

1

Scientists sometimes replace one scientific model with a different model.

For example, in the early 20th Century the plum pudding model of the atom was replaced by the nuclear model of the atom.

Explain what led to the plum pudding model of the atom being replaced by the nuclear model of the atom.

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**(Total 6 marks)**

2

A student models the random nature of radioactive decay using 100 dice.

He rolls the dice and removes any that land with the number 6 facing upwards.

He rolls the remaining dice again.

The student repeats this process a number of times.

The table below shows his results.

| Roll number | Number of dice remaining |
|-------------|--------------------------|
| 0           | 100                      |
| 1           | 84                       |
| 2           | 70                       |
| 3           | 59                       |
| 4           | 46                       |
| 5           | 40                       |
| 6           | 32                       |
| 7           | 27                       |
| 8           | 23                       |

(a) Give **two** reasons why this is a good model for the random nature of radioactive decay.

1 .....

.....

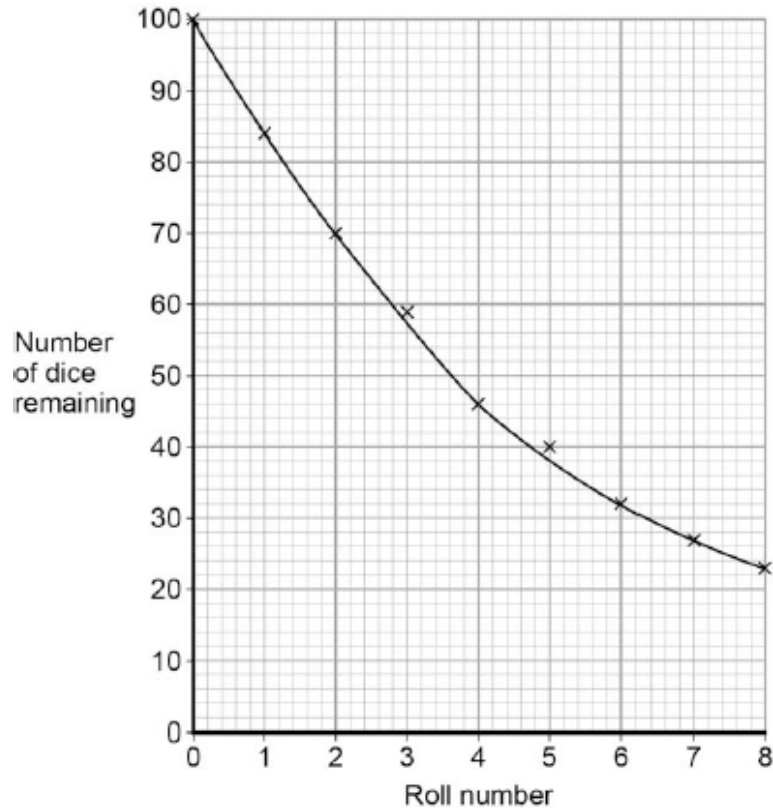
2 .....

.....

(2)

- (b) The student's results are shown in **Figure 1**.

**Figure 1**



Use **Figure 1** to determine the half-life for these dice using this model.

Show on **Figure 1** how you work out your answer.

Half-life = ..... rolls

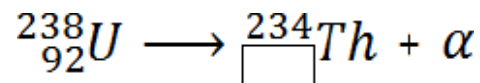
(2)

- (c) A teacher uses a protactinium (Pa) generator to produce a sample of radioactive material that has a half-life of 70 seconds.

In the first stage in the protactinium generator, uranium (U) decays into thorium (Th) and alpha ( $\alpha$ ) radiation is emitted.

The decay can be represented by the equation shown in **Figure 2**.

**Figure 2**



Determine the atomic number of thorium (Th) 234.

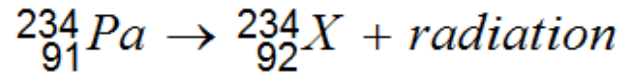
Atomic number = .....

(1)

- (d) When protactinium decays, a new element is formed and radiation is emitted.

The decay can be represented by the equation shown in **Figure 3**.

**Figure 3**



When protactinium decays, a new element, **X**, is formed.

Use information from **Figure 2** and **Figure 3** to determine the name of element **X**.

.....

(1)

- (e) Determine the type of radiation emitted as protactinium decays into a new element.

Give a reason for your answer.

.....

.....

.....

.....

(2)

- (f) The teacher wears polythene gloves as a safety precaution when handling radioactive materials.

The polythene gloves do **not** stop the teacher's hands from being irradiated.

Explain why the teacher wears polythene gloves.

.....

.....

.....

.....

(2)

(Total 10 marks)

**3**

Atoms contain three types of particle.

- (a) Draw a ring around the correct answer to complete the sentence.

The particles in the nucleus of the atom are

|                         |
|-------------------------|
| electrons and neutrons. |
| electrons and protons.  |
| neutrons and protons.   |

(1)

(b) Complete the table to show the relative charges of the atomic particles.

| Particle | Relative charge |
|----------|-----------------|
| Electron | -1              |
| Neutron  |                 |
| Proton   |                 |

(2)

(c) (i) A neutral atom has no overall charge.

Explain this in terms of its particles.

.....

.....

.....

.....

(2)

(ii) Complete the sentence.

An atom that loses an electron is called an .....

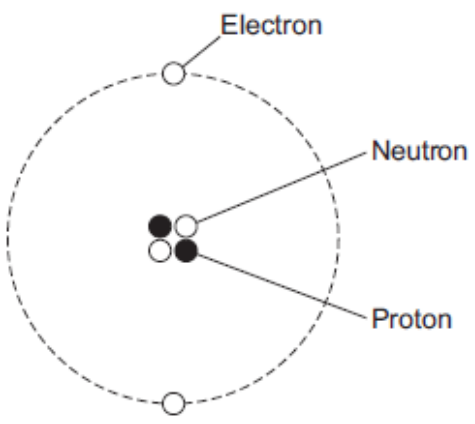
and has an overall ..... charge.

(2)



4

(a) The figure below shows a helium atom.



(i) Which **one** of the particles in the atom is **not** charged?

Draw a ring around the correct answer.

**electron                  neutron                  proton**

(1)

(ii) Which **two** types of particle in the atom have the same mass?

..... and .....

(1)

(iii) What is the atomic number of a helium atom?

Draw a ring around the correct answer.

**2                  4                  6**

Give a reason for your answer.

.....  
.....

(2)

(b) Alpha particles are one type of nuclear radiation.

(i) Name **one** other type of nuclear radiation.

.....

(1)

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

|                  |                 |                |
|------------------|-----------------|----------------|
| <b>electrons</b> | <b>neutrons</b> | <b>protons</b> |
|------------------|-----------------|----------------|

The difference between an alpha particle and a helium atom is that the alpha particle does **not** have any .....

(1)

(iii) Which **one** of the following is a property of alpha particles?

Tick (✓) **one** box.

Have a long range in air

Are highly ionising

Will pass through metals

(1)

(c) Doctors may use nuclear radiation to treat certain types of illness.

Treating an illness with radiation may also harm a patient.

(i) Complete the following sentence.

The risk from treating a patient with radiation is that the radiation may  
..... healthy body cells.

(1)

(ii) Draw a ring around the correct answer to complete the sentence.

Radiation may be used to treat a patient if the risk from the

radiation is

|                   |
|-------------------|
| much bigger than  |
| about the same as |
| much smaller than |

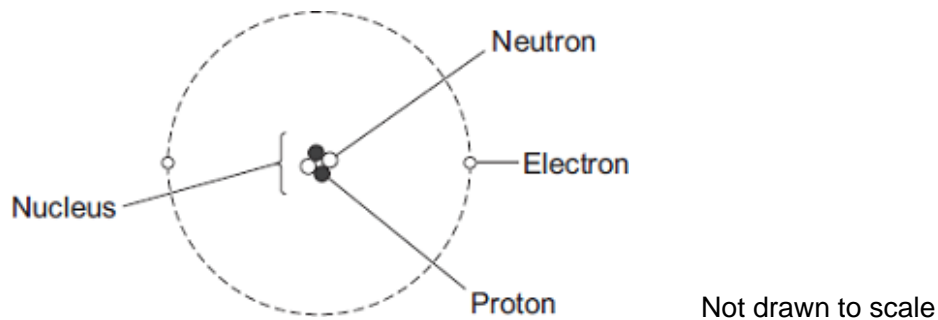
the possible benefit of having the treatment.

(1)

(Total 9 marks)



**5** The diagram shows the structure of an atom.



(a) In 1931 scientists thought that atoms contained **only** protons and electrons.

Suggest what happened in 1932 to change the idea that atoms contained only protons and electrons.

.....  
 .....

(1)

(b) The table gives information about the particles in an atom.

Complete the table by adding the names of the particles.

| Particle | Relative Mass | Relative Charge |
|----------|---------------|-----------------|
|          | 1             | 0               |
|          | very small    | -1              |
|          | 1             | +1              |

(2)

(Total 3 marks)

**6** There are many different isotopes of gold. The isotope, gold-198, is radioactive. An atom of gold-198 decays by emitting a beta particle.

(a) Complete the following sentences.

All atoms of gold have the same number of .....

and the same number of .....

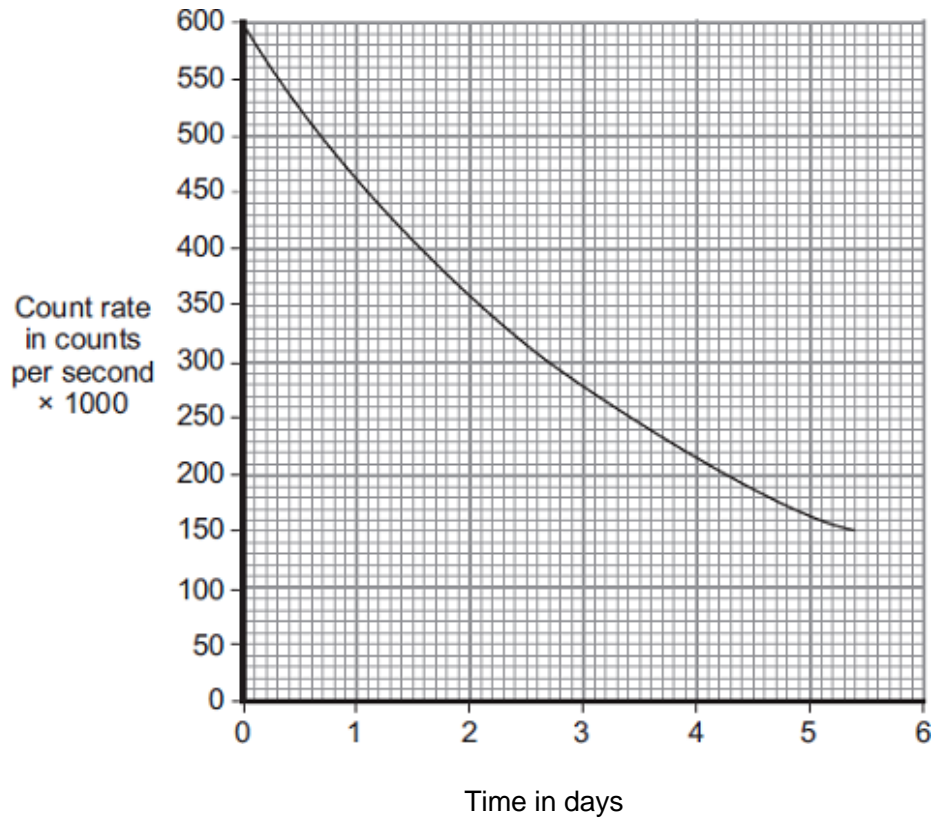
The atoms from different isotopes of gold have different numbers of .....

A beta particle is an ..... emitted

from the ..... of an atom.

(3)

(b) The graph shows how the count rate from a sample of gold-198 changes with time.



Use the graph to calculate the half-life of gold-198.

Show clearly on the graph how you obtain your answer.

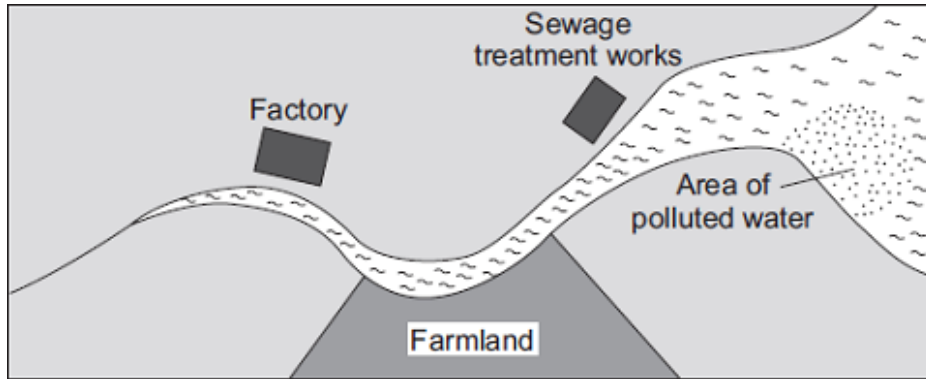
.....  
.....

Half-life = ..... days

(2)

(c) The diagram shows a map of a river and the river estuary.

Environmental scientists have found that water flowing into one part of the river estuary is polluted. To find where the pollution is coming from, the scientists use a radioactive isotope, gold-198.



The gold-198 is used to find where the pollution is coming from.

Explain how.

.....

.....

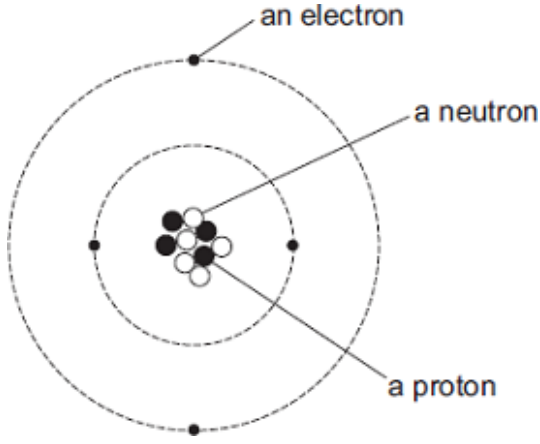
.....

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(2)  
(Total 7 marks)

7

The diagram represents an atom of beryllium. The three types of particle that make up the atom have been labelled.



(a) Use the labels from the diagram to complete the following statements.

Each label should be used once.

The particle with a positive charge is .....

The particle with the smallest mass is .....

The particle with no charge is .....

(2)

(b) What is the mass number of a beryllium atom?

Draw a ring around your answer.

|   |   |   |    |
|---|---|---|----|
| 4 | 5 | 9 | 13 |
|---|---|---|----|

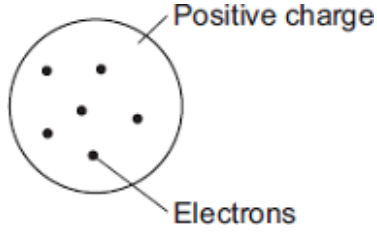
Give a reason for your answer.

.....  
.....

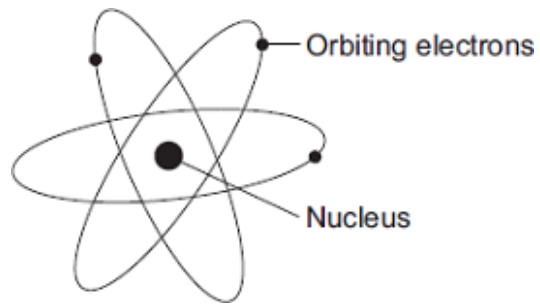
(2)  
(Total 4 marks)

8

In the early part of the 20th century, scientists used the 'plum pudding' model to explain the structure of the atom.



Following work by Rutherford and Marsden, a new model of the atom, called the 'nuclear' model, was suggested.



Describe the differences between the two models of the atom.

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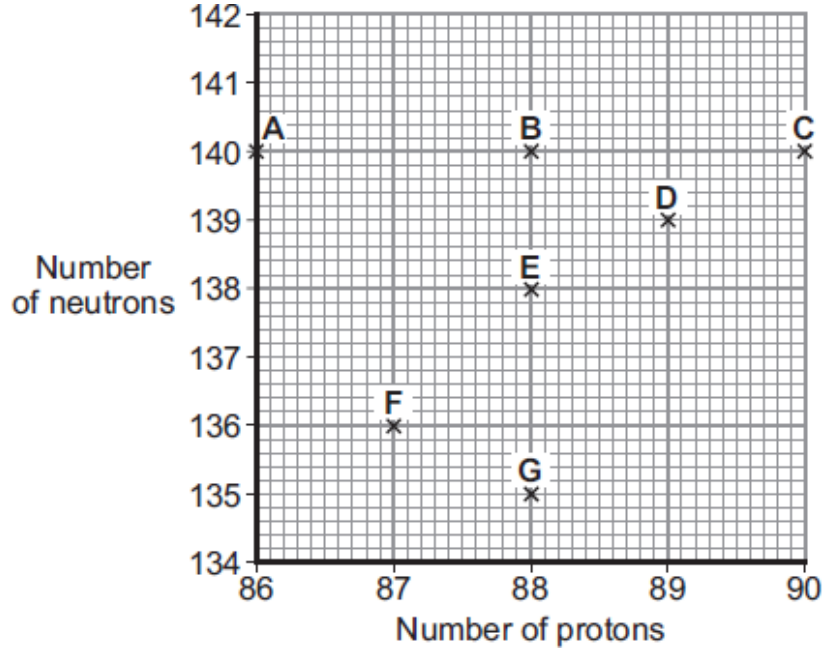
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**(Total 4 marks)**

9

(a) The chart gives the number of protons and neutrons within the nuclei of 7 different atoms, A – G.



