1

(a) A radioactive source emits alpha (α), beta (β) and gamma (γ) radiation.

(i) Which **two** types of radiation will pass through a sheet of card?

....

(1)

(ii) Which **two** types of radiation would be deflected by an electric field?

....

(1)

(iii) Which type of radiation has the greatest range in air?

....

(1)

(b) A student suggests that the radioactive source should be stored in a freezer at – 20 °C.
The student thinks that this would reduce the radiation emitted from the source.

Suggest why the student is wrong.

....

....

(1)

(c) Phosphorus-32 is a radioactive isotope that emits beta radiation.

(i) How is an atom of phosphorus-32 different from an atom of the stable isotope
phosphorus-31?

....

....

(1)

(ii)   The graph shows how the count rate of a sample of phosphorus-32 changes with time.
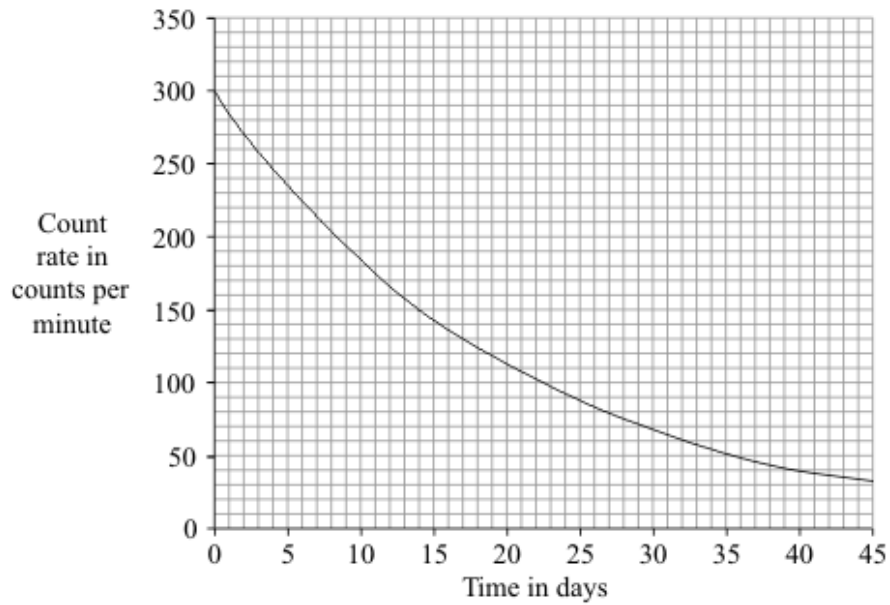
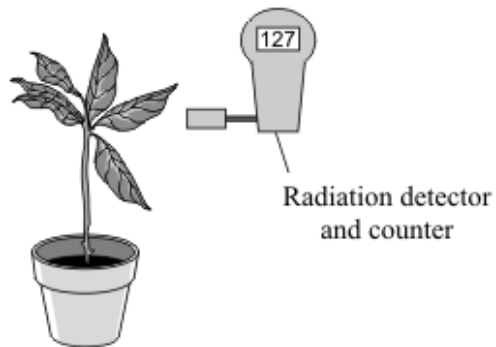
Use the graph to calculate the half-life of phosphorus-32.

Show clearly how you used the graph to obtain your answer.

....

....

Half-life = ... days

(2)

(iii)   Plants use phosphorus compounds to grow. Watering the root system of a plant with a solution containing a phosphorus-32 compound can help scientists to understand the growth process.

Radiation detector and counter

Explain why phosphorus-32 is suitable for use as a tracer in this situation.

....

....

....

....

(2)
(Total 9 marks)

2 (a) The names of three types of nuclear radiation are given in **List A**. Some properties of these three types of radiation are given in **List B**.

Draw a straight line to link each type of radiation in **List A** to its correct property in **List B**. Draw only three lines.

List A
Type of nuclear radiation

List B
Property of radiation

| alpha |

| beta |

| gamma |

not deflected by an electric field

stopped by thin metal but not paper

the most strongly ionising

will not harm living cells

(3)

(b) Nuclear radiation is given out from the centre of some types of atom.

What name is given to the centre of an atom? ....

(1)

(c)   One of the substances in the table is used as a radioactive tracer. A hospital patient breathes in air containing the tracer. The radiation given out is measured by a doctor using a detector outside the patient's body.

Substance	Radiation given out	Solid, liquid or gas
X	alpha	gas
Y	gamma	gas
Z	gamma	solid

Which **one** of the substances, **X**, **Y** or **Z**, should be used as the tracer? ....

Give **two** reasons for your answer.

1 ....

....

2 ....

....

(3)

(d)   Radiation can also be used to kill the bacteria on fresh food.

Give **one** reason why farmers, shop owners or consumers may want food to be treated with radiation.

....

....

(1)
(Total 8 marks)

3 Radon is a radioactive element. The graph shows how the number of radon atoms in a sample of air changes with time.
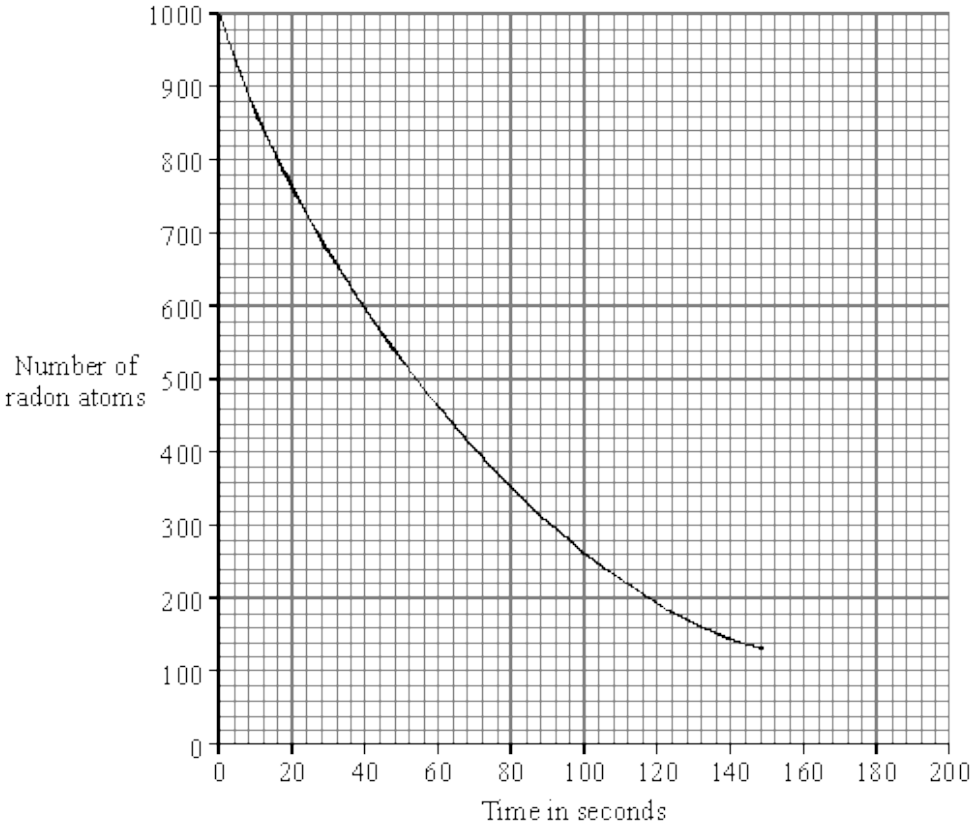
(i) How long did it take the number of radon atoms in the sample of air to fall from 1000 to 500?

