

Choose the answer from the box.

25	**50**	**100**	**200**

After one half-life, the activity of polonium-210 in the sample

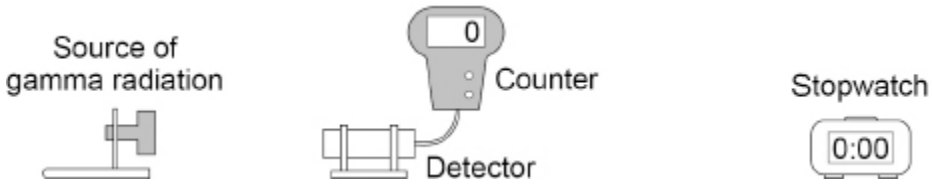
was _____ Bq.

(1)

The scientist investigated another radioactive isotope that is a source of gamma radiation.

Figure 1 shows the equipment used.

Figure 1



(e) The count-rate is the number of counts detected each second.

In 30 seconds the number of counts detected was 1500.

Calculate the count-rate.

_____

_____

_____

Count-rate = _____ counts per second

(2)

The scientist placed a thick sheet of lead between the source of gamma radiation and the detector.

(f) What was the effect of the sheet of lead on the count-rate?

Give a reason for your answer.

Effect _____

_____

Reason _____

_____

(2)

(g) The lead was irradiated by the gamma radiation.

What happened to the lead when it was irradiated by the gamma radiation?

Tick (✓) **one** box.

The lead atoms became radioactive.	☐
The lead gained atoms from the radioactive source.	☐
The lead was exposed to gamma radiation.	☐

(1)

(h) Gamma radiation is emitted from the nucleus of an atom.

Complete the sentence.

Choose the answer from the box.

electromagnetic waves	**high speed electrons**
neutrons	**positively charged ions**

Gamma radiation consists of _____.

(1)

(i) **Figure 2** shows the scientist holding the radioactive source using tongs.

Figure 2

Suggest **one** reason why using long tongs rather than short tongs was safer for the scientist.

_____

_____

(1)

(Total 11 marks)

1.

(a) the number of neutrons

1

(b) lead-210 has unstable nuclei

1

(c) high speed electrons ejected from nuclei

1

(d) 50 (kBq)

allow an answer in the range 49 (kBq) to 50 (kBq)

1

(e) 25 (kBq)

allow ecf from part (d)

1

(f) age = 50 (years)

1

(g) the estimated age would be lower

1

(h) gamma

1

(i) alpha

1

[9]

2.

(a) *alpha particle*

(a particle consisting of) two neutrons **and** two protons (from the nucleus)

allow helium nucleus

1

beta particle

(a high-speed) electron (from the nucleus)

1

gamma ray

(a high frequency / energy) electromagnetic wave / radiation (from the nucleus)

1

(b) 198 0

***1** mark for the top row*

1

80 –1

***1** mark for the bottom row*

1

(c) 2.75 (days)

allow 2.7 to 2.8

allow an answer consistent with a correct pair of values for activity

*allow **1** mark for a horizontal line drawn from 11*

2

(d) activity = 6.0 (kBq)

subsequent marks may be awarded if an activity of 7.0 (kBq) is used

1

$$\frac{22 - 6.0}{22} \times 100$$

1

72.7...(%)

1

73 (%)

allow a percentage calculated using data from the graph given to two significant figures

1

(e) any **two** from:

- beta only has a short range (in tissue)
- increases the chance of killing the cancer cells
- decreases the risk to healthy cells

2

(f) the risk of removing the sample is greater than the risk of leaving the sample in the patient

or

the activity will reduce to a safe level in a short time

allow the risk of leaving the sample in the patient is very small

1

[14]

3. (a) radium-228 atoms have two more neutrons

1

(b) 6 years

1

(c) decrease the distance between the toothpaste and the detector

1

(d) 2940

answers may be in either order

3180

1

(e) the tube of toothpaste used

1

(f) the activity of the toothpaste

1

(g) there is less risk

1

(h) nuclear radiation is ionising

1

[8]

4. (a) 2 protons and 2 neutrons

ignore helium nucleus

1

(b) 118

1

(c) **Level 2:** Scientifically relevant facts, events or processes are identified and given in detail to form an accurate account.

4–6

Level 1: Facts, events or processes are identified and simply stated but their relevance is not clear.

1–3

No relevant content

0

Indicative content

Plum pudding model
- the atom is a ball of positive charge
- electrons are embedded in the ball

Reasons why the plum pudding model was replaced
- the results were not correctly predicted by the plum pudding model
- the plum pudding model did not predict that some particles would be deflected
- the large angle deflections suggest that the atom contains a nucleus
- all deflections suggest that the nucleus is charged
- most alpha particles were not deflected suggesting that atoms are mostly empty space

Nuclear model
- mass is concentrated in the nucleus
- the nucleus is charged
- the atom is mostly empty space
- electrons orbit the nucleus in the nuclear model

(d) James Chadwick

1

[9]

5. (a) **Irradiating**

EITHER

radiation enters the water

allow risk for hazard throughout

allow alpha / beta / gamma enters the water

allow the water does not become radioactive

1

(which) does not affect the hazard

dependent on MP1

1

OR

because radiation can kill pathogens (1)

allow named pathogens e.g. bacteria, viruses

(irradiating) decreases the hazard (1)

dependent on MP1

contaminating

because radioactive isotopes will enter the water / body

1

(contaminating) increases the hazard

dependent on MP3

1

(b) $^{52}_{23}V \rightarrow {}^{52}_{24}Cr + {}^{0}_{-1}\beta$

1

(c) **radon-222**

activity remained (almost) the same

allow the radiation emitted (each second) decreased by a small amount

1

because 7.4 minutes is only a very small fraction of 3.8 days

allow 7.4 minutes is much smaller than 3.8 days

1

vanadium-52

activity decreased by a factor of 4

1

because 2 half-lives had passed

allow the time is much less than the half-life

1

(d) peer review

1

[10]

6. (a) alpha

1

(b) 2

1

(c) 82

1

(d) 50

1

(e) $\frac{1500}{30}$

1

50 (counts per second)

1

(f) the count-rate decreased

allow decreased to (almost) zero

1

because (gamma) radiation is absorbed by lead

allow (gamma) radiation cannot penetrate (thick) lead

1

(g) the lead was exposed to gamma radiation

1

(h) electromagnetic waves

1

(i) any one from:

- (longer tongs give) a greater distance between the scientist and the radioactive source
- (longer tongs) reduce the amount of radiation the scientist is exposed to
- (longer tongs) reduce the risk of cell mutation

allow (longer tongs) reduce the risk of cancer

1

[11]