Which of these atoms are isotopes of the same element?

.....

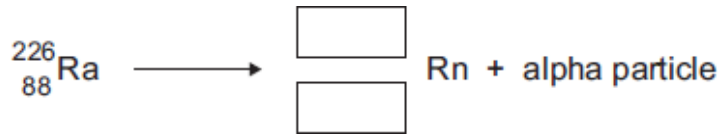
Give a reason for your answer.

.....  
.....

(2)

(b) Radium-226 is a radioactive isotope that decays into radon gas by emitting alpha particles.

The decay can be represented by the equation below.



(i) Complete the equation by writing the correct number in each of the boxes.

(2)

- (ii) A sample of radium-226 has a count rate of 400 counts per second.  
The half-life of radium-226 is 1600 years.

How long will it be before the count rate has fallen to 50 counts per second?

Show clearly how you work out your answer.

.....  
.....  
.....

Length of time = ..... years

(2)

- (c) In 1927, a group of women who had been employed to paint watch faces with a luminous paint sued their former employer over the illnesses caused by the paint. The women had been told that the paint, which contained radium, was harmless.

The company owners and the scientists working for the company knew that radium was harmful and took precautions to protect themselves from the radiation. The women were given no protection.

What important issue did the treatment of the women by the company owners and scientists raise?

Draw a ring around your answer.

**economic**      **environmental**      **ethical**      **social**

Give a reason for your answer.

.....  
.....

(2)

- (d) In the 1920s, many people, including doctors, thought that radium could be used as a treatment for a wide range of illnesses. Medical records that suggested radium could be harmful were generally ignored. When some of the women who had used the luminous paint died, their deaths were not blamed on radium.

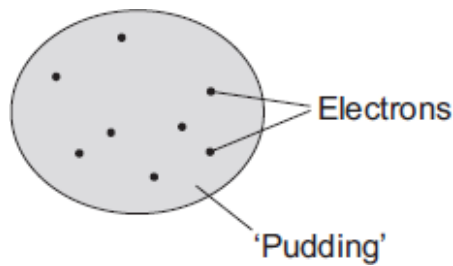
Suggest a reason why the evidence suggesting that radium was harmful was generally ignored.

.....  
.....  
.....

(1)  
(Total 9 marks)

10

The 'plum pudding' model of the atom was used by scientists in the early part of the 20th century to explain atomic structure.



- (a) Those scientists knew that atoms contained electrons and that the electrons had a negative charge. They also knew that an atom was electrically neutral overall.

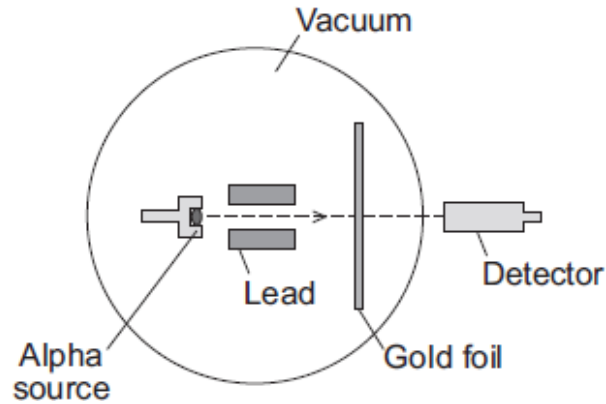
What did this allow the scientists to deduce about the 'pudding' part of the atom?

.....  
.....

(1)



- (b) An experiment, designed to investigate the 'plum pudding' model, involved firing alpha particles at a thin gold foil.



If the 'plum pudding' model was correct, then most of the alpha particles would go straight through the gold foil. A few would be deflected, but by less than  $4^\circ$ .

The results of the experiment were unexpected. Although most of the alpha particles did go straight through the gold foil, about 1 in every 8 000 was deflected by more than  $90^\circ$ .

Why did this experiment lead to a new model of the atom, called the nuclear model, replacing the 'plum pudding' model?

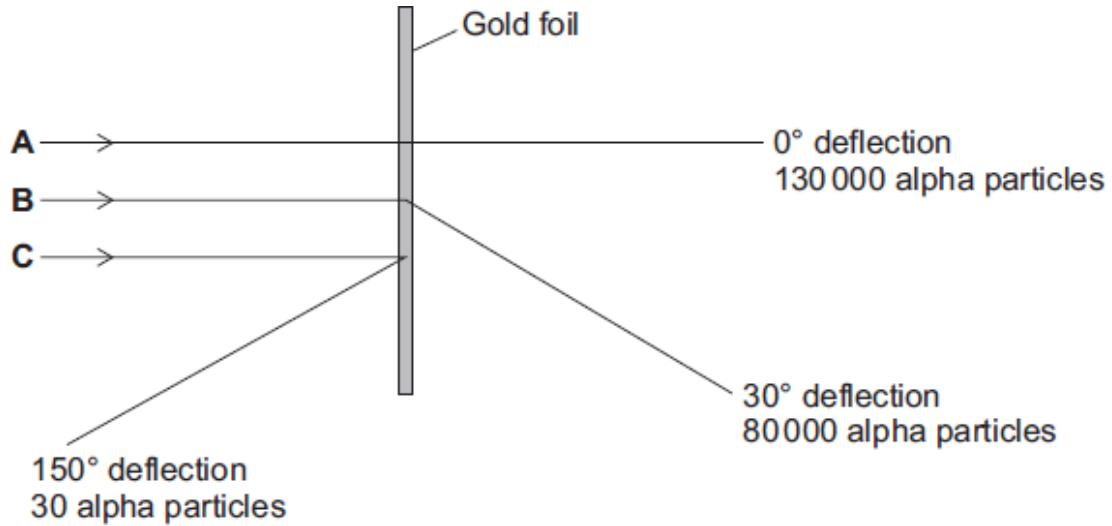
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(1)

- (c) The diagram shows the paths, **A**, **B** and **C**, of three alpha particles. The total number of alpha particles deflected through each angle is also given.



- (i) Using the nuclear model of the atom, explain the three paths, **A**, **B** and **C**.

**A** .....

.....

**B** .....

.....

**C** .....

.....

(3)

- (ii) Using the nuclear model, the scientist E. Rutherford devised an equation to predict the proportion of alpha particles that would be deflected through various angles.

The results of the experiment were the same as the predictions made by Rutherford.

What was the importance of the experimental results and the predictions being the same?

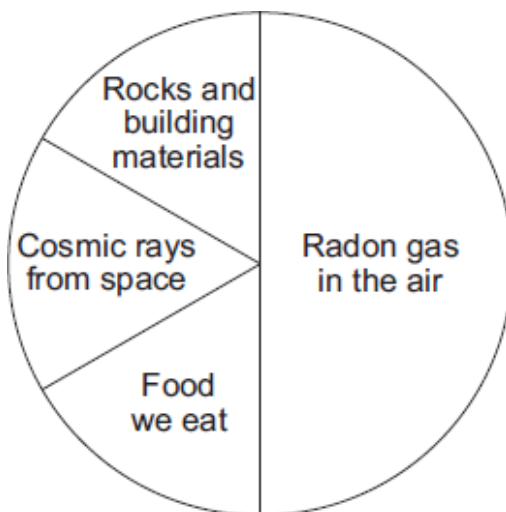
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(1)  
(Total 6 marks)

11

The pie chart shows the average proportions of natural background radiation from various sources in the UK.



(a) (i) Complete the following sentence.

On average, ..... of the natural background radiation in the UK comes from radon gas.

(1)

- (ii) Radon gas is found inside homes.

The table shows the results from measuring the level of radon gas inside four homes in one area of the UK.

| Home | Level of radon gas in Bq per m <sup>3</sup> of air |
|------|--|
| 1    | 25   |
| 2    | 75   |
| 3    | 210  |
| 4    | 46   |
| Mean | 89   |

One of the homes has a much higher level of radon gas than the other three homes.

What should be done to give a more reliable mean for the homes in this area of the UK?

Put a tick (✓) in the box next to your answer.

ignore the data for home number 3

measure the radon gas level in more homes in this area

include data for homes from different areas of the UK

(1)

- (b) Each atom of radon has 86 protons and 136 neutrons.

- (i) How many electrons does each atom of radon have?

Draw a ring around your answer.

50

86

136

222

(1)

(ii) How many particles are there in the nucleus of a radon atom?

Draw a ring around your answer.

50

86

136

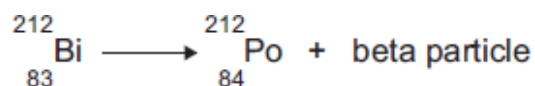
222

(1)  
(Total 4 marks)

12

(a) Atoms of the isotope bismuth-212 decay by emitting either an alpha particle or a beta particle.

The equation represents what happens when an atom of bismuth-212 decays by beta emission into an atom of polonium-212.



(i) The bismuth atom and the polonium atom have the same mass number (212).

What is the *mass number* of an atom?

.....

(1)

(ii) Beta decay does **not** cause the mass number of an atom to change.

Explain why not.

.....  
.....  
.....  
.....

(2)

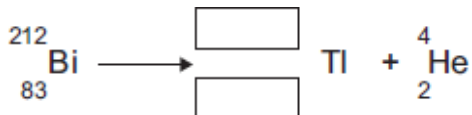
- (b) When an atom of bismuth-212 emits an alpha particle, the atom decays into an atom of thallium.

An alpha particle is the same as a helium nucleus.  
The symbol below represents an alpha particle.



- (i) The equation below represents the alpha decay of bismuth-212.

Complete the equation by writing the correct number in each of the two boxes.



(2)

- (ii) It is impossible for the alpha decay of bismuth-212 to produce the same element as the beta decay of bismuth-212.

Explain why.

.....

.....

.....

.....

(2)  
(Total 7 marks)

**13**

The names of three different processes are given in **List A**.  
Where these processes happen is given in **List B**.

Draw a line to link each process in **List A** to where the process happens in **List B**.

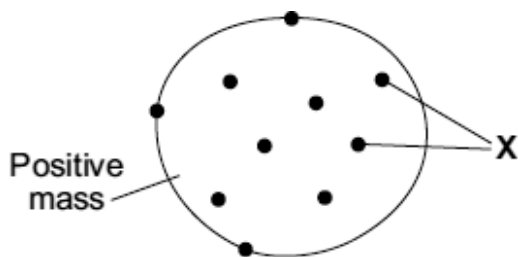
Draw only **three** lines.

| <b>List A</b>   | <b>List B</b>   |
|---|---|
| <b>Process</b>  | <b>Where it happens</b>   |
| <div data-bbox="217 623 505 722">fusion</div>         | <div data-bbox="743 525 1117 623">in a star</div>                   |
| <div data-bbox="217 821 505 919">chain reaction</div> | <div data-bbox="743 722 1117 821">in a nuclear reactor</div>        |
| <div data-bbox="217 1018 505 1117">alpha decay</div>  | <div data-bbox="743 919 1117 1018">in a smoke precipitator</div>    |
|   | <div data-bbox="743 1117 1117 1215">in the nucleus of an atom</div> |

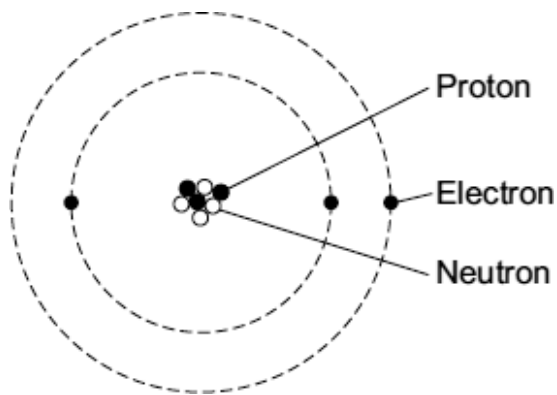
**(Total 3 marks)**

14

The diagrams show two different models of an atom.



**'Plum pudding' model**



**Model used today**

- (a) The particles labelled 'X' in the plum pudding model are also included in the model of the atom used today.

What are the particles labelled 'X'?

.....

(1)

- (b) Scientists decided that the 'plum pudding' model was wrong and needed replacing.

Which **one** of the following statements gives a reason for deciding that a scientific model needs replacing?

Tick (✓) **one** box.

The model is too simple.

The model has been used by scientists for a long time.

The model cannot explain the results from a new experiment.

(1)



- (c) The table gives information about the three types of particle that are in the model of the atom used today.

| Particle | Relative mass | Relative charge |
|----------|---------------|-----------------|
|          | 1             | +1              |
|          | very small    | -1              |
|          | 1             | 0               |

Complete the table by adding the names of the particles.

(2)  
(Total 4 marks)

15

- (a) Background radiation is all around us all the time.

- (i) Radon is a natural source of background radiation.

Name another natural source of background radiation.

.....

(1)

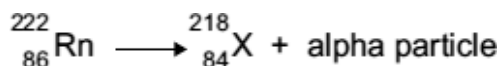
- (ii) X-rays are an artificial source of background radiation.

Name another artificial source of background radiation.

.....

(1)

- (iii) An atom of radon-222 decays by emitting an alpha particle.  
The equation representing the decay is shown below.



How can you tell from the equation that 'X' is not an atom of radon?

.....

.....

(1)

(b) Having an X-ray taken increases your exposure to radiation.

The table gives:

- the radiation doses received for 6 different medical X-rays;
- the number of days' of exposure to natural background radiation each dose is equivalent to.

| <b>Medical X-ray</b> | <b>Radiation dose received<br/>(in arbitrary units)</b> | <b>Equivalent number of days<br/>of exposure to natural<br/>background radiation</b> |
|----------------------|---|--|
| <b>Chest</b>         | 2   | 2.4  |
| <b>Skull</b>         | 7   | 8.4  |
| <b>Pelvis</b>        | 22  | 26.4   |
| <b>Hip</b>           | 44  | 52.8   |
| <b>Spine</b>         | 140   |  |
| <b>CT head scan</b>  | 200   | 240  |

A hospital patient has an X-ray of the spine taken.

Calculate the number of days of exposure to natural background radiation that an X-ray of the spine is equivalent to.

Show how you work out your answer.







.....  
.....  
.....

Equivalent number of days = .....

(2)

- (c) Scientists have shown that X-rays increase the risk of developing cancer. The scientists came to this conclusion by studying the medical history of people placed in one of two groups, **A** or **B**. The group into which people were put depended on their X-ray record.

- (i) Person **J** has been placed into group **A**. Place each of the people, **K**, **L**, **M**, **N** and **O**, into the appropriate group, **A** or **B**.

|                             |   |   |   |   |   |   |
|-----------------------------|---|---|---|---|---|---|
| <b>Person</b>               | <b>J</b><br> | <b>K</b><br> | <b>L</b><br> | <b>M</b><br> | <b>N</b><br> | <b>O</b><br> |
| <b>Medical X-ray record</b> | 3 arm   | None  | None  | 2 skull   | None  | 4 leg   |

| <b>Group A</b> | <b>Group B</b> |
|----------------|----------------|
| <b>J</b>       |                |

(1)

- (ii) To be able to make a fair comparison, what is important about the number of people in each of the two groups studied by the scientists?

.....  
 .....

(1)

- (iii) What data would the scientists have compared in order to come to the conclusion that X-rays increase the risk of developing cancer?

.....  
 .....

(1)

- (iv) The chance of developing cancer due to a CT head scan is about 1 in 10 000.  
The chance of developing cancer naturally is about 1 in 4.

A hospital patient is advised by a doctor that she needs to have a CT head scan.  
The doctor explains to the patient the risks involved.

Do you think that the patient should give her permission for the CT scan to be taken?

Draw a ring around your answer.

**Yes**

**No**

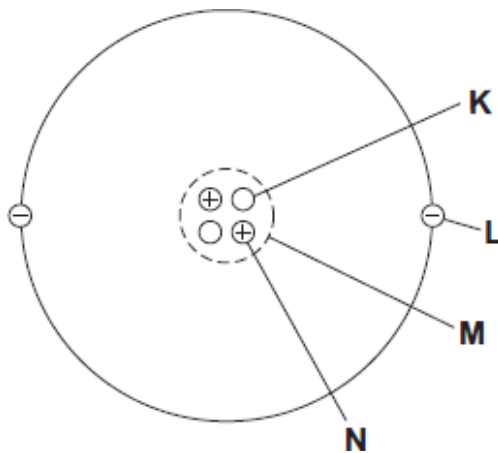
Give a reason for your answer.

.....  
.....

(1)  
(Total 9 marks)

**16**

- (a) The diagram represents a helium atom.



- (i) Which part of the atom, **K**, **L**, **M** or **N**, is an electron?

Part

(1)

- (ii) Which part of the atom, **K**, **L**, **M** or **N**, is the same as an alpha particle?

Part

(1)

(b) A radioactive source emits alpha particles.

What might this source be used for?

Put a tick (✓) in the box next to your answer.