Time = ... seconds

(1)

(ii) How long is the half-life of radon?

Half-life = ... seconds

(1)

(iii) Complete this sentence by crossing out the **two** lines in the box that are wrong.

As a radioactive material gets older, it emits

| less |
| a constant level of |
| more |

radiation per second.

(1)
(Total 3 marks)

4 The detector and counter are used in an experiment to show that a radioactive source gives out alpha and beta radiation only.
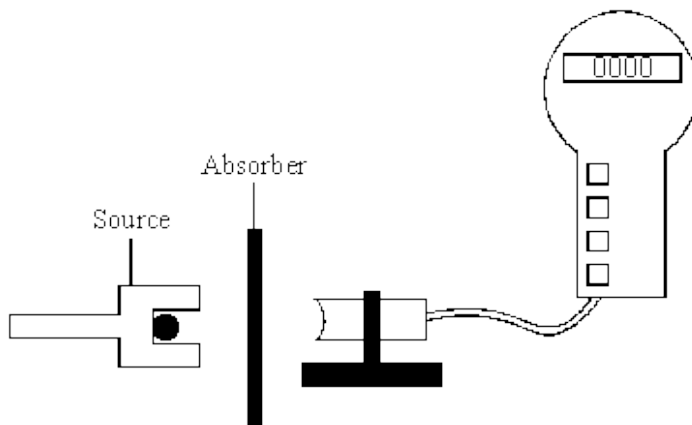

Two different types of absorber are placed one at a time between the detector and the source. For each absorber, a count is taken over ten minutes and the average number of counts per second worked out. The results are shown in the table.

Absorber used	Average counts per second
No absorber	33
Card 1 mm thick	20
Metal 3 mm thick	2

Explain how these results show that alpha and beta radiation is being given out, but gamma radiation is **not** being given out.

....

....

....

....

....

....

(Total 3 marks)

5 (a) The table gives information about six radioactive isotopes.

Isotope	Type of radiation emitted	Half-life
hydrogen-3	beta particle	12 years
iridium-192	gamma ray	74 days
polonium-210	alpha particle	138 days
polonium-213	alpha particle	less than 1 second
technetium-99	gamma ray	6 days
uranium-239	beta particle	24 minutes

(i) What is an alpha particle?

....

(1)

(ii) Two isotopes of polonium are given in the table. How do the nuclei of these two isotopes differ?

....

(1)

(iii) A doctor needs to monitor the blood flow through a patient's heart. The doctor injects a radioactive isotope into the patient's bloodstream. The radiation emitted by the isotope is then detected outside the body.

Which **one** of the isotopes in the table would the doctor inject into the bloodstream?

....

Explain the reasons for your choice.

....

....

....

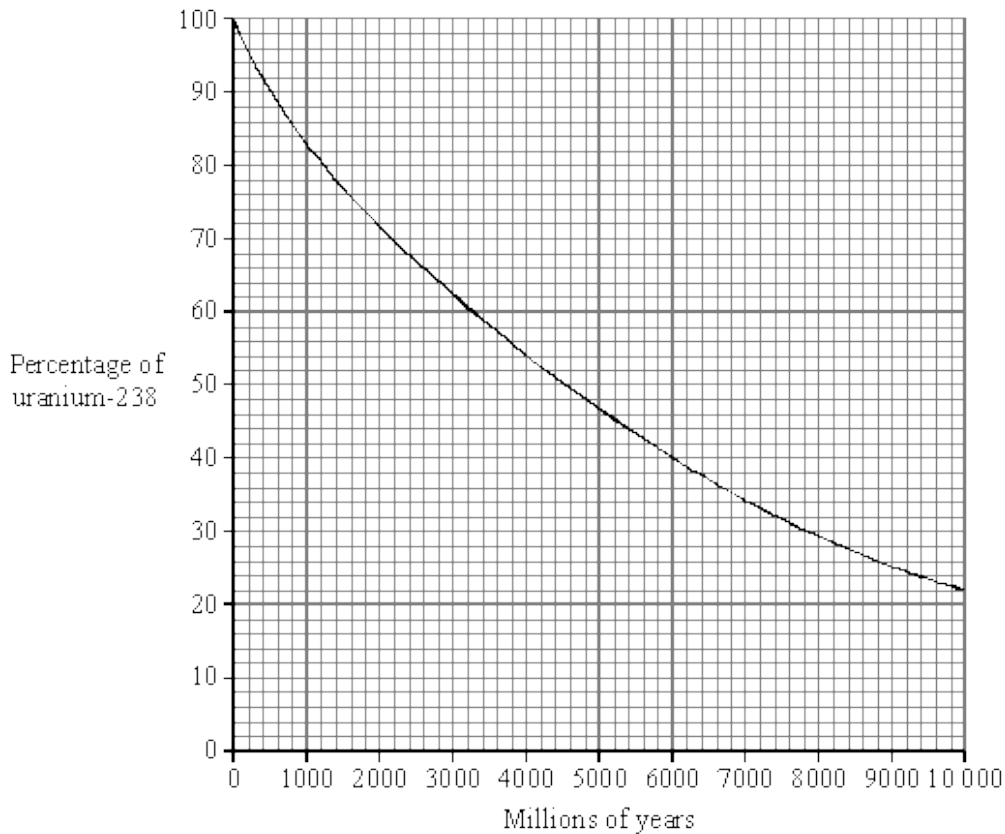...

(3)

(b) Igneous rock contains uranium-238 which eventually changes to the stable isotope lead-206. The graph shows how the percentage of uranium-238 nuclei present in an igneous rock changes with time.

A rock sample is found to have seven atoms of uranium-238 for every three atoms of lead-206. Use the graph to estimate the age of the rock. Show clearly how you obtain your answer.

....

....