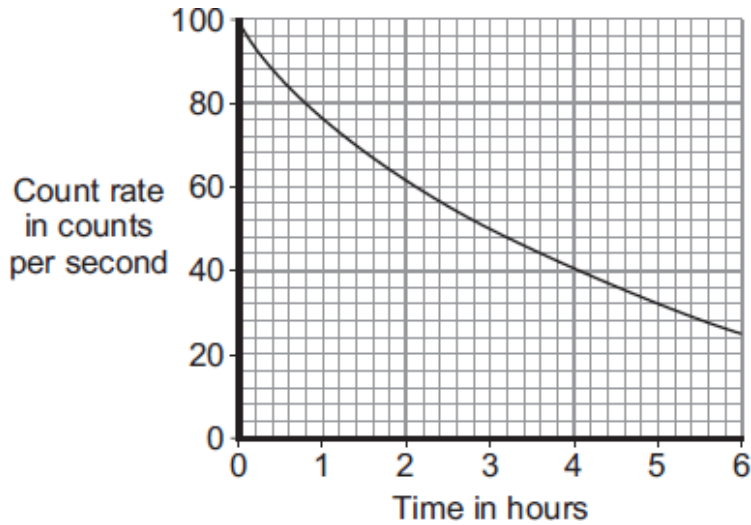
to monitor the thickness of aluminium foil as it is made in a factory

to make a smoke detector work

to inject into a person as a medical tracer

(1)

(c) The graph shows how the count rate from a source of alpha radiation changes with time.



What is the count rate after 4 hours?

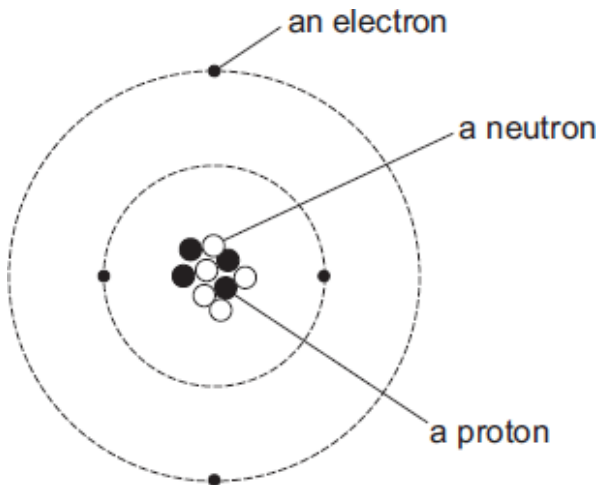
..... counts per second

(1)

(Total 4 marks)

17

The diagram represents an atom of beryllium. The three types of particle that make up the atom have been labelled.



(a) Use the labels from the diagram to complete the following statements.

Each label should be used once.

The particle with a positive charge is .....

The particle with the smallest mass is .....

The particle with no charge is .....

(2)

(b) What is the atomic number of a beryllium atom?

Draw a ring around your answer.

|   |   |   |    |
|---|---|---|----|
| 4 | 5 | 9 | 13 |
|---|---|---|----|

Give a reason for your answer.

.....  
.....

(2)

(c) Which **one** of the following statements describes what can happen to an atom to change it into an ion?

Tick (✓) **one** box.

The atom loses a neutron.

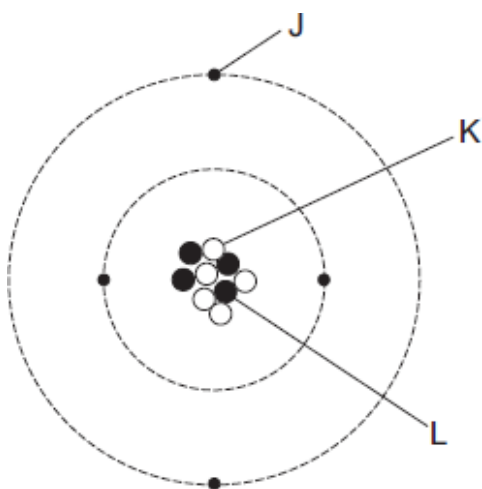
The atom loses an electron.

The atom loses a proton.

(1)  
(Total 5 marks)

18

The diagram represents an atom of beryllium.



(a) Complete the following statements by writing one of the letters, **J**, **K** or **L**, in each box.

Each letter should be used only **once**.

The particle with a positive charge is

The particle with the smallest mass is

The particle with no charge is

(2)

(b) Give the reason why all atoms have a total charge of zero.

.....  
.....

(1)

(c) Complete the following sentence.

There are several isotopes of beryllium. Atoms of different beryllium

isotopes will have different numbers of .....

(1)



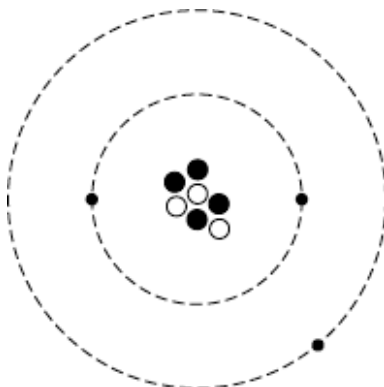
(d) What happens to the structure of an atom to change it into an ion?

.....  
.....

(1)  
(Total 5 marks)

19

The diagram represents an atom of lithium.



(a) (i) Complete the following table of information for an atom of lithium.

|                     |  |
|---------------------|--|
| Number of protons   |  |
| Number of electrons |  |
| Number of neutrons  |  |

(2)

(ii) What is the mass number of a lithium atom?

Draw a ring around your answer.

|   |   |   |    |
|---|---|---|----|
| 3 | 4 | 7 | 10 |
|---|---|---|----|

Give a reason for your answer.

.....  
.....

(2)

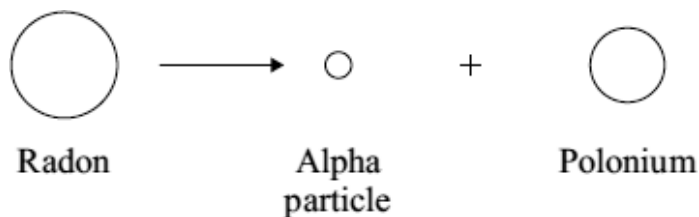
(b) Complete the following sentence by drawing a ring around the correct line in the box.

An atom that has lost an electron is called

- |                 |
|-----------------|
| an ion          |
| an isotope      |
| a positive atom |

(1)

(c) When an alpha particle is emitted from the nucleus of a radon atom, the radon changes into polonium.



**Not to scale**

An alpha particle consists of 2 protons and 2 neutrons.

(i) Complete the following sentence by drawing a ring around the correct line in the box.

The mass of a polonium atom is

- |              |
|--------------|
| greater than |
| the same as  |
| smaller than |

the mass of a radon atom.

(1)

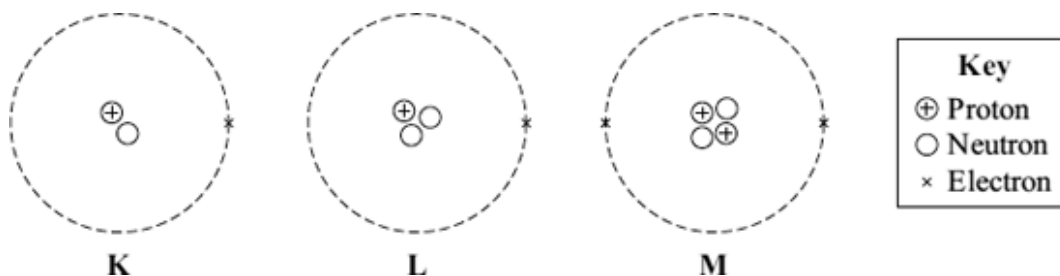
(ii) Give a reason for your answer to part (c)(i).

.....  
.....

(1)  
**(Total 7 marks)**

20

(a) The diagram represents 3 atoms, **K**, **L** and **M**.



(i) Which **two** of the atoms are isotopes of the same element?

..... and .....

(1)

(ii) Give a reason why the **two** atoms that you chose in part (a)(i) are:

(1) atoms of the same element .....

.....

(2) different isotopes of the same element. ....

.....

.....

(2)

(b) The table gives some information about the radioactive isotope thorium-230.

|               |     |
|---------------|-----|
| mass number   | 230 |
| atomic number | 90  |

(i) How many electrons are there in an atom of thorium-230?

.....

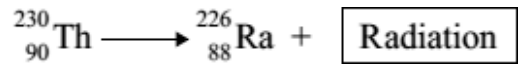
(1)

(ii) How many neutrons are there in an atom of thorium-230?

.....

(1)

- (c) When a thorium-230 nucleus decays, it emits radiation and changes into radium-226.



What type of radiation, alpha, beta or gamma, is emitted by thorium-230?

.....

Explain the reason for your answer.

.....  
.....  
.....  
.....  
.....

(3)  
(Total 8 marks)

21

Most elements have some *isotopes* which are *radioactive*.

- (a) What is meant by the terms:

(i) *isotopes*

.....  
.....

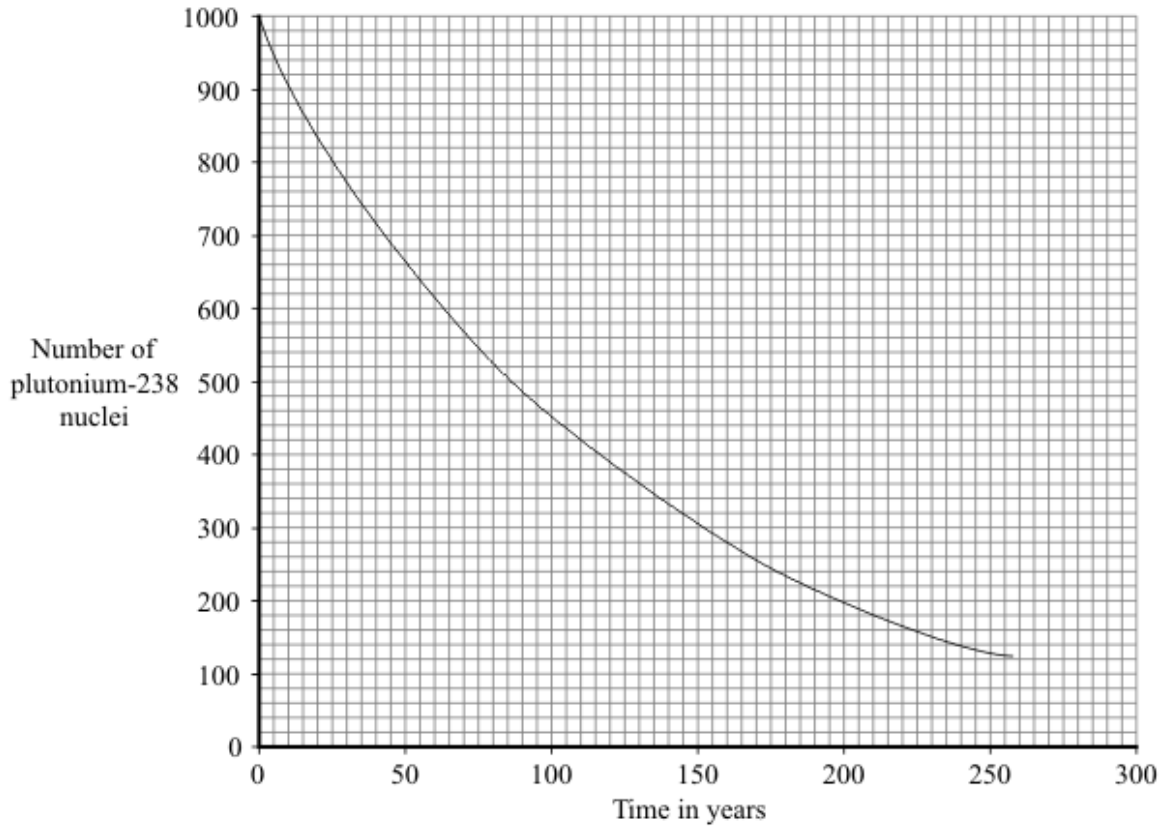
(1)

(ii) *radioactive?*

.....  
.....

(1)

- (b) The graph shows how the number of nuclei in a sample of the radioactive isotope plutonium-238 changes with time.



Use the graph to find the half-life of plutonium-238.

Show clearly on the graph how you obtain your answer.

Half-life = ..... years

(2)

- (c) The Cassini spacecraft launched in 1997 took seven years to reach Saturn.

The electricity to power the instruments on board the spacecraft is generated using the heat produced from the decay of plutonium-238.

- (i) Plutonium-238 decays by emitting alpha particles.

What is an alpha particle?

.....

(1)

- (ii) During the 11 years that Cassini will orbit Saturn, the output from the generators will decrease.

Explain why.

.....  
 .....  
 .....  
 .....

(2)

- (d) Plutonium-238 is highly dangerous. A tiny amount taken into the body is enough to kill a human.

- (i) Plutonium-238 is unlikely to cause any harm if it is outside the body but is likely to kill if it is inside the body.

Explain why.

.....  
 .....  
 .....  
 .....

(2)

- (ii) In 1964, a satellite powered by plutonium-238 was destroyed, causing the release of radioactive material into the atmosphere.

Suggest why some environmental groups protested about the launch of Cassini.

.....  
 .....

(1)

(Total 10 marks)

22

- (a) Complete the following table for an atom of uranium-238 ( ${}_{92}^{238}\text{U}$ )

|                    |     |
|--------------------|-----|
| mass number        | 238 |
| number of protons  | 92  |
| number of neutrons |     |

(1)

(b) Complete the following sentence.

The name given to the number of protons in an atom is the proton number or the

.....

(1)

(c) An atom of uranium-238 ( ${}_{92}^{238}\text{U}$ ) decays to form an atom of thorium-234 ( ${}_{90}^{234}\text{Th}$ ).

(i) What type of radiation, alpha, beta or gamma, is emitted by uranium-238?

.....

(1)

(ii) Why does an atom that decays by emitting alpha or beta radiation become an atom of a different element?

.....

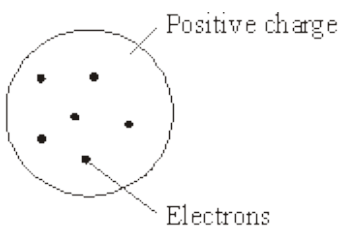
.....

(1)

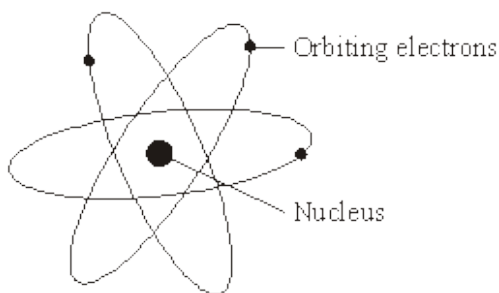
(Total 4 marks)

23

In the early part of the 20th century, scientists used the 'plum pudding' model to explain the structure of the atom.



Following work by Rutherford and Marsden, a new model of the atom, called the 'nuclear' model, was suggested.



(a) Describe the differences between the two models of the atom.

.....

.....

.....

.....

.....

.....

.....

.....

(4)

(b) In their investigation, Rutherford and Marsden fired positively charged alpha particles at a very thin sheet of gold. Over a period of several months, the scientists made over 100 000 measurements. These measurements showed that:

- a very small number of alpha particles were deflected backwards from the gold foil.

Use the nuclear model to explain this experimental result.

.....

.....

.....

.....

(2)

(c) Why did the work of Rutherford and Marsden convince many scientists that the 'plum pudding' model of the atom was incorrect?

.....

.....

.....

.....

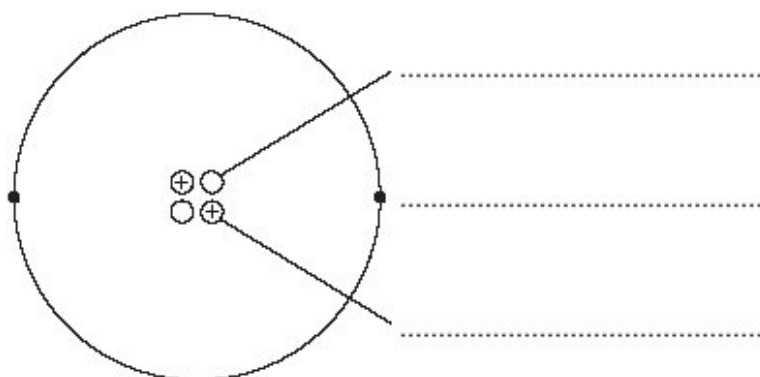
(2)

(Total 8 marks)



24

The diagram shows a helium atom.



(a) (i) Use the words in the box to label the diagram.

|          |         |        |
|----------|---------|--------|
| electron | neutron | proton |
|----------|---------|--------|

(2)

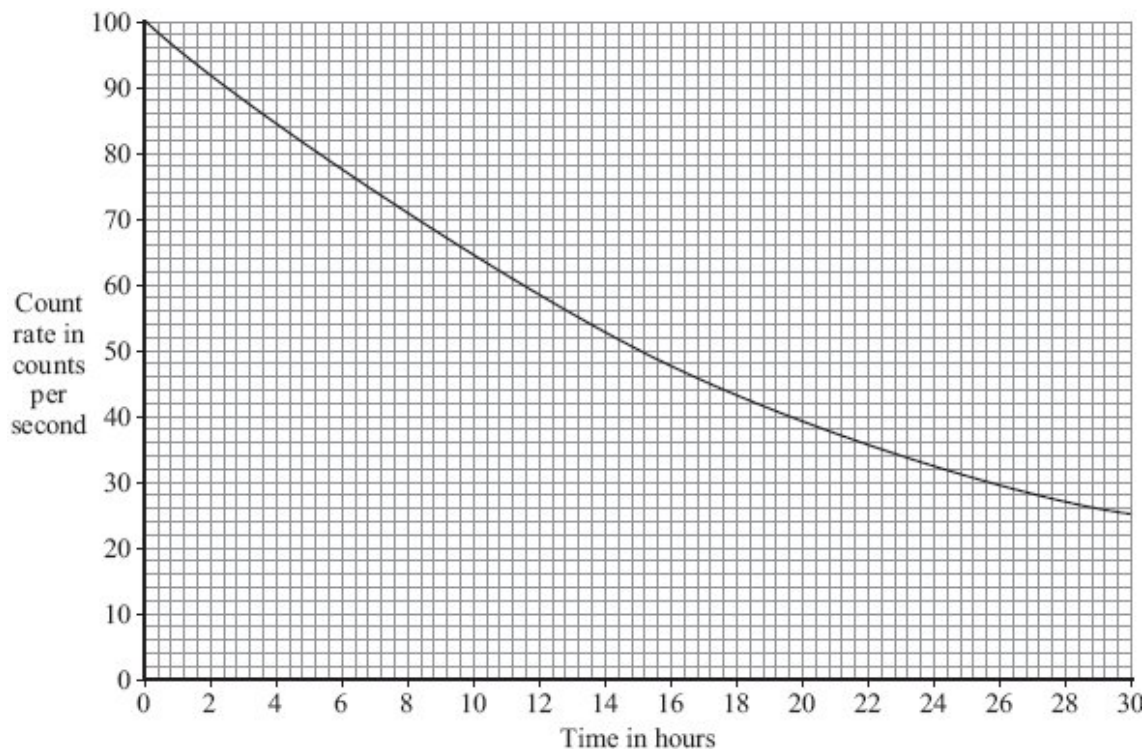
(ii) An alpha particle is the same as the nucleus of a helium atom.

How is an alpha particle different from a helium atom?

.....  
.....

(1)

(b) The graph shows how the count rate from a sample of radioactive sodium-24 changes with time.



- (i) How many hours does it take for the count rate to fall from 100 counts per second to 50 counts per second?

Time = ..... hours

(1)

- (ii) What is the half-life of sodium-24?

Half-life = ..... hours

(1)

- (c) A smoke detector contains a small amount of americium-241.

Americium-241 is a radioactive substance which emits alpha particles. It has a half-life of 432 years.

- (i) Which **one** of the following statements gives a reason why the americium-241 inside the smoke detector will **not** need replacing?

Put a tick (✓) in the box next to your answer.

The alpha particles have a low energy.

People replace smoke detectors every few years.

Americium-241 has a long half-life.

(1)

- (ii) The diagram shows the label on the back of the smoke detector.



Why do people need to know that the smoke detector contains a radioactive material?

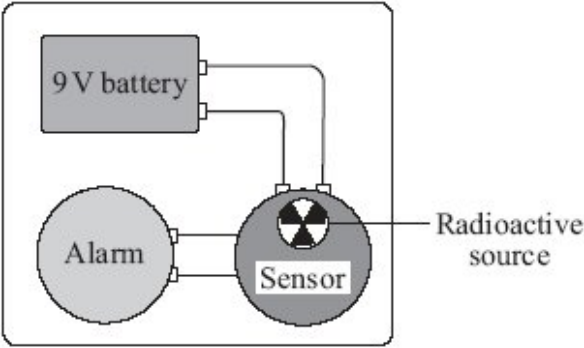
.....

.....

(1)  
(Total 7 marks)

25

(a) The diagram shows the parts of a smoke detector. The radioactive source emits alpha particles.



The alpha particles ionise the air inside the sensor which causes a small electric current. Any smoke getting into the sensor changes the current. The change in current sets the alarm off.

(i) The smoke detector would **not** work if a radioactive source that emitted only gamma rays was used.

Why not?

.....  
.....

(1)

(ii) Curium-242 is a radioactive isotope with a half-life of 160 days. It emits alpha particles.

Why is curium-242 **not** suitable for use inside smoke detectors?

.....  
.....

(1)

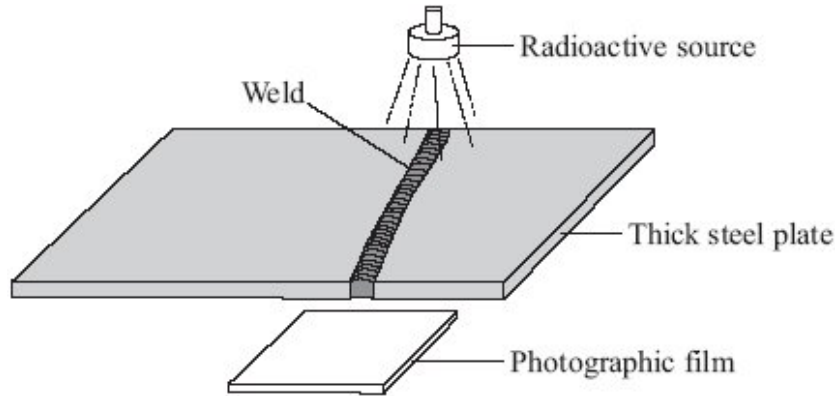
(iii) Curium-242 and curium-244 are two of the isotopes of the element curium.

How is an atom of curium-242 different from an atom of curium-244?

.....  
.....

(1)

- (b) Sections of steel are often joined by welding them together. The diagram shows how a radioactive source can be used to check for tiny cracks in the weld.



Cracks in the weld will be shown up on the photographic film below the thick steel plate.

- (i) Which type of source, alpha, beta or gamma, should be used to check the weld?

.....

(1)

- (ii) Give a reason why the other two types of source **cannot** be used.

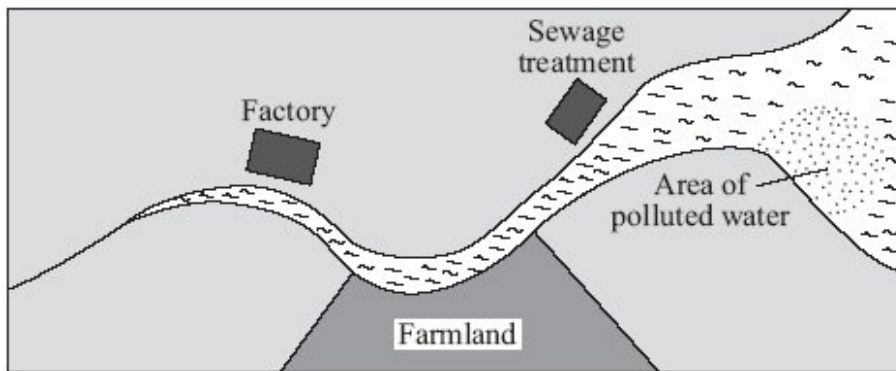
.....

.....

(1)

- (c) The diagram shows a map of a river and its estuary.

Environmental scientists have found that the water flowing into one part of the river estuary is polluted. To find where the pollution is coming from, the scientists use a radioactive isotope, gold-198.

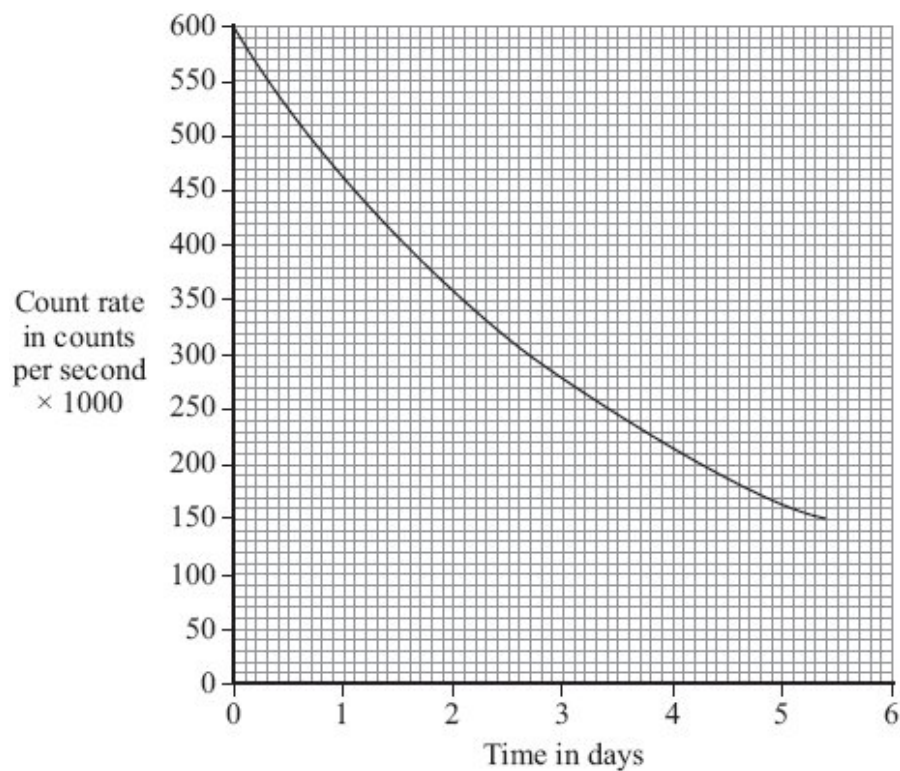


(i) Explain how the gold-198 is used to find where the pollution is coming from.

.....  
.....  
.....  
.....

(2)

(ii) The graph shows how the count rate from a sample of gold-198 changes with time.



Use the graph to calculate the half-life of gold-198.

Show clearly on the graph how you obtain your answer.

.....  
.....

Half-life = ..... days

(2)  
(Total 9 marks)

26

The table gives information about the three types of particle that make up an atom.

| Particle | Relative mass | Relative charge |
|----------|---------------|-----------------|
| Proton   |               | +1              |
| Neutron  | 1             |                 |
| Electron | very small    | -1              |

(a) Complete the table by adding the **two** missing values. (2)

(b) Use the information in the table to explain why an atom has no overall electrical charge.

.....  
.....  
.....  
.....

(2)

(c) Uranium has two natural isotopes, uranium-235 and uranium-238.  
Uranium-235 is used as a fuel inside a nuclear reactor.  
Inside the reactor, atoms of uranium-235 are split and energy is released.

(i) How is the structure of an atom of uranium-235 different from the structure of an atom of uranium-238?

.....  
.....

(1)

(ii) The nucleus of a uranium-235 atom must absorb a particle before the atom is able to split.

What type of particle is absorbed?

.....

(1)

(iii) The nucleus of an atom splits into smaller parts in a reactor.

What name is given to this process?

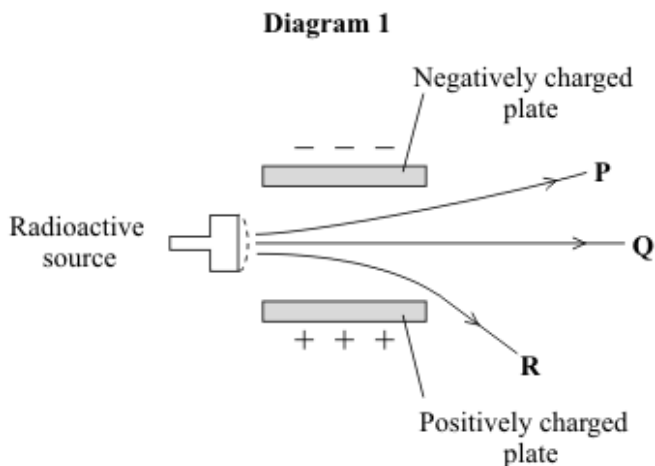
.....

(1)

**(Total 7 marks)**

27

A radioactive source emits alpha ( $\alpha$ ), beta ( $\beta$ ) and gamma ( $\gamma$ ) radiation. The diagram shows what happens to the radiation as it passes between two charged metal plates.



(a) Which line **P**, **Q** or **R** shows the path taken by:

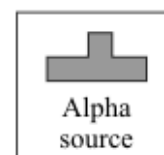
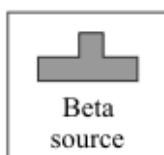
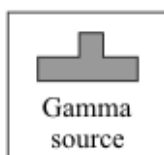
(i) alpha radiation .....

(1)

(ii) gamma radiation? .....

(1)

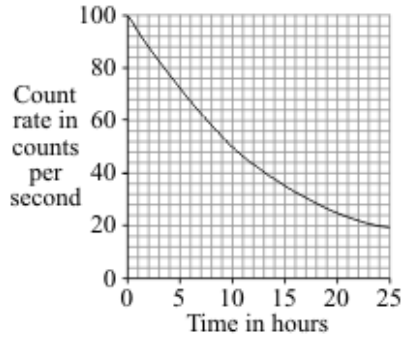
(b) The diagram shows three different boxes and three radioactive sources. Each source emits only one type of radiation and is stored in a different box. The box reduces the amount of radiation getting into the air.



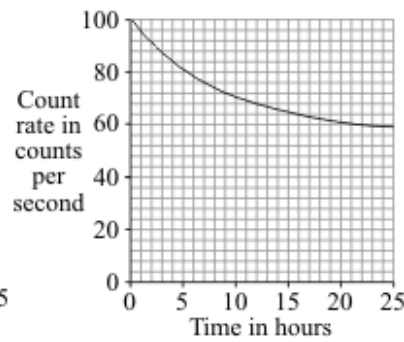
Draw **three** lines to show which source should be stored in which box so that the minimum amount of radiation gets into the air.

(2)

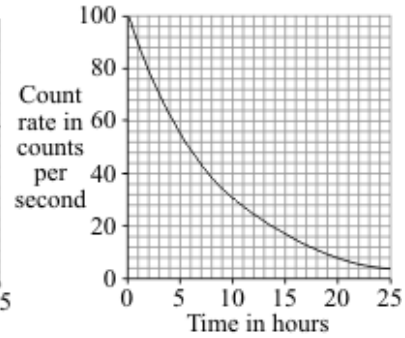
- (c) The graphs show how the count rates from three different radioactive sources, **J**, **K**, and **L**, change with time.



**J**



**K**



**L**

- (i) Which source, **J**, **K**, or **L**, has the highest count rate after 24 hours?

.....

(1)

- (ii) For source **L**, what is the count rate after 5 hours?

..... counts per second

(1)

- (iii) Which source, **J**, **K**, or **L**, has the longest half-life?

.....

(1)

- (iv) A radioactive source has a half-life of 6 hours.

What might this source be used for?

Put a tick (✓) in the box next to your choice.

To monitor the thickness of paper as it is made in a factory

To inject into a person as a medical tracer

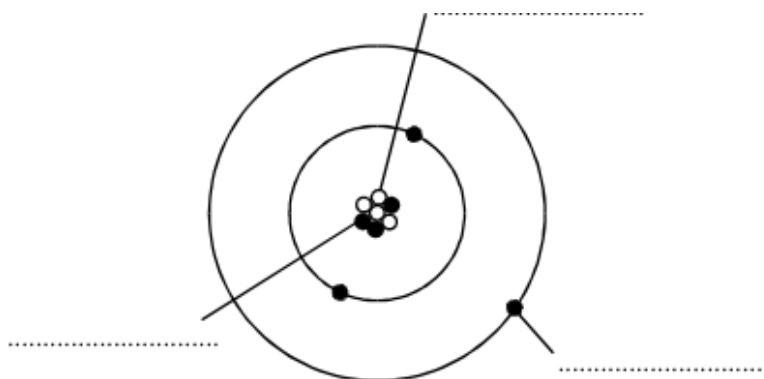
To make a smoke alarm work

(1)  
(Total 8 marks)



28

The diagram represents an atom of lithium.



- (i) Complete the diagram by writing in the spaces the name of each type of particle. Use only words given in the box. Each word may be used once or not at all.

|          |         |         |        |
|----------|---------|---------|--------|
| electron | neutron | nucleus | proton |
|----------|---------|---------|--------|

(3)

- (ii) Which type of particle found inside the atom is uncharged?

.....

(1)

- (iii) What is the mass number of this atom, 3, 4, 7 or 10?

.....

Give a reason for your choice.

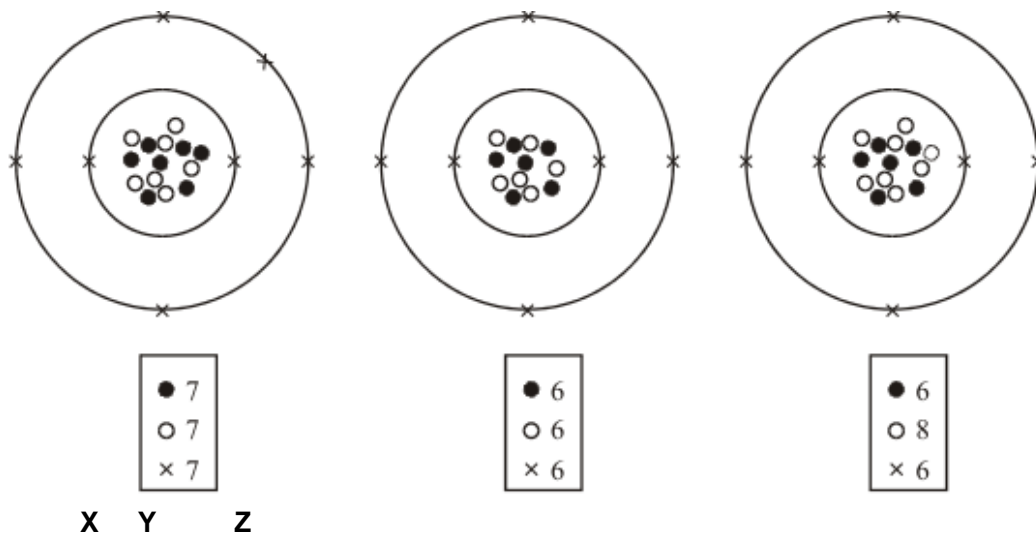
.....