Age of rock = ... million years
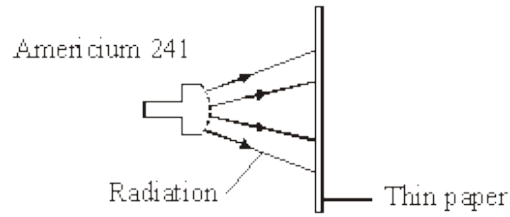
(2)
(Total 7 marks)

6 A smoke detector fitted inside a house contains a radioactive source, americium 241.

(a) Complete the following table of information for an atom of americium 241.

Number of neutrons	146
Number of protons	95
Number of electrons	

(1)

(b)   The diagram shows that the radiation given out by americium 241 does not go through paper.

Which type of radiation, alpha (α), beta (β), or gamma (γ) is given out by americium 241?

....

(1)

(c)   Explain why the radiation given out by the americium 241 is unlikely to do any harm to people living in the house.

....

....

....

....

(2)

(d)   Complete the sentence by choosing an answer from the box.

| less than | more than | the same as |

After many years the radiation emitted by americium 241 will be ....

when the smoke detector was new.

(1)
(Total 5 marks)

7   A beta particle is a high-energy electron.

(i)   Which part of an atom emits a beta particle?

....

(1)

(ii)   How does the composition of an atom change when it emits a beta particle?

....
(1)
(Total 2 marks)

8   (a)   Radiation can cause cancer. The graph shows that the risk of cancer depends on the radiation dose a person is exposed to.
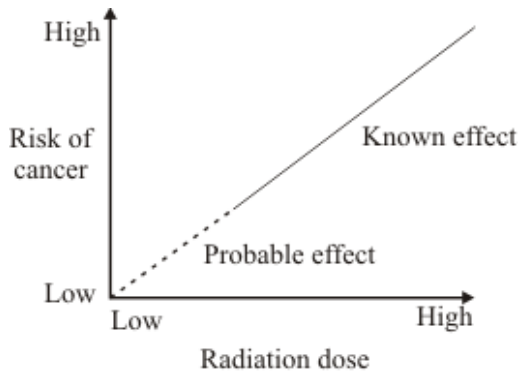
Complete the following sentence.

The .... the dose of radiation a person gets, the greater the risk of cancer.

(1)

(b)   A worker in a nuclear power station wears a special badge (diagram **1**). Diagram **2** shows what is inside the badge. When the film inside the badge is developed, it will be dark in the places where it has absorbed radiation.
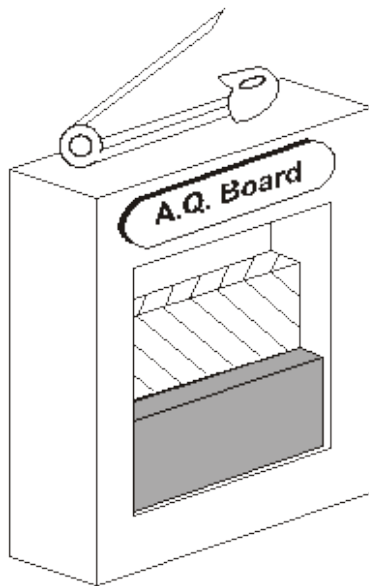
Diagram 1
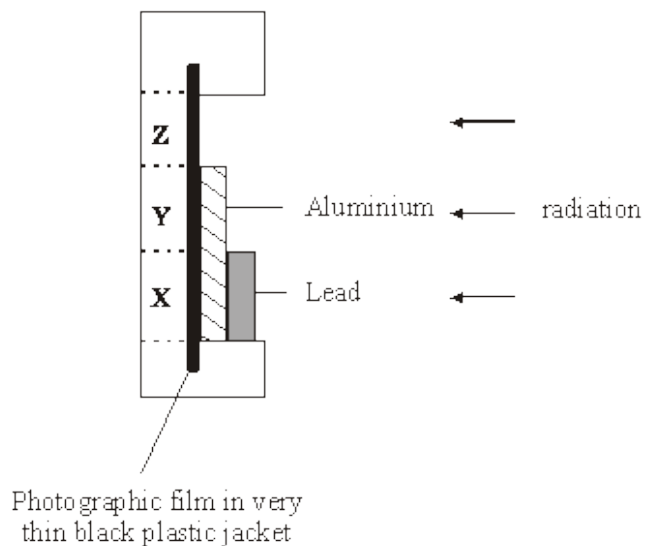
Diagram 2

Which part of the film, **X**, **Y** or **Z,** would darken if the worker had received a dose of alpha radiation?

....

Give a reason for your answer.

....

....

(2)
(Total 3 marks)

9 The table shows how the count rate from a radioactive substance changes in 10 days.

Time in days	0	2	4	6	8	10
Count rate in countsper minute	880	555	350	220	140	90

(a) Draw a graph of count rate against time.

The first two points have been plotted for you.
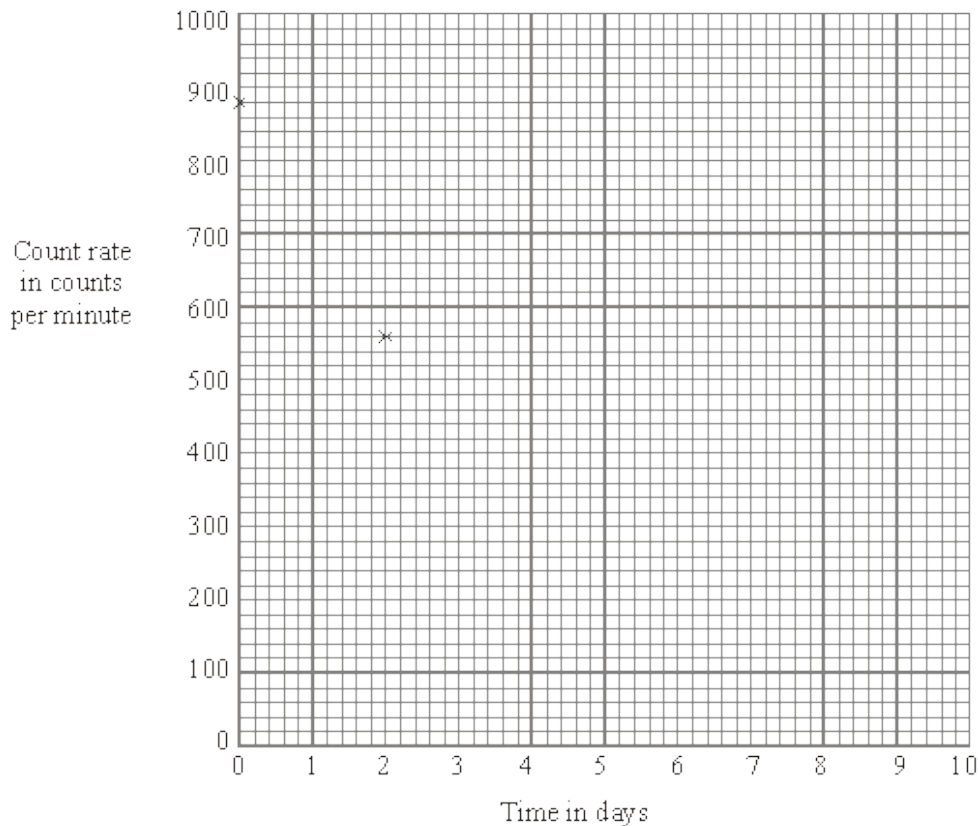
(3)

(b)   (i)   Use your graph to find out how long it takes for the count rate to fall from 880 counts per minute to 440 counts per minute.