.....

(2)  
(Total 6 marks)

29

(a) The diagrams represent three atoms X, Y and Z.



Which **two** of the atoms are from the same element?

.....

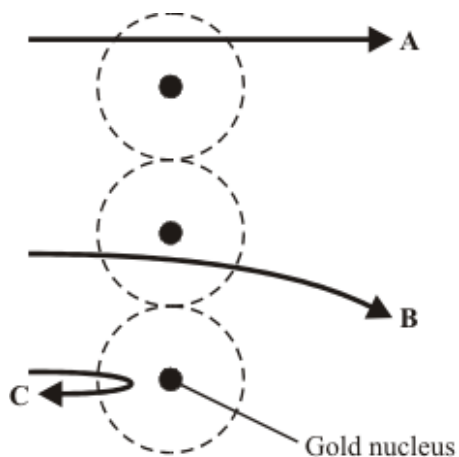
Give a reason for your answer.

.....

.....

(2)

(b) In the early part of the 20<sup>th</sup> century some scientists investigated the paths taken by positively charged alpha particles into and out of a very thin piece of gold foil. The diagram shows the paths of three alpha particles.



Explain the different paths **A**, **B** and **C** of the alpha particles.

To gain full marks in this question you should write your ideas in good English. Put them into a sensible order and use the correct scientific words.

.....

.....

.....

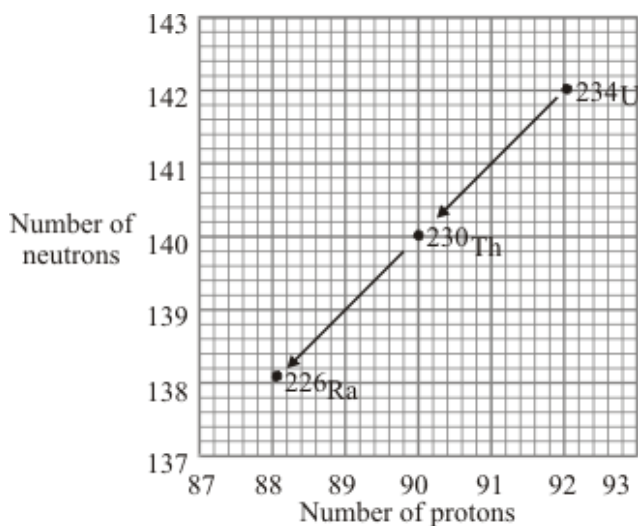
.....

.....

(3)  
(Total 5 marks)

30

- (a) Uranium-234 ( $^{234}\text{U}$ ) is a radioactive element. The graph shows the number of protons and neutrons in the nuclei of the elements formed when uranium-234 decays.



- (i) How does the graph show that uranium-234 ( $^{234}\text{U}$ ) and thorium-230 ( $^{230}\text{Th}$ ) emit alpha particles?

.....

(1)

- (ii) What makes uranium and thorium different elements?

.....

(1)

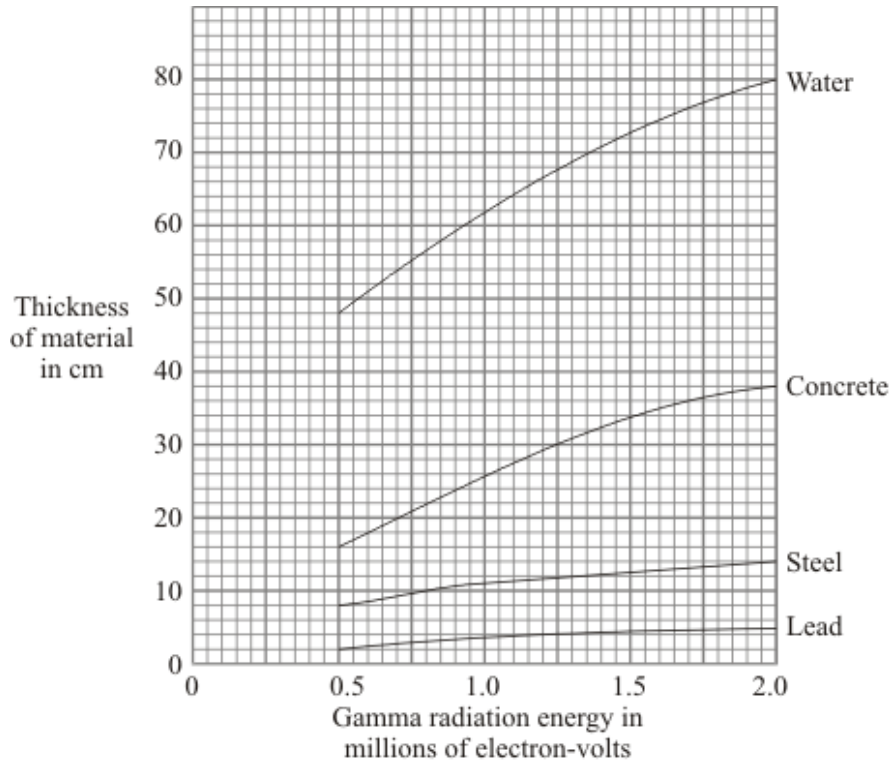
(iii) Radioactive decay may also produce gamma radiation.

Why does the emission of gamma radiation **not** cause a new element to be formed?

.....  
.....

(1)

(b) The graph shows how the thickness of different materials needed to absorb 90% of the gamma radiation emitted by a source depends on the energy of the radiation. The energy of the gamma radiation is given in units called electron-volts.



(i) Which of the materials shown is least effective at absorbing gamma radiation? Use the information in the graph to give a reason for your answer.

.....  
.....

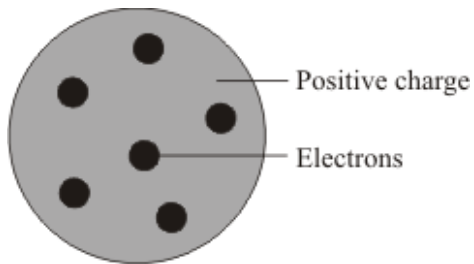
(1)

(ii) For gamma radiation of energy 1.5 million electron-volts, how many times more effective is steel than water at absorbing the radiation? Show clearly how you obtain your answer.

.....  
.....  
.....

(2)

- (c) Scientists in the early twentieth century thought that atoms were made up of electrons scattered inside a ball of positive charge. This was called the 'plum-pudding' model of the atom.



### Plum pudding model

Rutherford and Marsden did an experiment, in which a beam of alpha particles was aimed at a thin sheet of gold.

Explain how the results of this experiment led to a new model of the atom.

You may include one or more diagrams in your answer.

.....

.....

.....

.....

.....

.....

(3)  
(Total 9 marks)

31

(a) The table gives information about five radioactive isotopes.

| Isotope         | Type of radiation emitted | Half-life |
|-----------------|---------------------------|-----------|
| Californium-241 | alpha ( $\alpha$ )        | 4 minutes |
| Cobalt-60       | gamma ( $\gamma$ )        | 5 years   |
| Hydrogen-3      | beta ( $\beta$ )          | 12 years  |
| Strontium-90    | beta ( $\beta$ )          | 28 years  |
| Technetium-99   | gamma ( $\gamma$ )        | 6 hours   |

(i) What is an alpha ( $\alpha$ ) particle?

.....  
.....

(1)

(ii) What is meant by the term half-life?

.....  
.....

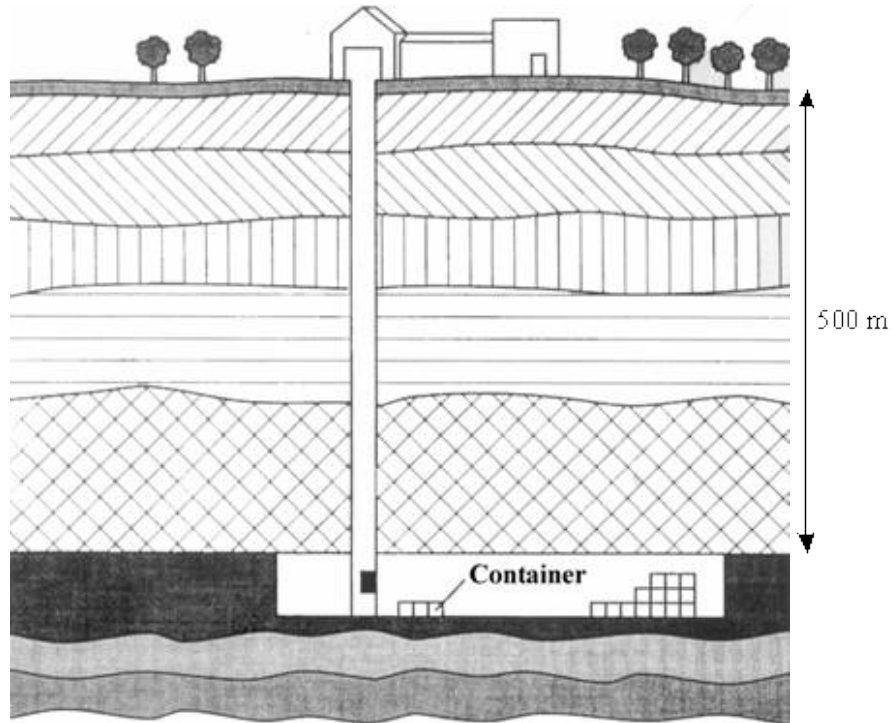
(1)

(iii) Which **one** of the isotopes could be used as a tracer in medicine? Explain the reason for your choice.

.....  
.....  
.....  
.....

(3)

- (b) The increased use of radioactive isotopes is leading to an increase in the amount of radioactive waste. One method for storing the waste is to seal it in containers which are then placed deep underground.



Some people may be worried about having such a storage site close to the area in which they live. Explain why.

.....

.....

.....

.....

.....

.....

.....

(3)  
(Total 8 marks)

32

Radon is a radioactive gas. Radon makes a major contribution to background radiation levels. Radon atoms decay by the emission of *alpha particles*.

- (a) (i) What is an *alpha particle*?

.....

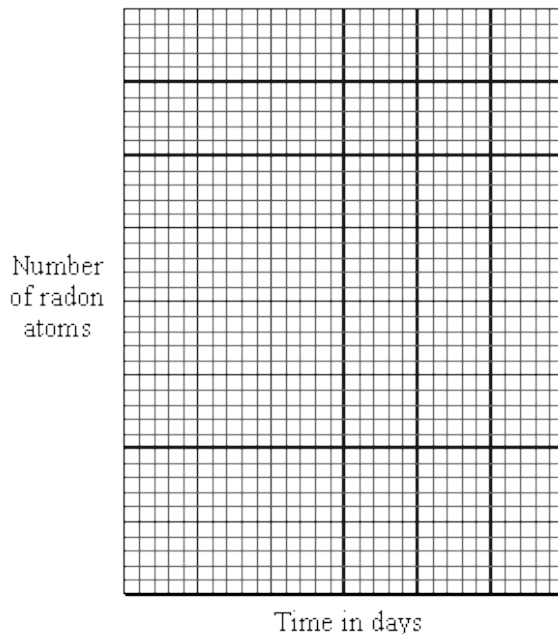
(1)

(ii) From which part of the radon atom does the alpha particle come?

.....

(1)

(b) (i) A sample of air contains 40 000 radon atoms. The half-life of radon is four days. Draw a graph to show how the number of radon atoms present in a sample of air will change over a period of 12 days.



(3)

(ii) After 20 days, how many of the radon atoms from the original sample of air will have decayed? Show clearly how you work out your answer.

.....  
.....  
.....

Number of radon atoms decayed = .....

(3)

(c) Fairly constant concentrations of radon gas have been found in some deep mine shafts.

(i) Suggest why the concentration of radon gas remains fairly constant although the radon gas decays.

.....  
.....

(1)



- (ii) Explain why the long term exposure to large concentrations of radon gas could be a danger to health.

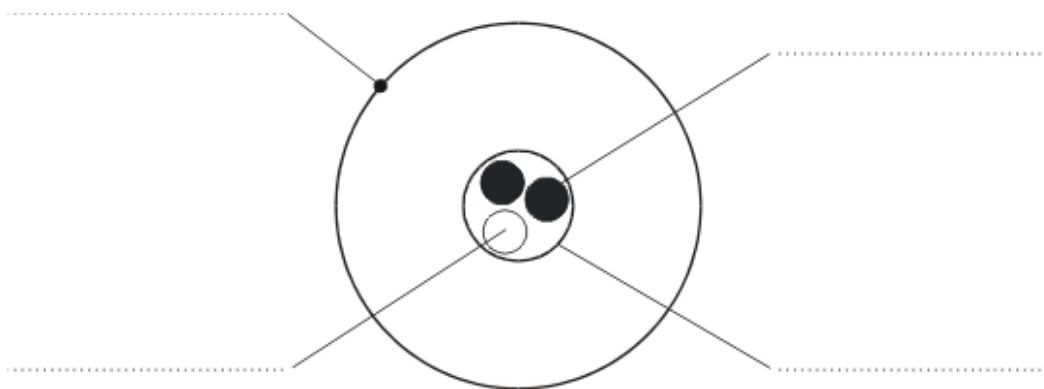
.....  
 .....  
 .....  
 .....

(2)  
 (Total 11 marks)

**33**

- (a) Tritium ( ${}^3_1\text{H}$ ) is an isotope of hydrogen. Tritium has a proton number of 1 and a mass number of 3.

- (i) The diagram below shows a simple model of a tritium atom. Complete the diagram by adding the names of the particles indicated by the labels.



(4)

- (ii) Explain how the nucleus of an ordinary hydrogen atom is different from the nucleus of a tritium atom. Ordinary hydrogen atoms ( ${}^1_1\text{H}$ ) have a mass number of 1.

.....  
 .....  
 .....

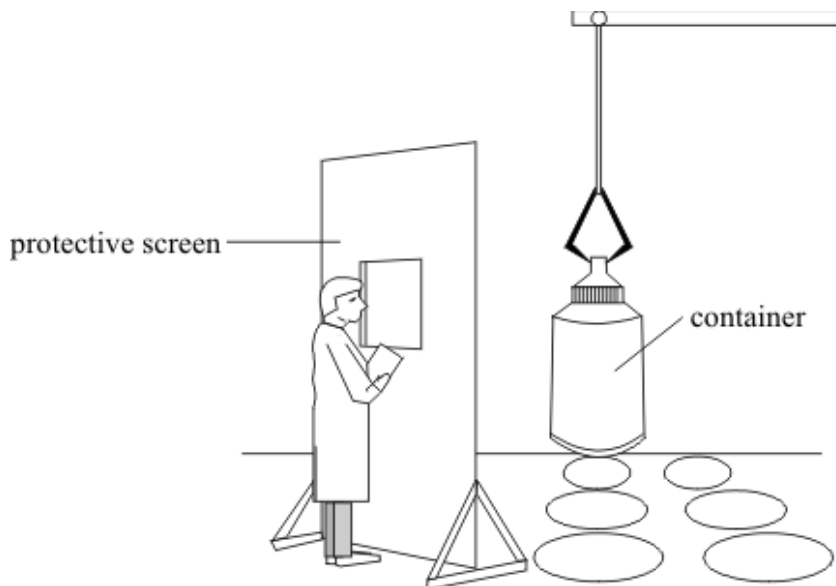
(2)

- (iii) Tritium is a radioactive substance which emits beta ( $\beta$ ) radiation. Why do the atoms of some substances give out radiation?

.....  
 .....

(2)

- (b) Tritium is one of the elements found in the waste material of the nuclear power industry. The diagram below shows a worker behind a protective screen. The container holds a mixture of different waste materials which emit alpha ( $\alpha$ ), beta ( $\beta$ ) and gamma ( $\gamma$ ) radiation.



Suggest a suitable material for the protective screen. The material should prevent radiation from the container reaching the worker. Explain your answer.

.....

.....

.....

(2)  
(Total 10 marks)

34

- (a) Complete the table about atomic particles.

| ATOMIC PARTICLE | RELATIVE MASS | RELATIVE CHARGE |
|-----------------|---------------|-----------------|
| proton          |               | +1              |
| neutron         | 1             | 0               |
| electron        | negligible    |                 |

(2)

- (b) Use the Data Sheet to help you to answer some parts of this question.

Read the following passage about potassium.

Potassium is a metallic element in Group 1 of the Periodic Table.  
It has a proton (atomic) number of 19.

Its most common isotope is potassium-39, ( ${}_{19}^{39}\text{K}$ ).

Another isotope, potassium-40, ( ${}_{19}^{40}\text{K}$ ), is a radioisotope.

- (i) State the number of protons, neutrons and electrons in potassium-39.

Number of protons .....

Number of neutrons .....

Number of electrons .....

(2)

- (ii) Explain why potassium-40 has a different mass number from potassium-39.

.....

(1)

- (iii) What is meant by a *radioisotope*?

.....

.....

(1)

- (iv) Atoms of potassium-40 change into atoms of a different element. This element has a proton (atomic) number of 20 and a mass number of 40.

Name, or give the symbol of, this new element.

.....

(1)

- (v) Explain in terms of atomic structure, why potassium-39 and potassium-40 have the same chemical reactions.

.....

(1)

- (c) (i) Name a suitable detector that could be used to show that potassium-40 gives out radiation.

.....

(1)

- (ii) Name a disease which can be caused by too much exposure to a radioactive substance such as potassium-40.

.....

(1)  
(Total 10 marks)

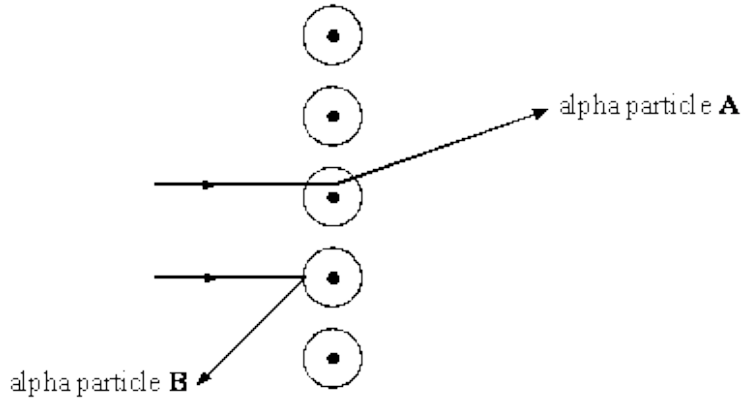
35

- (a) Atoms are made up of three types of particle called protons, neutrons and electrons. Complete the table below to show the relative mass and charge of a neutron and an electron. The relative mass and charge of a proton has already been done for you.

| PARTICLE | RELATIVE MASS | RELATIVE CHARGE |
|----------|---------------|-----------------|
| proton   | 1             | +1              |
| neutron  |               |                 |
| electron |               |                 |

(2)

- (b) The diagram below shows the paths of two alpha particles **A** and **B**, into and out of a thin piece of metal foil.



The paths of the alpha particles depend on the forces on them in the metal. Describe the model of the atom which is used to explain the paths of alpha particles aimed at thin sheets of metal foil.

.....

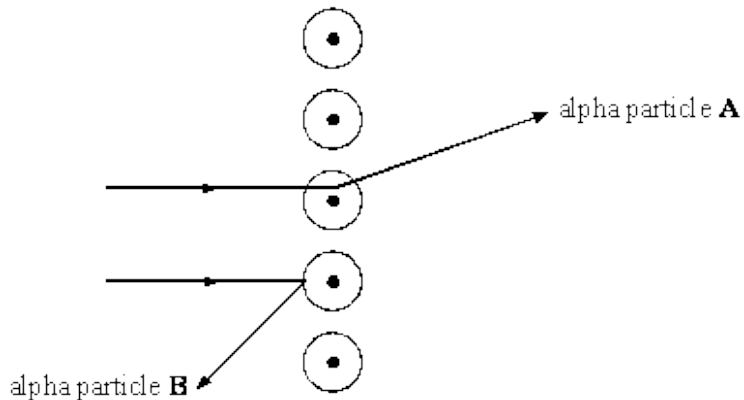
.....

.....

(3)  
(Total 5 marks)

**36**

The diagram below shows the paths of two alpha particles **A** and **B** into and out of a thin piece of metal foil.



- (a) The paths of the alpha particles depend on the forces on them in the metal.  
Describe the model of the atom which is used to explain the paths of alpha particles aimed at thin sheets of metal foil.

.....

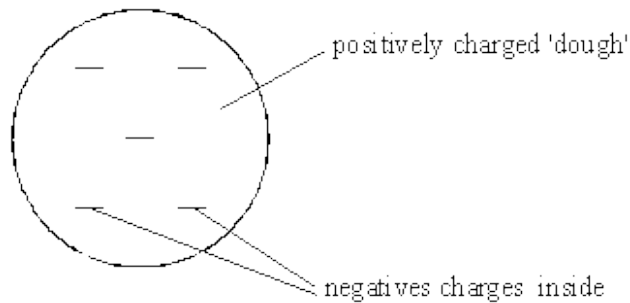
.....

.....

.....

(3)

- (b) Scientists used to believe that atoms were made up of negative charges embedded in a positive 'dough'. This is called the 'plum pudding' model of the atom.  
The diagram below shows a model of such an atom.



- (i) Explain how the 'plum pudding' model of the atom can explain why alpha particle **A** is deflected through a very small angle.

.....

.....

.....

.....

.....

(2)

- (ii) Explain why the 'plum pudding' model of the atom can not explain the large deflection of alpha particle **B**.

.....

.....

.....

.....

.....

.....

(3)

- (c) We now believe that atoms are made up of three types of particles called protons, neutrons and electrons.

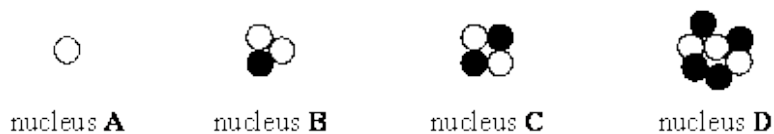
Complete the table below to show the relative mass and charge of a neutron and an electron. The relative mass and charge of a proton have already been done for you.

| PARTICLE | RELATIVE MASS | RELATIVE CHARGE |
|----------|---------------|-----------------|
| proton   | 1             | +1              |
| neutron  |               |                 |
| electron |               |                 |

(2)

- (d) The diagrams below show the nuclei of four different atoms **A**, **B**, **C** and **D**.

Key: ○ – proton    ● – neutron



- (i) State the mass number of C.

.....

- (ii) Which two are isotopes of the same element?

..... and .....

Explain your answer.

.....  
 .....  
 .....  
 .....

(4)  
 (Total 14 marks)

37

Use the Data Sheet to help you answer this question. This question is about elements and atoms.

- (a) About how many different elements are found on Earth? Draw a **ring** around the correct number.

40      50      60      70      80      90

(1)

- (b) The following are parts of an atom:

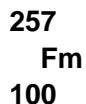
**electron      neutron      nucleus      proton**

Choose from the list the one which:

- (i) has no electrical charge; .....
- (ii) contains two of the other particles; .....
- (iii) has very little (negligible) mass. ....

(3)

- (c) Scientists have been able to make new elements in nuclear reactors. One of these new elements is fermium. An atom of fermium is represented by the symbol below.

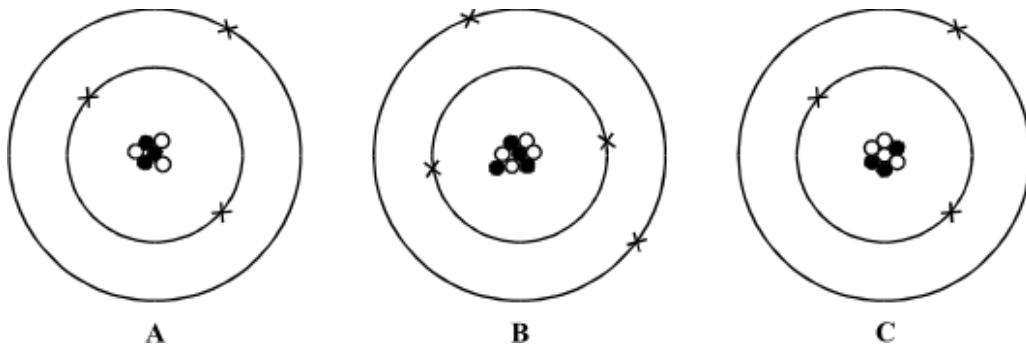


- (i) How many protons does this atom contain? .....
- (ii) How many neutrons does this atom contain? .....

(2)  
(Total 6 marks)

38

The diagrams below represent three atoms, **A**, **B** and **C**.





(a) Two of the atoms are from the **same** element.

(i) Which of **A**, **B** and **C** is an atom of a different element? .....

(ii) Give **one** reason for your answer.

.....  
.....  
.....

(2)

(b) Two of these atoms are isotopes of the same element.

(i) Which **two** are isotopes of the same element? ..... and .....

(ii) Explain your answer.

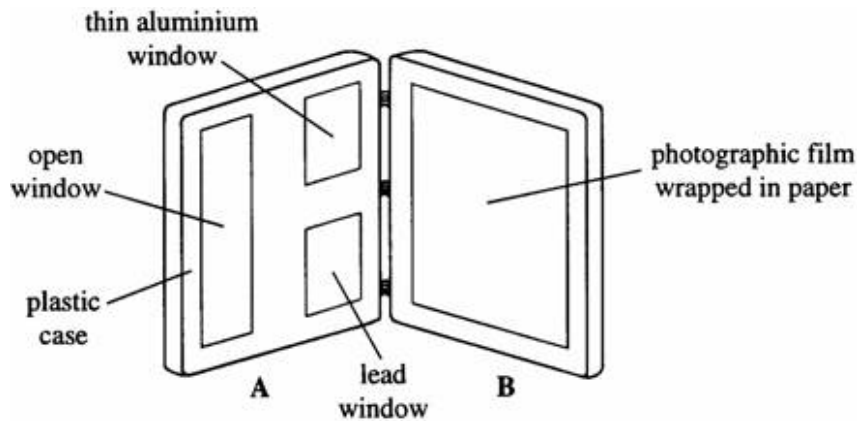
.....  
.....  
.....

(3)

(Total 5 marks)

39

The diagram shows a film badge worn by people who work with radioactive materials. The badge has been opened. The badge is used to measure the amount of radiation to which the workers have been exposed.



(a) The detector is a piece of photographic film wrapped in paper inside part **B** of the badge. Part **A** has “windows” as shown.

Complete the sentences below.

When the badge is closed

(i) ..... radiation and ..... radiation can pass through the open window and affect the film.

(1)

(ii) Most of the ..... radiation will pass through the lead window and affect the film.

(1)

(b) Other detectors of radiation use a gas which is ionised by the radiation.

(i) Explain what is meant by *ionised*.

.....  
.....

(1)

(ii) Write down **one** use of ionising radiation.

.....

(1)

(c) Uranium-238 has a very long half-life. It decays via a series of short-lived radioisotopes to produce the stable isotope lead-204.

Explain, in detail, what is meant by:

(i) *half-life*,

.....  
.....

(1)

(ii) *radioisotopes*.

.....  
.....  
.....  
.....

(2)

(d) The relative proportions of uranium-238 and lead-204 in a sample of igneous rock can be used to date the rock.

A rock sample contains three times as many lead atoms as uranium atoms.

(i) What fraction of the original uranium is left in the rock?

(Assume that there was no lead in the original rock.)

.....  
 .....

(1)

(ii) The half-life of uranium-238 is 4500 million years.

Calculate the age of the rock.

.....  
 .....

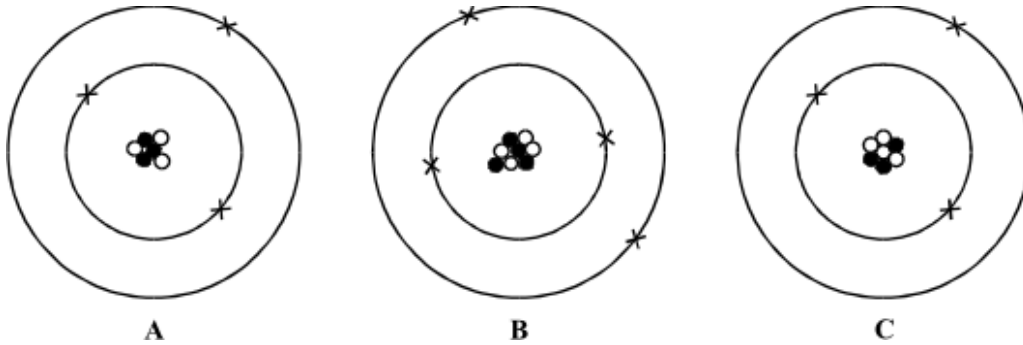
Age ..... million years

(2)

(Total 10 marks)

40

The diagrams below represent three atoms, **A**, **B** and **C**.



(a) Two of these atoms are from the **same** element.

(i) Which of **A**, **B** and **C** is an atom of a different element? .....

(ii) Give **one** reason for your answer.

.....  
 .....

(2)

- (b) Two of these atoms are isotopes of the same element.
- (i) Which **two** are isotopes of the same element? ..... and .....
- (ii) Explain your answer.

.....

.....

.....

(3)

- (c) Which of the particles  $\ominus$ ,  $\bullet$  and **X**, shown in the diagrams:

- (i) has a positive charge; .....
- (ii) has no charge; .....
- (iii) has the smallest mass? .....

(3)

- (d) Using the same symbols as those in the atom diagrams, draw an alpha particle.

(1)

(Total 9 marks)

41

In some areas of the U.K. people are worried because their houses are built on rocks that release radon.

Read the information about radon.

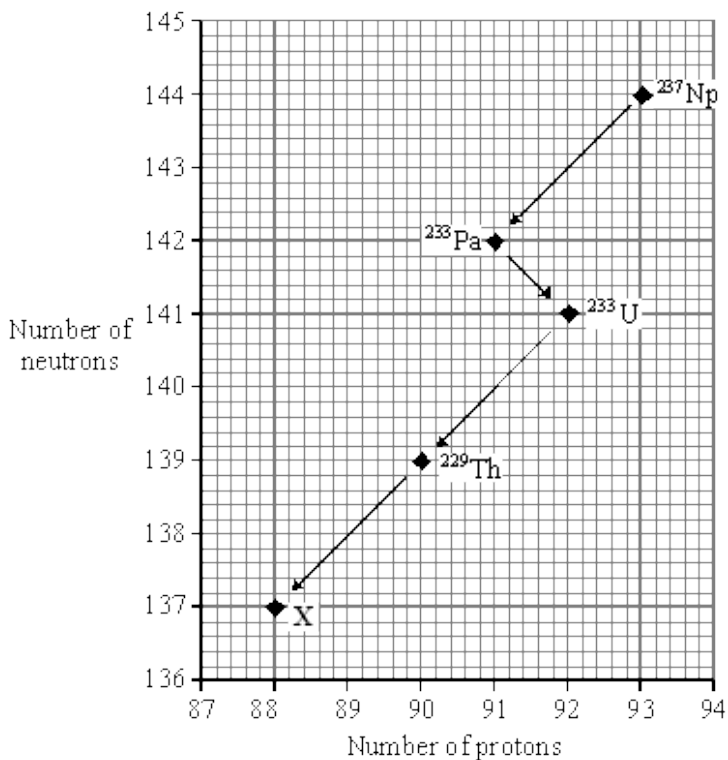
- It is a gas.
- It is formed by the breakdown of radium.
- It emits alpha radiation.
- Each radon atom has 86 protons.
- Each radon atom has 136 neutrons.

- (i) How many electrons has each atom of radon? .....
- (ii) What is the mass (nucleon) number of radon? .....

(Total 2 marks)

42

Neptunium-237 ( $^{237}\text{Np}$ ) is a radioactive element. The graph shows the numbers of neutrons and protons in the nuclei of the elements formed when  $^{237}\text{Np}$  decays.



- (a) Use the periodic table on the Data Sheet to identify element X.

.....

(1)

- (b) Why are  $^{233}\text{Pa}$  and  $^{233}\text{U}$  considered to be different elements?

.....  
 .....

(1)

- (c) What type of radiation is released when  $^{237}\text{Np}$  decays to form  $^{233}\text{Pa}$ ?

.....

(1)

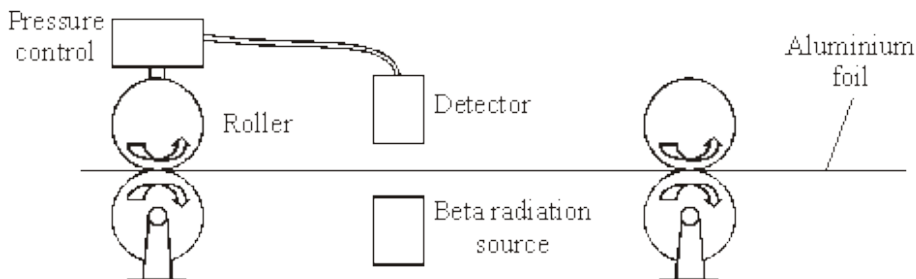
(d) What change takes place in the nucleus when  $^{233}\text{Pa}$  changes into  $^{233}\text{U}$ ?

.....

(1)  
(Total 4 marks)

43

The diagram shows how the thickness of aluminium foil is controlled. The thicker the aluminium foil, the more radiation it absorbs.



(a) The designers used a beta radiation source for this control system.

(i) Why would an alpha radiation source be unsuitable in this control system?

.....  
.....

(1)

(ii) Why would a gamma radiation source be unsuitable in this control system?

.....  
.....

(1)

(b) The substance used in the beta radiation source is radioactive.

(i) Why are some atoms radioactive?

.....  
.....

(1)

(ii) Explain why radiation is dangerous to humans.

.....  
.....  
.....  
.....

(2)  
(Total 5 marks)

44

(a) Complete the sentences about atoms.

In an atom, the number of electrons is equal to the number of .....

All atoms of an element have the same number of .....

Isotopes of the same element have different numbers of .....

(3)

(b) Complete the sentence.