Time = ... days

(1)

(ii)   What is the half-life of this substance?

Half-life = ... days

(1)

(c)   The table gives the half-life and type of radiation given out by four different radioactive isotopes.

Radioactive isotope	Half-life in days	Radiation given out
bismuth-210	5.0	beta
polonium-210	138.0	alpha and gamma
radon-222	3.8	alpha
thorium-234	24.1	beta and gamma

Some samples of each isotope have the same count rate today. Which sample will have the lowest count rate one month from today?

....

Give a reason for your answer.

....

(2)
(Total 7 marks)

10   Read the information in the box and then answer the questions.

> Igneous rocks contain potassium-40. This is a radioactive isotope. It has a half-life of 1300 million years.
>
> Potassium-40 decays into argon-40 which is stable.
>
> Argon escapes from molten rock. Any argon found in an igneous rock must have been produced since the rock solidified.
>
> A sample of an igneous rock has one atom of potassium-40 for every three atoms of argon-40.

(i)   What fraction of the potassium-40 has not yet decayed?

....

(ii)   Calculate the age of the rock.

....

Age of rock = ... million years

(1)
(Total 2 marks)

11 (a)   The graph shows how a sample of barium-143, a radioactive *isotope* with a short *half-life,* decays with time.
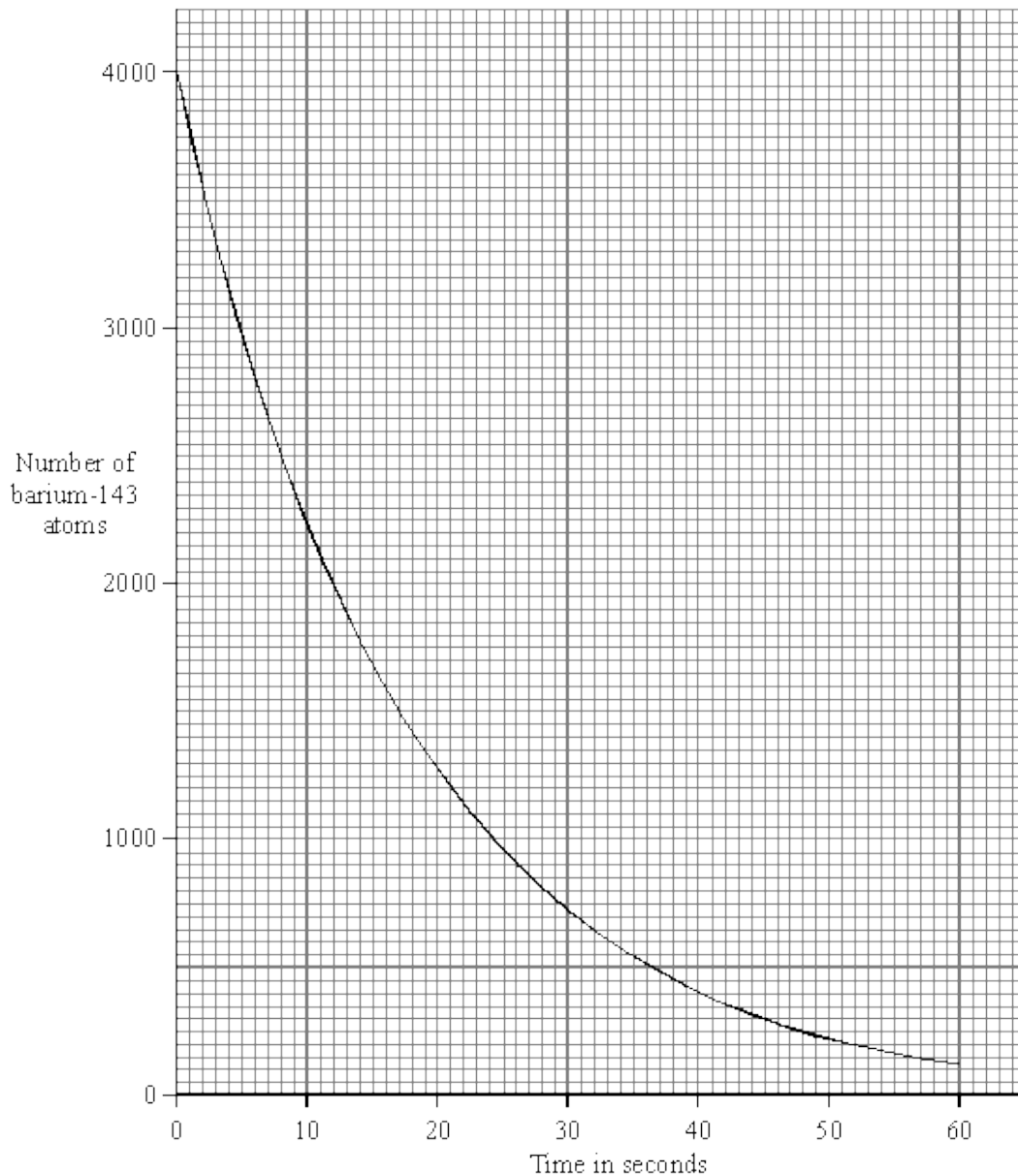
(i)   What is meant by the term *isotope?*

        ....

        ....

(1)

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

        ....

        ....

(1)

(iii)   Use the graph to find the half-life of barium-143.

                            Half-life = ... seconds

(1)

(b)   Humans take in the radioactive isotope carbon-14 from their food. After their death, the proportion of carbon-14 in their bones can be used to tell how long it is since they died. Carbon-14 has a half-life of 5700 years.

(i)   A bone in a living human contains 80 units of carbon-14. An identical bone taken from a skeleton found in an ancient burial ground contains 5 units of carbon-14. Calculate the age of the skeleton. Show clearly how you work out your answer.

        ....

        ....

        ....

                            Age of skeleton = ... years

(2)

(ii)   Why is carbon-14 unsuitable for dating a skeleton believed to be about 150 years old?

        ....

        ....

(1)

(c)   The increased industrial use of radioactive materials is leading to increased amounts of radioactive waste. Some people suggest that radioactive liquid waste can be mixed with water and then safely dumped at sea. Do you agree with this suggestion? Explain the reason for your answer.

....

....

....

....

....

....

....

....

(3)
(Total 9 marks)

12 The radioactive isotope, carbon-14, decays by beta (β) particle emission.

(a)   What is a beta (β) particle?

....

....

(1)

(b) Plants absorb carbon-14 from the atmosphere. The graph shows the decay curve for 1 g of carbon-l4 taken from a flax plant.
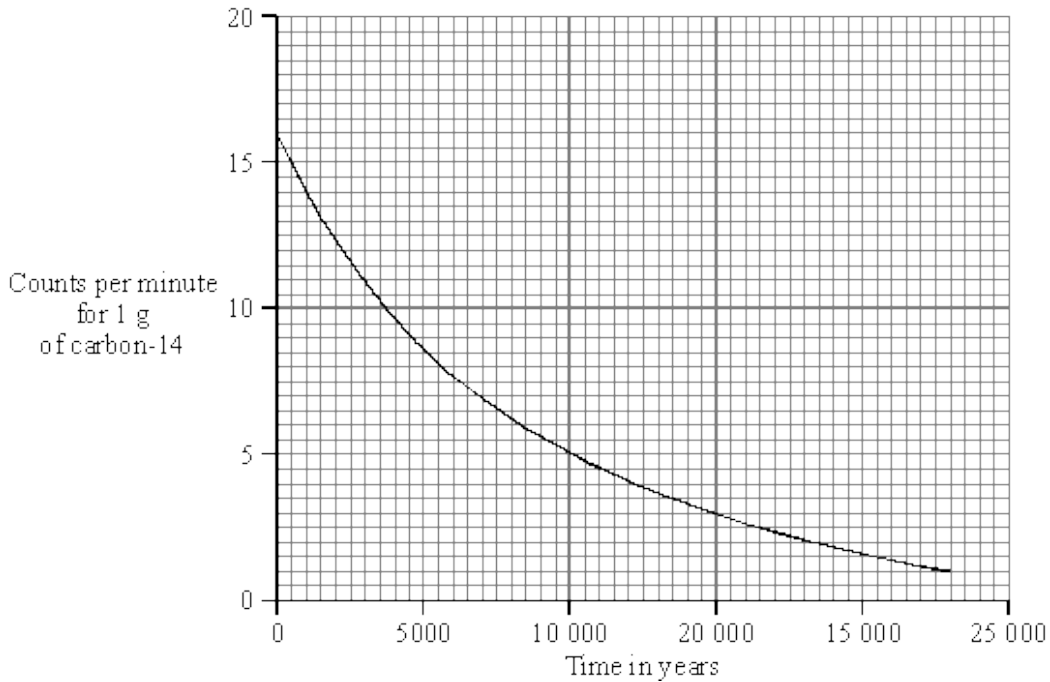
Use the graph to find the half-life of carbon-l4. You should show clearly on your graph how you obtain your answer.

Half-life = ... years.

(2)

(c) Linen is a cloth made from the flax plant. A recent exhibition included part of a linen shirt, believed to have belonged to St. Thomas à Becket, who died in 1162. Extracting carbon-14 from the cloth would allow the age of the shirt to be verified.

If 1 g of carbon-14 extracted from the cloth were to give 870 counts in 1 hour, would it be possible for the shirt to have once belonged to St. Thomas à Becket? You must show clearly the steps used and reason for your decision.

....

....

....

....

(3)
(Total 6 marks)

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

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

(i) What is an alpha (α) 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.

500 m

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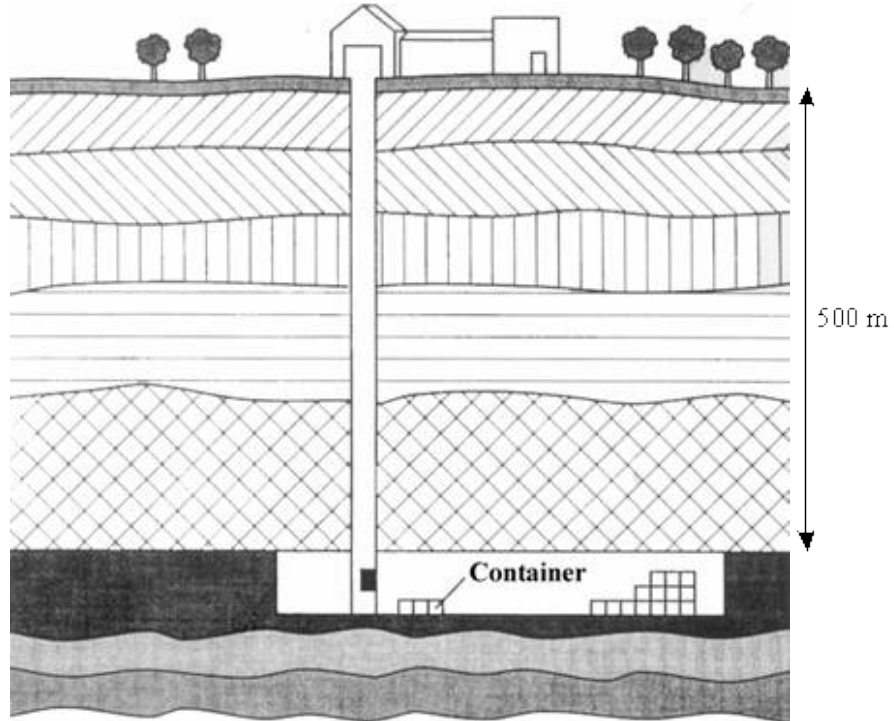
Some people may be worried about having such a storage site close to the area in which they live. Explain why.

....

....

....

....

....

....

....

(3)
(Total 8 marks)

14

(a)   The diagram shows a hazard sign.

What type of hazard does this sign warn you about?

....

(1)

(b)   The names of three types of radiation are given in the box.

alpha (α)   beta (β)   gamma (γ)

Complete each sentence by choosing the correct type of radiation from those given in the box. Each type of radiation should be used once or not at all.

(i)   The type of radiation that travels at the speed of light is ....

(1)

(ii)   The type of radiation that is stopped by thick paper is ....