When an atom of a radioactive element emits alpha radiation, an atom of a different element is formed. A different element is formed because the radioactive element has lost

.....

(1)  
(Total 4 marks)

45

${}_{43}^{99}\text{Tc}$  (technetium) is produced by the radioactive decay of  ${}_{42}^{99}\text{Mo}$  (molybdenum).

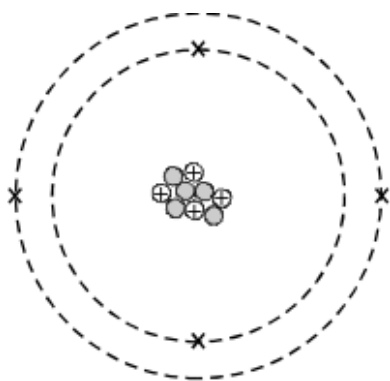
What change occurs in the nucleus of a molybdenum atom when this happens?

.....  
.....

(Total 1 mark)

46

The diagram shows an atom.



How many protons are there in the nucleus of the atom? .....

What is the mass number of the atom? .....

**(Total 2 marks)**



## Mark schemes

1

### Level 3 (5–6 marks):

A detailed and coherent explanation is provided. The student gives examples that argue a strong case and demonstrate deep knowledge. The student makes logical links between clearly identified, relevant points.

### Level 2 (3–4 marks):

An attempt to link the description of the experiment and the results with differences between the two models. The student gives examples of where the plum pudding model does not explain observations. The logic used may not be clear.

### Level 1 (1–2 marks):

Simple statements are made that the nuclear model is a better model. The response may fail to make logical links between the points raised.

### 0 marks:

No relevant content.

### Indicative content

- alpha particle scattering experiment
- alpha particles directed at gold foil
- most alpha particles pass straight through
- (so) most of atom is empty space
- a few alpha particles deflected through large angles
- (so) mass is concentrated at centre of atom
- (and) nucleus is (positively) charged
- plum pudding model has mass spread throughout atom
- plum pudding model has charge spread throughout atom

[6]

2

(a) cannot predict which dice / atom will 'decay'

*accept answers given in terms of 'roll a 6'*

1

cannot predict when a dice / atom will 'decay'

1

(b) 3.6 to 3.7 (rolls)

*allow 1 mark for attempt to read graph when number of dice = 50*

2

(c) 90

1

(d) uranium

1

(e) beta

1

proton number has gone up (as neutron decays to proton and  $e^-$ )

1

(f) prevents contamination

**or**

prevents transfer of radioactive material to teacher's hands

1

which would cause damage / irradiation over a longer time period.

1

**[10]**

**3**

(a) neutrons and protons

1

(b) 0

1

(+)1

1

(c) (i) total positive charge = total negative charge

*accept protons and electrons have an equal opposite charge*

1

(because) no of protons = no of electrons

1

(ii) ion

1

positive

1

- (d) Marks awarded for this answer will be determined by the quality of communication as well as the standard of the scientific response. Examiners should apply a best-fit approach to the marking.

**0 marks**

No relevant content

**Level 1 (1 – 2 marks)**

There is a basic description of at least **one** of the particles in terms of its characteristics.

**Level 2 (3 – 4 marks)**

There is a clear description of the characteristics of **both** particles

**or**

a full description of either alpha **or** beta particles in terms of their characteristics.

**Level 3 (5 – 6 marks)**

There is a clear and detailed description of **both** alpha and beta particles in terms of their characteristics.

**examples of the physics points made in the response:**

**structure**

- alpha particle consists of a helium nucleus
- alpha particle consists of 2 protons and 2 neutrons
- a beta particle is an electron
- a beta particle comes from the nucleus

**penetration**

- alpha particles are very poorly penetrating
- alpha particles can penetrate a few cm in air
- alpha particles are absorbed by skin
- alpha particles are absorbed by thin paper
- beta particles can penetrate several metres of air
- beta particles can pass through thin metal plate / foil
- beta particles can travel further than alpha particles in air
- beta particles can travel further than alpha particles in materials eg metals

**deflection**

- alpha particles and beta particles are deflected in opposite directions in an electric field
  - beta particles are deflected more than alpha particles
  - alpha particles have a greater charge than beta particles but beta particles have much less mass
- or**
- beta particles have a greater specific charge than alpha particles

|          |   |            |
|----------|---|------------|
| <b>4</b> | (a) (i) neutron   | 1          |
|          | (ii) neutron<br>proton<br><i>both required, either order</i>  | 1          |
|          | (iii) 2   | 1          |
|          | number of <u>protons</u><br><i>do not accept number of electrons</i>  | 1          |
|          | (b) (i) any <b>one</b> from:  |            |
|          | • beta  |            |
|          | • gamma<br><i>accept correct symbols</i><br><i>accept positron / neutrino / neutron</i><br><i>cosmic rays is insufficient</i> | 1          |
|          | (ii) electrons  | 1          |
|          | (iii) are highly ionising   | 1          |
|          | (c) (i) mutate / destroy / kill / damage / change / ionise<br><i>Harm is insufficient</i>                                     | 1          |
|          | (ii) much smaller than  | 1          |
|          |   | <b>[9]</b> |
| <b>5</b> | (a) neutron discovered  | 1          |
|          | (b) neutron<br><i>all 3 in correct order</i><br><br>electron<br><i>allow 1 mark for 1 correct</i><br><br>proton               | 2          |
|          |   | <b>[3]</b> |
| <b>6</b> | (a) protons, electrons<br><i>both required, either order</i>  | 1          |

neutrons 1

electron, nucleus  
*both required, this order* 1

(b) 2.7 (days)  
*allow 1 mark for showing correct use of the graph* 2

(c) put source into water at **one** point on bank  
*accept the idea of testing different parts of the river bank at different times* 1

see if radiation is detected in polluted area  
*accept idea of tracing*

**or**

put source into water at three points on bank (1)  
see if radiation is detected downstream of factory **or** farmland **or** sewage treatment works (1)

1 [7]

7

(a) proton  
*all 3 in correct order*

electron  
*allow 1 mark for 1 correct do **not***

neutron  
*accept letters p, e, n*

2

(b) 9  
*reason only scores if 9 is chosen*

1

number of neutrons and protons

1 [4]

8

any **two** pairs from:

*to gain credit it must be clear which model is being described  
do **not** accept simple descriptions of the diagram without  
comparison*

- nuclear model mass is concentrated at the centre / nucleus (1)  
*accept the nuclear model has a nucleus / the plum pudding model  
does not have a nucleus for 1 mark*

plum pudding model mass is evenly distributed (1)

- nuclear model positive charge occupies only a small part of the atom (1)

plum pudding model positive charge spread throughout the atom (1)

- nuclear model electrons orbit some distance from the centre (1)  
*accept electrons in shells / orbits provided a valid comparison is  
made with the plum pudding model*

plum pudding electrons embedded in the (mass) of positive (charge) (1)

*do **not** accept electrons at edge of plum pudding*

- nuclear model the atom mainly empty space (1)

plum pudding model is a 'solid' mass (1)

[4]

9

(a) **B E G**

*all 3 required and no other  
any order*

1

same number of / 88 protons (and different numbers of neutrons)

*same number of electrons is insufficient*

1

(b) (i) 222

1

86

1

(ii) 4800

*allow 1 mark for obtaining 3 half-lives*

2

(c) ethical

1

deceived / lied to (about safety of working conditions)  
*accept (women) not warned of the dangers*  
*given no protection is insufficient*

**or**

value own / scientists' lives more than women

**or**

did not treat women humanely

1

- (d) accept any sensible suggestion  
eg  
too many interests in continued use of radium

evidence may cause public unrest  
*do **not** accept not enough evidence*

doctors not want to be blamed for illnesses (caused by radium)  
*accept doctors not wanting to be sued (for harm caused by using radium)*

doctors thought (possible) benefits outweighed (possible) risks  
*do **not** accept did not know radium could be harmful*  
*believe radium could treat illnesses is insufficient*

1

[9]

10

- (a) has an equal amount of positive charge  
*accept pudding/it is positive*

1

- (b) (experimental) results could not be explained using 'plum pudding' model  
**or**  
(experimental) results did not support plum pudding model  
*accept (experimental) results disproved plum pudding model*

1

- (c) (i) **A** – most of atom is empty space **or** most of atom concentrated at the centre

1

**B** – nucleus is positive (so repels alpha particles)  
*accept nucleus has the same charge as alpha*

1

**C** – nucleus is very small  
*accept nucleus is positive if not scored for B*

**or**

nucleus is a concentrated mass  
*accept nucleus has a very concentrated charge*

1

- (ii) (if predictions correct, this) supports the new model  
*answers should be in terms of the nuclear model*  
*accept supports his/new/nuclear theory*  
*accept proves for supports*  
*accept shows predictions/ Rutherford was correct*

1

[6]

11

- (a) (i) half / 50 %  
 (ii) Measure the radon gas level in more homes in this area  
 (b) (i) 86  
 (ii) 222

1

1

1

1

[4]

12

- (a) (i) (total) number of protons plus neutrons  
*accept number of nucleons*  
*accept amount for number*  
*do not accept number of particles in the nucleus*  
 (ii) number of neutrons decreases by one  
 number of protons increases by one  
*accept for both marks a neutron changes into a proton*  
 (b) (i)  ${}_{81}^{208}\text{Th}$   
*correct order only*  
 (ii) the number of protons determines the element  
*accept atomic number for number of protons*

1

1

1

1

1

1



alpha and beta decay produce different changes to the number of protons  
*there must be a comparison between alpha and beta which is more than a description of alpha and beta decay alone*

or

alpha and beta decay produce different atomic numbers  
*ignore correct reference to mass number*

1

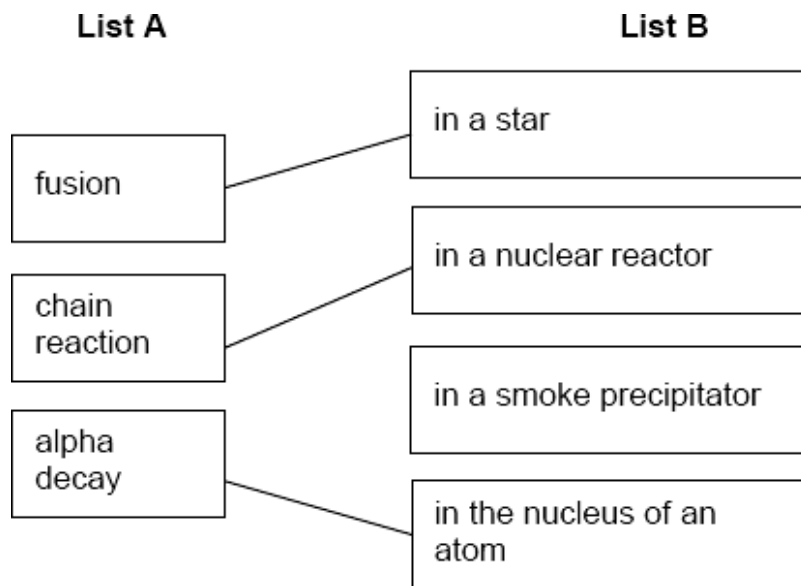
[7]

13

three lines correct

*allow 1 mark for each correct line*

*if more than 1 line is drawn from a box in **List A**, mark each line incorrect*



[3]

14

(a) electron(s)

1

(b) 3<sup>rd</sup> box ticked

The model cannot explain the results from a new experiment

1

(c) all three correct

| Particle |
|----------|
| Proton   |
| Electron |
| Neutron  |

*allow 1 mark for 1 correct*

2

[4]

15

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

- food / drink
- rocks / building materials
- cosmic rays / rays from space  
*accept correctly named example*

1

(ii) any **one** from:

- nuclear power / coal power (stations)  
*accept nuclear waste*
- nuclear accidents  
*accept named accident eg Chernobyl*
- nuclear weapons testing  
*accept named medical procedure which involves a radioactive source*  
*accept radiotherapy*  
*nuclear activity / radiation is insufficient*  
*do **not** accept CT scans*

1

(iii) different number of / fewer protons

*accept does not have 86 protons*  
*accept only has 84 protons*

**or**

different atomic number

*do **not** accept bottom number different*  
*reference to mass number negates this mark*

1

(b) 168

*accept 169 if clear, correct method is shown*  
*allow 1 mark for a correct dose ratio involving the spine*  
*eg 2:140 etc*  
*or ratio of days to dose is 1.2*  
*or ratio of dose to days is 0.83*

2

(c) (i)

|                    |                    |
|--------------------|--------------------|
| <b>Group<br/>A</b> | <b>Group<br/>B</b> |
| <b>J M O</b>       | <b>K L N</b>       |

*all correct*  
*any order within each group*

1

(ii) similar (number) / same (number) / large (number)  
*accept the same specific number in each group eg three*  
*reference to other factors such as age is neutral*

1

(iii) how many people in each group developed cancer  
*a clear comparison is required*

1

(iv) *there are no marks for **Yes** or **No** the*  
*mark is for the reason*

**Yes**

the benefit of having the scan is greater than the risk

**or**

the risk is (very) small (compared to the chance from natural causes)

*accept the risk is much greater from natural causes*

**No**

no additional risk is acceptable

1

[9]

16

(a) (i) L

1

(ii) M

1

(b) To make a smoke detector work.

1

(c) 40

*no tolerance*

1

[4]

17

(a) proton

electron

neutron

*all 3 in correct order*

*allow 1 mark for 1 correct*

*do **not** accept letters p, e, n*

2

(b) 4

*reason only scores if 4 is chosen*

1

number of protons

*accept number of electrons*

*accept there are 4 protons and 4 electrons*

*do **not** accept there are 4 protons and electrons*

1

(c) The atom loses an electron.

1

[5]

18

(a) L

J

K

*all 3 in correct order*

*allow 1 mark for 1 correct*

2

(b) number of electrons = number of protons

*accept amount for number*

1

(c) neutrons

*this answer only*

1

(d) loses / gains electron(s)

1

[5]

19

(a) (i) all correct

*accept presented as a tally chart*

|                     |   |
|---------------------|---|
| Number of protons   | 3 |
| Number of electrons | 3 |
| Number of neutrons  | 4 |

*allow 1 mark for 1 correct*

2

(ii) 7

*reason may score even if 7 not chosen*

1

number of protons and neutrons

*accept number of particles in the nucleus*

*accept number of nucleons*

*do **not** accept number of electrons and neutrons*

1

(b) an ion

1

(c) (i) smaller than

1

(ii) radon loses an alpha (particle)

**or**

radon loses an (alpha) particle

**or**

(mass of) polonium plus an alpha = (mass) radon

**or**

radon loses 2 protons and 2 neutrons (to become polonium)

*accept radon has less protons and neutrons*

1

[7]

20

(a) (i) **K** and **L**

*both answers required either order*

1

(ii) (1) same number of protons  
*accept same number of electrons*  
*accept same atomic number* 1

(2) different numbers of neutrons 1

(b) (i) 90 1

(ii) 140 1

(c) alpha (particle)  
*reason may score even if beta or gamma is chosen* 1

mass number goes down by 4  
**or**  
number of protons and neutrons goes down by 4  
**or**  
number of neutrons goes down by 2  
*candidates that answer correctly in terms of why gamma  
and beta decay are not possible gain full credit* 1

atomic / proton number goes down by 2  
**or**  
number of protons goes down by 2  
*accept an alpha particle consists of 2 neutrons and 2 protons for 1  
mark*  
*accept alpha equals  ${}^4_2\text{He}$  or  ${}^4_2\alpha$  for 1 mark*  
*an alpha particle is a helium nucleus is insufficient for this mark* 1

[8]

21

(a) (i) (atoms / elements with) the same number of protons but different numbers of neutrons  
*accept (atoms / elements with) different mass number but same atomic number* 1

(ii) substances that give out radiation  
*accept alpha, beta or gamma for radiation*  
*accept an unstable nucleus that decays*  
*radioactive decay takes place is insufficient* 1

- (b) 85 years  
*± 2 years*  
*allow 1 mark for showing correct method on the graph* 2
- (c) (i) a helium nucleus  
*accept 2 neutrons and 2 protons*  
*accept  ${}_2^4\text{He}$*   
*do **not** accept helium atom* 1
- (ii) the rate of decay (of plutonium) decreases  
*accept fewer (plutonium) nuclei (to decay)*  
*accept radioactivity decreases* 1
- less heat produced  
*do **not** accept energy for heat* 1
- (d) (i) (outside the body)  
 alpha (particles) cannot penetrate into the body  
 (inside the body) 1
- (heat produced from decay) damages / kills cells / tissues  
*accept causes cancer for damages / kills cells / tissues*  
*accept **highly** toxic* 1
- (ii) any **one** from:
- worried same could happen again
  - an accident may cause radiation to be spread around the Earth / atmosphere
  - idea of soil contamination resulting from accident / release of radioactive material
  - idea of negative effect on health resulting from accident / release of radioactive material
- accept any sensible suggestion* 1

[10]

22

(a) 146

1

(b) atomic number

1

(c) (i) alpha

1

(ii) number of protons changes

*accept atomic number changes*

*accept loses or gains protons*

*do **not** accept protons with any other particle e.g. number of protons and neutrons changes incorrect*

*do **not** accept any reference to mass number*

1

[4]

23

(a) any **two** pairs from:

- nuclear model mass is concentrated at the centre / nucleus (1)

plum pudding model mass is evenly distributed (1)