(1)
(Total 3 marks)

15

(a)   A radiation detector and counter were used to detect and measure the radiation emitted from a weak source. The graph shows how the number of counts recorded in one minute changed with time.
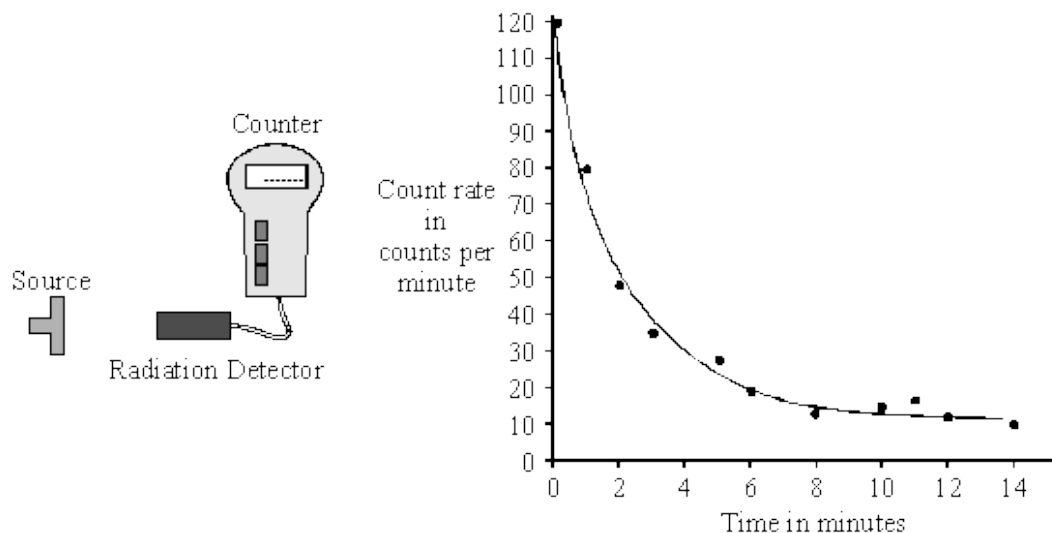
(i) Even though the readings from the counter were accurately recorded, not all the points fit the smooth curve. What does this tell us about the process of radioactive decay?

....

(1)

(ii) After ten minutes the number of counts recorded each minute is almost constant. Explain why.

....

....

....

(2)

(b) The radioactive isotope sodium-24 injected into the bloodstream can be used to trace blood flow to the heart. Sodium-24 emits both *beta particles* and *gamma rays*.

(i) What is a *beta particle*?

....

(1)

(ii) What is a *gamma ray*?

....

....

(1)

(iii) The count rate from a solution containing sodium-24 decreases from 584 counts per minute to 73 counts per minute in 45 hours. Calculate the half-life of sodium-2.2. Show clearly how you work out your answer.

....

....

....

Half-life = ... hours

(3)

(iv) Give **one** advantage of using sodium-24 to trace blood flow compared to using an isotope with a half-life of:

[A] ten years; ....

....

(1)

[B] ten seconds. ....

....

(1)
(Total 10 marks)

16 (a) Two sources of radiation look identical. One source emits only alpha radiation, the other only beta radiation. Describe **one** way to find out which source emits the alpha radiation. You can assume a radiation detector and counter are available. You may wish to draw a diagram to help with your answer.

....

....

....

....

....

....

(3)

(b) The diagram shows a beta radiation source and detector used to measure the thickness of cardboard as it is made. The table gives the detected count rate at different times.
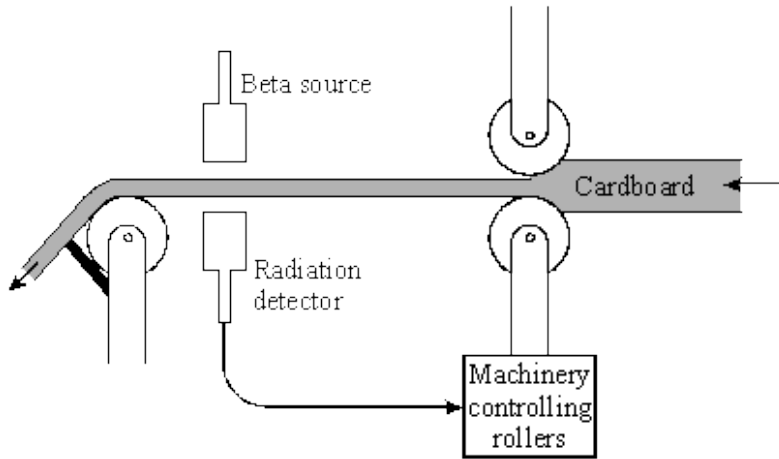
Time	Count rate in counts/minute
09:00	120
09:30	122
10:00	119
10:30	165
11:00	118

(i) Between 09:00 and 10:00 the cardboard is produced at the correct constant thickness. Give a reason for the small variation in count rate.

....

....

(1)

(ii) What can you say about the thickness of the cardboard being made at 10:30?

....

Explain the reason for your answer.

....

....

....

(3)

(iii)   Explain why gamma radiation is not suitable for detecting changes to the thickness of the cardboard.

....

....

(1)
(Total 8 marks)

17   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.
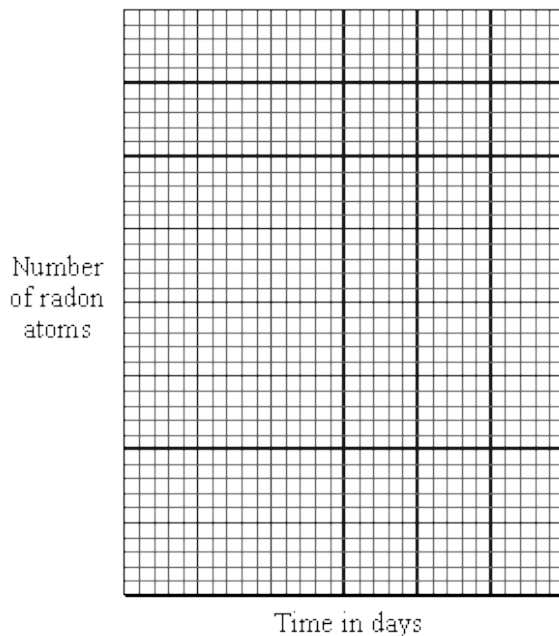
(3)

(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.

....

....

....

....
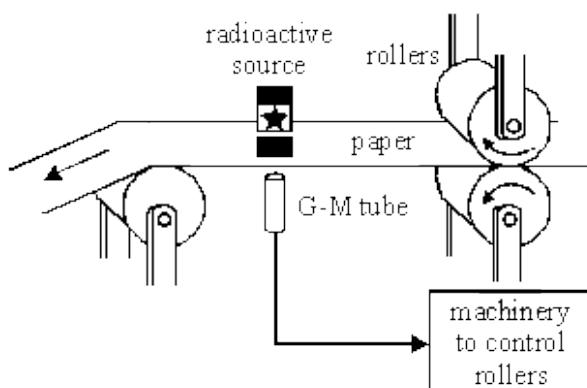
(2)
(Total 11 marks)

18 The diagram below shows a method of controlling the thickness of paper produced at a paper mill. A radioactive source which emits beta radiation is placed on one side of the paper and a radiation detector is placed on the other.

(a)   How will the amount of radiation reaching the detector change as the paper gets thicker?

....

....

(1)

(b)   Explain, as fully as you can:

(i)   why a radioactive source which emits alpha (α) radiation could **not** be used for this
application.

....

....

....

....

(1)

(ii)   why a radioactive source which emits gamma (γ) radiation could **not** be used for this
application.

....

....

....

....

(1)

(iii)   why a radioactive source which emits beta (β) radiation **can** be used for
this application.

....

....

....

....

(2)

(c)   Americium-241 is a radioisotope used in smoke detectors. It has a proton number of 95 and a mass number of 241.

How long would it take the americium-241 in a smoke detector to decrease to one eighth of its original number of radioactive atoms?

....

....

....

Answer = ...

(3)
(Total 8 marks)

19   People who work in places where radiation is present, for example in X-ray departments in hospitals, have to wear a "film badge". These badges are sent away regularly to check on the amount of radiation to which the person has been exposed. Simply described, the badge is some photographic film in a suitable holder.

(a)   (i)   Why is the "film badge" of little use in detecting alpha particles?

....

(1)

(ii)   How does the "film badge" show radiation has reached it?

....

(1)

(b)   Radioactivity can cause harm. It also has a number of valuable uses.

(i)   How can radioactivity harm our bodies?

....

....

(1)

(ii)   Give **two** medical uses of radioactive isotopes.

1. ....

2. ....

(2)

(c)   A radioactive isotope of lead has a half-life of 10.6 hours.

A small sample of lead containing this isotope has a count rate of 8000 counts per minute.

How long will it be before the count rate is 1000 counts per minute?

....

....

Time = ... hours

(2)
(Total 7 marks)

20   (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.
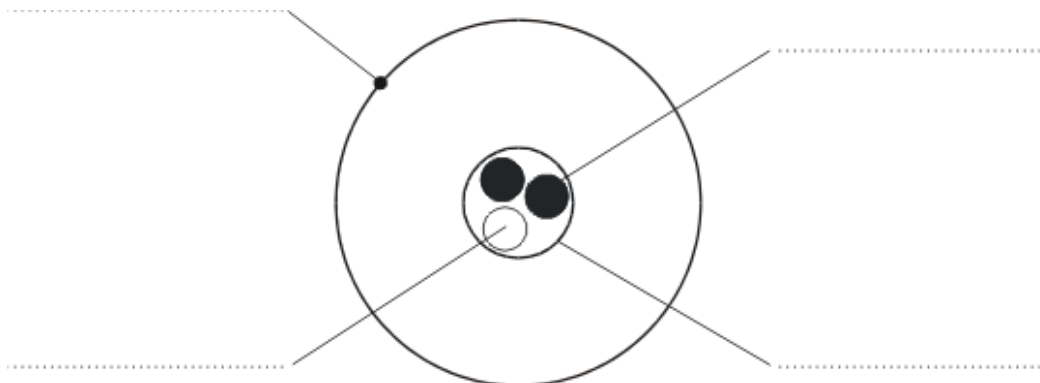
(4)

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

....

....

....

(2)

(iii)   Tritium is a radioactive substance which emits beta (β) 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 (α), beta (β) and gamma (γ) radiation.
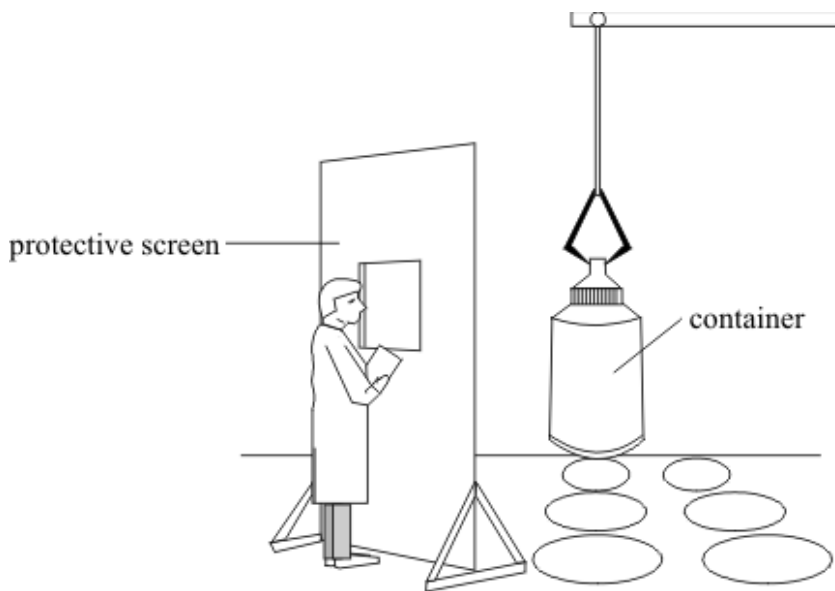
Suggest a suitable material for the protective screen. The material should prevent radiation from the container reaching the worker. Explain your answer.

....

....

....

(2)
(Total 10 marks)

21 (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, ($^{40}_{19}K$).

Another isotope, potassium-40, ($^{40}_{19}K$), 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)

22 (a) A radioactive isotope has a half-life of 10 minutes.
At the start of an experiment, the activity of a sample of this isotope was 800 counts per second after allowing for background radiation.

Calculate how long it would be before the activity fell from 800 counts per second to 200 counts per second.

....

....

Time .... min.

(2)

(b)   A physicist investigates a solid radioactive material. It emits alpha particles, beta particles and gamma rays.
The physicist does not touch the material.

Explain why the alpha particles are less dangerous than the beta particles and gamma rays.

....

....

....

....

(2)
(Total 4 marks)

23 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.
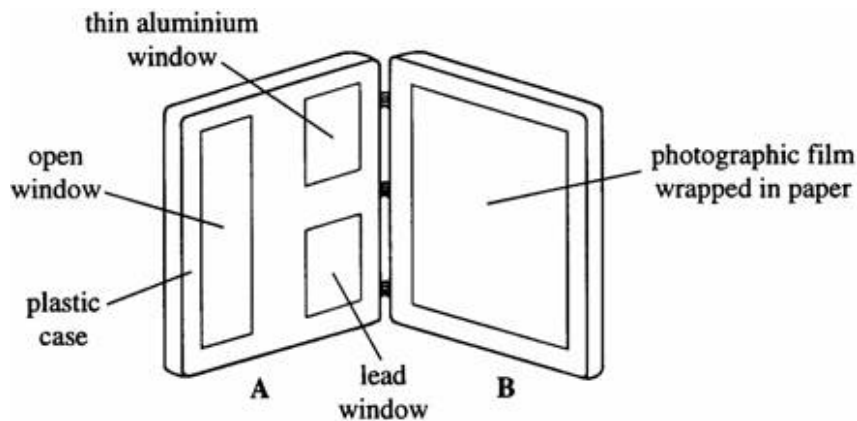
(a)   The detector is a piece of photographic film wrapped in paper inside part **B** of the badge.
Part **A** has "windows" as shown.