*accept the nuclear model has a nucleus/the plum pudding model does not have a nucleus for 1 mark*

- nuclear model positive charge occupies only a small part of the atom (1)

plum pudding model positive charge spread throughout the atom (1)

*accept electrons in shells/ orbits provided a valid comparison is made with the plum pudding model*

*do **not** accept on its own*

*do **not** accept electrons at edge of plum pudding*

- nuclear model electrons orbit some distance from the centre / nucleus (1)

plum pudding electrons embedded in the (mass) of positive (charge) (1)

- nuclear model the atom mainly empty space (1)

plum pudding model is a 'solid' mass (1)

*to gain credit it must be clear which model is being described*

*do **not** accept simple descriptions on the diagram without comparison*

4



- (b) nucleus must be positive to deflect/ repel alpha particles  
*answers in terms of electrons/negative charge causing deflection  
 negates mark answers in terms of reflection negates mark*

1

nucleus (very) small so few alpha particles deflected backwards  
*accept most of atom empty space so most pass through*

1

- (c) many/ 100 000 measurements taken  
*accept results for measurements accept data valid / reliable*

1

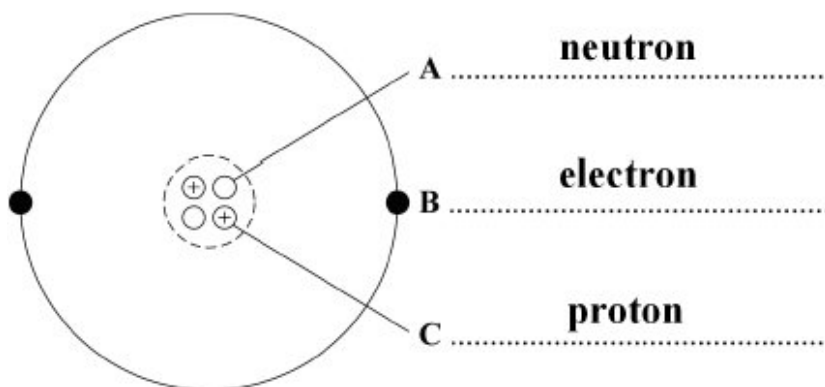
findings could not be explained by plum pudding model  
*accept a specific finding that could not be explained  
 eg some alpha particles were deflected backwards*

1

[8]

24

- (a) (i)



*all 3 labels correct  
 allow 1 mark for 1 correct label*

2

- (ii) has no electrons  
*it = alpha  
 allow alpha has a positive(charge)  
 allow a helium (atom) has no (charge)  
 do **not** accept general properties of alpha  
 do **not** accept general answers in terms of size / density / mass etc*

1

- (b) (i) 15 (hours)  
*accept any answer between 14.8 and 15.2 inclusive*

1

- (ii) 15 (hours) or their (b) (i) 1
- (c) (i) americium-241 has a long half life 1
- (ii) any **one** from:
- alpha (particles) are harmful to ...  
*accept radiation / radioactive material is harmful to ...*  
*accept specific example of harm*  
*eg can cause cancer*  
*accept radiation is poisonous if ingested / inhaled*  
*do **not** accept it is poisonous / in case of leakage*
  - so they dispose of it safely / appropriately
  - so they don't break it open / open it  
*accept do **not** touch the radioactive source*
  - so they can make a choice about having a radioactive source (in the house)  
*it = radioactive material*

1

[7]

25

- (a) (i) gamma hardly ionises the air 1  
*accept does not ionise*  
*accept gamma radiation is not charged*  
*do **not** accept answers in terms of danger of gamma or other properties*
- (ii) half-life (too) short 1  
*accept need frequent replacement 'it' refers to curium-242*
- (iii) (two) fewer neutrons 1  
*accept different numbers of neutrons if a number is specified it must be correct*  
*do **not** accept more neutrons unless curium-244 is specified*
- (b) (i) gamma 1  
*accept correct symbol*
- (ii) both absorbed by the metal / steel / weld 1  
*only scores if (b)(i) is correct*  
*accept cannot pass through the metal / steel / weld*

- (c) (i) put source into water at **one** point on bank  
*accept the idea of testing different parts of the river bank at different times*

1

see if radiation is detected in polluted area  
*accept idea of tracing*

1

- (ii) 2.7 (days)  
*allow 1 mark for showing correct use of the graph*

2

[9]

26

(a)

| Particle | Relative Mass | Relative charge |
|----------|---------------|-----------------|
| Proton   | 1             |                 |
| Neutron  |               | 0               |

*accept one, accept +1  
do **not** accept -1*

1

*accept zero  
do **not** accept no charge/ nothing/neutral unless given with 0*

1

- (b) equal numbers/amounts of protons and electrons

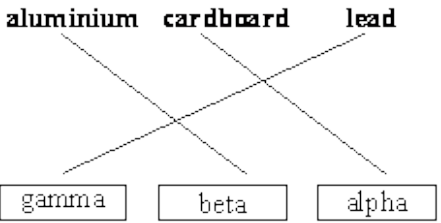
1

protons and electrons have equal but opposite charge  
*accept protons charge +1 and electron charge -1  
accept (charge) on proton  
cancels/balances (charge) on electron  
accept positive (charges) cancel out the negative(charges)  
neutrons have no charge is neutral  
do **not** accept total charge of protons, electrons (and neutrons) is 0  
unless qualified*

1

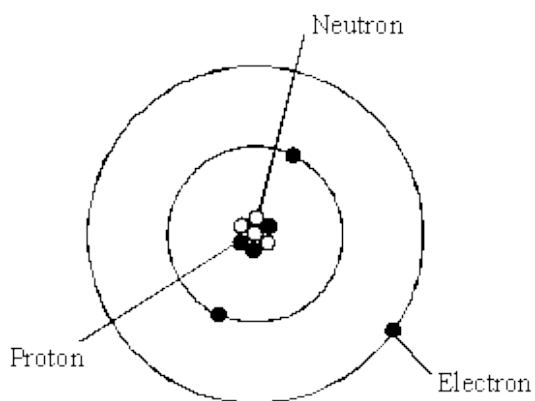
- (c) (i) (3) fewer neutrons  
*accept lower/ smaller mass number*  
*do **not** accept different numbers of neutrons*  
*any mention of fewer/more protons/electrons negates mark*  
*accept answers in terms of U-238 providing U-238 is specifically stated i.e. U-238 has (3) more neutrons* 1
- (ii) neutron 1
- (iii) (nuclear) fission  
*accept fision*  
*do **not** accept any spelling that may be taken as fusion* 1
- [7]**

**27**

- (a) (i) **P** 1
- (ii) **Q** 1
- (b) 3 lines correct
- aluminium   cardboard   lead**  
  
**gamma   beta   alpha**
- allow 1 mark for 1 correct line*  
*two lines drawn from any source or box – both incorrect* 2
- (c) (i) **K** 1
- (ii) 56  
*accept 50 – 60 inclusive* 1
- (iii) **K** 1
- (iv) to inject... tracer 1
- [8]**

28

(i) each correct label scores 1 mark



3

(ii) neutron

1

(iii) 7

1

number of protons and neutrons **or** number of nucleons or number of particles in the nucleus

*accept number of particles in the centre only if first answer = 7*

1

[6]

29

(a) Y and Z

1

they have the same number of protons **or** same atomic number

*accept they have the same number of electrons **or** same number of protons **and** electrons*

*allow only different in number of neutrons N.B. independent marks*

1

(b) **Quality of written communication**

*for correct use of terms underlined in B or C*

*Q ✓ Q ✗*

1

A – alpha particle passes straight through the empty space of the atom  
**or** it is a long way from the nucleus

*describes 3 tracks correctly for 2 marks*

*describes 2 or 1 track correctly for 1 mark*

B – alpha particle deflected / repelled / repulsed by the (positive) nucleus

C – alpha particle heading straight for the nucleus is deflected / repelled / repulsed backwards

*do **not** accept hits the nucleus*

*do **not** accept answers referring to refraction*

*do **not** accept answers in terms of reflected backwards unless qualified in terms of repulsion*

*mention of difference in charge on nucleus negates that track*

max 2

[5]

30

(a) (i) both lose 2 protons and (2) neutrons

*accept changes by 2 protons and 2 neutrons*

1

(ii) different number of protons (in the nucleus)

*accept different atomic number*

*do **not** accept different number of protons and neutrons or different mass number*

*ignore electrons*

1

(iii) gamma involves no change in the number of protons (in the nucleus)

**or** gamma is a wave (not a particle)

*do **not** accept number of neutrons*

*and / or protons*

*ignore electrons*

1

(b) (i) water because

*both material **and** reason required*

for all energy values the thickness

of water needed to absorb (90% of)

the radiation is more than the other materials

*accept thickness of water required is always more than the other materials*

1

(ii) 6

allow 1 mark for obtaining both correct values 72  
**and** 12 from graph  
allow 1 mark for incorrect values 71 and / or  
11 from graph evaluated correctly

2

(c) any **three** from:

*may be scored on annotated diagram provided  
not negated elsewhere*

- most (alpha) particles passed  
undeflected / straight through the gold
- suggesting most of the atom is empty (space)
- a few (alpha) particles scattered / deflected through (very) large angles  
*accept repelled*  
*do **not** accept reflected / rebound /  
bounce back*
- suggesting a concentrated / small nucleus
- nucleus is positive because it repels the positive (alpha) particles  
*no reference to experiment, maximum 1 mark*

3

[9]

31

(a) (i) helium nuclei

1

**or**

two protons and two neutrons or  $\frac{4}{2}$  He

*do **not** accept it is a particle emitted by an unstable nucleus of  
Californium -241*

(ii) time taken for the activity **or** count rate **or** number of nuclei  
**or** number of atoms **or** number of radioactive particles  
to decrease to half

1

(iii) Technetium-99

*this mark **cannot** score without Technetium- 99*

1

any **two** of the following:

- suitable short half-life or activity quickly reduced to a safe level or it doesn't stay in the body long  
*this mark **can** score if Cobalt -60 is given*
- (gamma emitter so) it can be detected outside the body
- less (ionising) damage to cells **or** tissue  
*this mark **can** score if Cobalt -60 is given*

2

(b) any **three** of the following:

- transport of waste into the area
- possibility of accident or leakage from transport
- safe levels not reached for hundreds or thousands of years
- Possible leakage **or** contamination of land **or** water **or** increase in background radiation
- increased risk of (radiation linked) illness **or** cancer

3

[8]

32

(a) (i) a helium nucleus

*accept  ${}^4_2\text{He}$*

*accept 2 protons + 2 neutrons*

*do **not** accept He*

*do **not** accept helium atom*

1

(ii) nucleus

*only answer, no alternative*

1



- (b) (i) each axis given a linear scale  
*time axis must go up to 12 days*  
*y-axis must go up to 40 000* 1
- curve concave to axis drawn 1
- curve shows correct half-life of four days  
*do **not** accept a straight line must show one half-life*  
*check first two plotted points correct to  $\pm$  half square*  
*a curve drawn dot-to-dot scores a maximum of 1 mark* 1
- (ii) 38 750  
*no tolerance*  
*allow 1 mark for 5 half-lives*  
*allow 1 mark for showing that 1 250 are undecayed* 3
- (c) (i) more radon enters shaft (through cracks in the rock face)  
*accept radon emitted from surroundings* 1
- (ii) (alpha) radiation will damage cell structure or ionise cells  
*accept kill cells* 1
- causing cancerous growth  
*an answer in terms of the daughter product polonium being a solid*  
*or lodging in the throat and also emitting alpha gains full credit* 1

[11]

33

- (a) (i) electron  
neutron  
proton  
nucleus  
*1 mark for each correct label* 4
- (ii) H-1 has no neutrons  
H-3 has 2 neutrons  
*more neutrons gets 1 mark* 2
- (iii) nucleus unstable 2

- (b) lead/concrete  
lead/concrete needed to stop gamma rays

2

[10]

34

- (a) 1.  
-1

2

*for 1 mark each*

- (b) (i) 19p,  
20n,  
19e

*all correct for 2 marks  
2 correct for 1 mark*

2

- (ii) K40 has an extra neutron/different number of neutrons/  
it has more neutrons/21 neutrons

*for 1 mark  
NOT fewer neutrons*

1

- (iii) radioactive/unstable nucleus/ nucleus disintegrates/  
emits radiation/it has too many neutrons

*for 1 mark*

1

- (iv) calcium/Ca

*for 1 mark*

1

- (v) 1 (e) in outer shell/same number of electrons/outer electron  
same distance from the nucleus

*for 1 mark*

1

- (c) (i) Geiger-Muller tube (photographic) film

*for 1 mark*

1

- (ii) cancer, leukaemia, radiation sickness etc.

*for 1 mark*

1

[10]

35

- (a) 1, 0  
 X, -1 (X = negligible / very small / (1/1840) to (1/2000), but not nothing)  
*2 for 4 correct*  
*1 for 2/3 correct*

2

- (b) has a nucleus which is positive charge  
 negative charges (electrons) orbit nucleus  
*each for 1 mark*

3

[5]

36

- (a) nucleus positive charge / protons in nucleus electrons / negative charges orbit nucleus  
*each for 1 mark*

3

- (b) (i) positive dough repels positive alpha particles **or** 2 positive charges repel forces small  
*each for 1 mark*

2

- (ii) large force needed + ves in plum pudding spread out – *may appear in (i)*  
 positive charge must be concentrated / in nucleus  
*(ignore references to electrons)*  
*for 1 mark each*

3

- (c) 1, 0  
 X, -1 (X = negligible / very small / (1/1840) (1/2000), but not nothing)  
*each row for 1 mark*

2

- (d) (i) 4  
*for 1 mark*

1

- (ii) B and C have the same number of protons / atomic number but different number of neutrons / mass number  
*each for 1 mark*

3

[14]

37

- (a) 90  
*for one mark*

1

- (b) (i) neutron  
*for one mark* 1
- (ii) nucleus  
*for one mark* 1
- (iii) electron  
*for one mark* 1
- (c) (i) 100  
*for one mark* 1
- (ii) 157  
*for one mark* 1

[6]

38

- (a) (i) B  
*for one mark* 2
- (ii) has a different number of electrons (protons)  
*for one mark*
- (b) (i) A and C  
*for one mark* 1
- (ii) same number of protons / electrons, same nuclear charge  
different number of neutrons / nuclear masses different  
*for 1 mark each* 2

[5]

39




- (a) (i) beta and gamma (*any order*)  
*for one mark* 1
- (ii) gamma  
*for one mark* 1

- (b) (i) particles / atoms / molecules become charged / gain / lose electrons  
*for one mark* 1
- (ii) e.g. to kill cancer cells (*allow* any use of alpha, beta or gamma or X<sup>-</sup> radiation)  
*for one mark* 1
- (c) (i) time taken for no. of atoms / no. of nuclei / mass of U238 / activity to halve – **not** radioactivity  
**or**  
time taken for count rate to halve  
*for one mark* 1
- (ii) atoms with unstable nuclei which emit radiation  
(*not* definition of isotope but isotope which is radioactive gets 1 mark)  
*for 1 mark each* 2
- (d) (i) 1 / 4 *accept* 25% or 0.25  
*for one mark* 1
- (ii) 2 × half life or 2 × 4500 million years (independent of (i))  
gains 1 mark  
**but**  
9000 million years *ecf* only if answer to (i) is  $\frac{1}{2}, \frac{1}{8}, \frac{1}{16}$ , etc.  
*gains 2 marks* 2

[10]


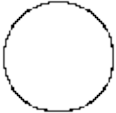
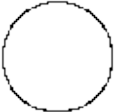
40

- (a) (i) B  
*for one mark* 1
- (ii) has 4 electrons / protons others only 3; B has a different no. of electrons / protons - *not* A and C have same no. of protons / electrons  
*for one mark* 1
- (b) (i) A and C  
*for one mark* 1
- (ii) same no. of protons / electrons different no. of neutrons  
**or**  
nuclei have the same charge but different mass  
*for 1 mark each* 2

- (c) (i)   
(ii)   
(iii) 

for 1 mark each

3

- (d)  $2p.2n$   allow  but not   
*(i.e. no mark if electrons shown)*  
for one mark

1

[9]

41

- (i) 86  
(ii) 222

1

1

[2]

42

- (a) radium

accept Ra

1

- (b) different numbers of protons

accept one has 91 protons, one has 92

or Pa has 91 protons, U has 92

do **not** credit they have different atomic numbers

reject different numbers of protons and neutrons

1

- (c) alpha

1

- (d) neutron changes into proton

accept electron lost / beta radiation

accept singular or plural answers

1

[4]

43

(a) (i) cannot penetrate aluminium  
*allow can only pass through air / paper too weak is neutral*

1

(ii) gamma rays not affected (by aluminium)  
*allow all / most (gamma rays) to pass through*  
*too strong is neutral*  
*danger is neutral*

1

(b) (i) (nuclei) unstable

1

(ii) causes harm / damage to body / cells  
*allow radiation sickness*

1

detail e.g., causes mutations / causes cancer / damages DNA /  
damages chromosomes

*allow two effects for 2 marks*

1

[5]

44

(a) protons

1

protons

*accept electrons*

1

neutrons

1

(b) protons

*reject mass*

1

[4]

45

neutron becomes proton / neutron emits electron / neutron emits beta particle  
*gains proton neutral*

[1]

46

- 4
- 9

*each for 1 mark*

[2]