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)

24   The diagram shows a badge worn by a worker at a nuclear power station.

Part of the outer black paper has been removed so that you can see the inside of the badge.
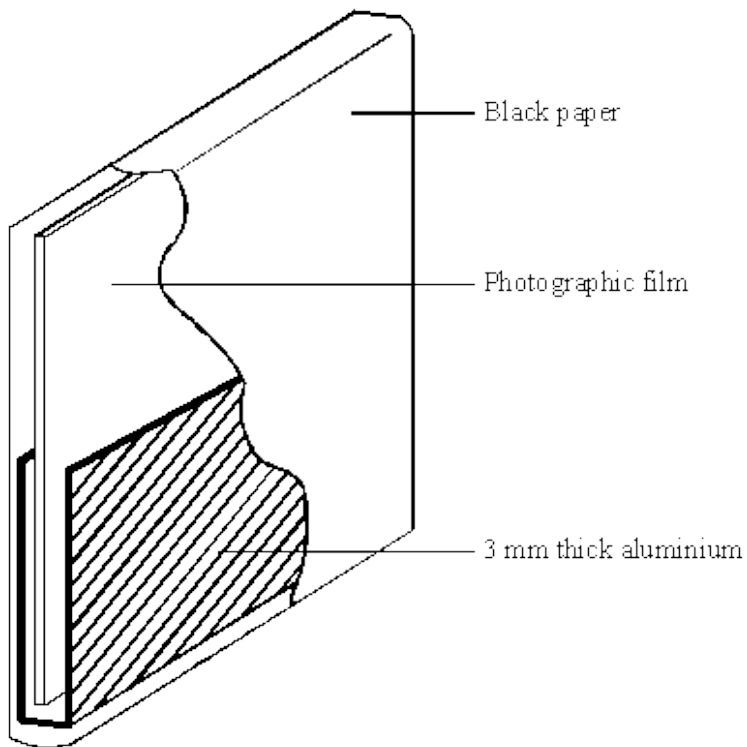
Scientists examined the worker's badge at the end of a day's work.

They found that the top part of the badge had been affected by radiation, but the bottom half had not.

What type of radiation had the worker been exposed to? Explain the reasons for your answer.

....

....

....

....

(Total 2 marks)

25 The diagram shows how the thickness of aluminium foil is controlled. The thicker the aluminium foil, the more radiation it absorbs.
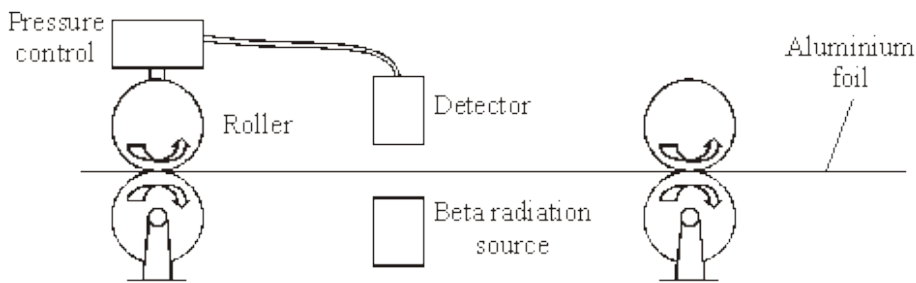
(a)   The designers used a beta radiation source for this control system.

(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)

26 (a) (i)   Describe the structure of alpha particles.

....

....

....

....

(2)

(ii)   What are beta particles?

....

....

....

(1)

(b)   Describe how beta radiation is produced by a radioactive isotope.

....

....

(1)
(Total 4 marks)

27 Iodine-131 (^{131}I) is a radioactive isotope used in medicine.

The graph shows how the count rate of a sample of iodine-131 changed over 24 days.
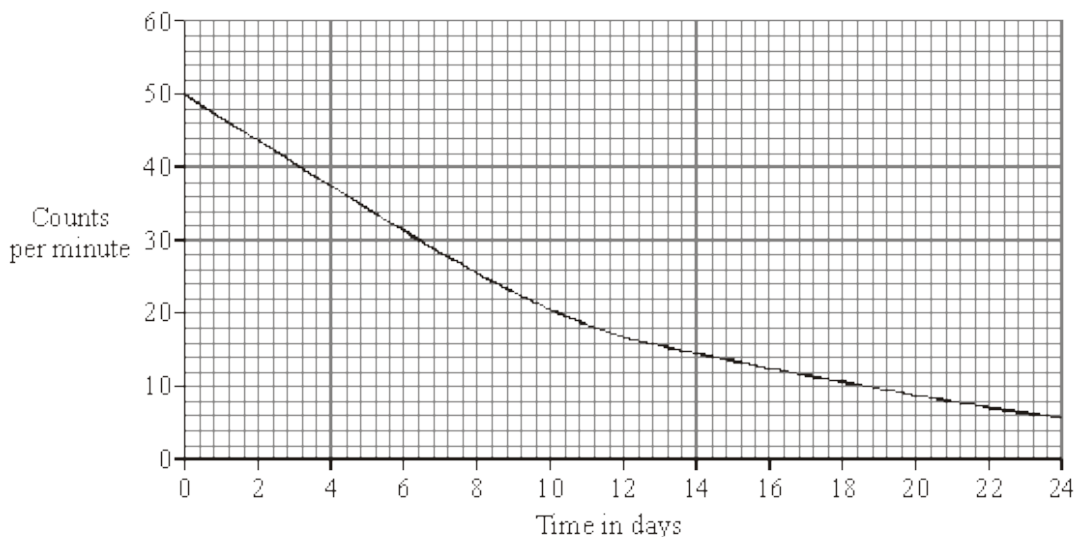
(i)   Use the graph to calculate the half-life of iodine-131. To obtain full marks you should show clearly how you work out your answer.

....

....

....

Half-life .... days

(2)

(ii)   Iodine-131 is used to destroy cancer cells in the human thyroid gland.

Explain why the length of the half-life of iodine-131 is important in this use.

....

....

....

....

(2)
(Total 4 marks)

28 (a) (i) Describe the structure of alpha particles.

....

....

....

....

(2)

(ii) What are beta particles?

....

....

....

(1)

(b) Describe how beta radiation is produced by a radioactive isotope.

....

(1)
(Total 4 marks)

29 Some students measure the level of radiation from a radioactive source during the same lesson each week over a period of six weeks.

Here are the results. (They have been corrected for background radiation.)

Time (weeks)	start	1	2	3	4	5	6
Level of radiation (average counts per minute)	66	44	34	29	16	12	8

(a)   Using the graph paper below, display these results in the most appropriate way.
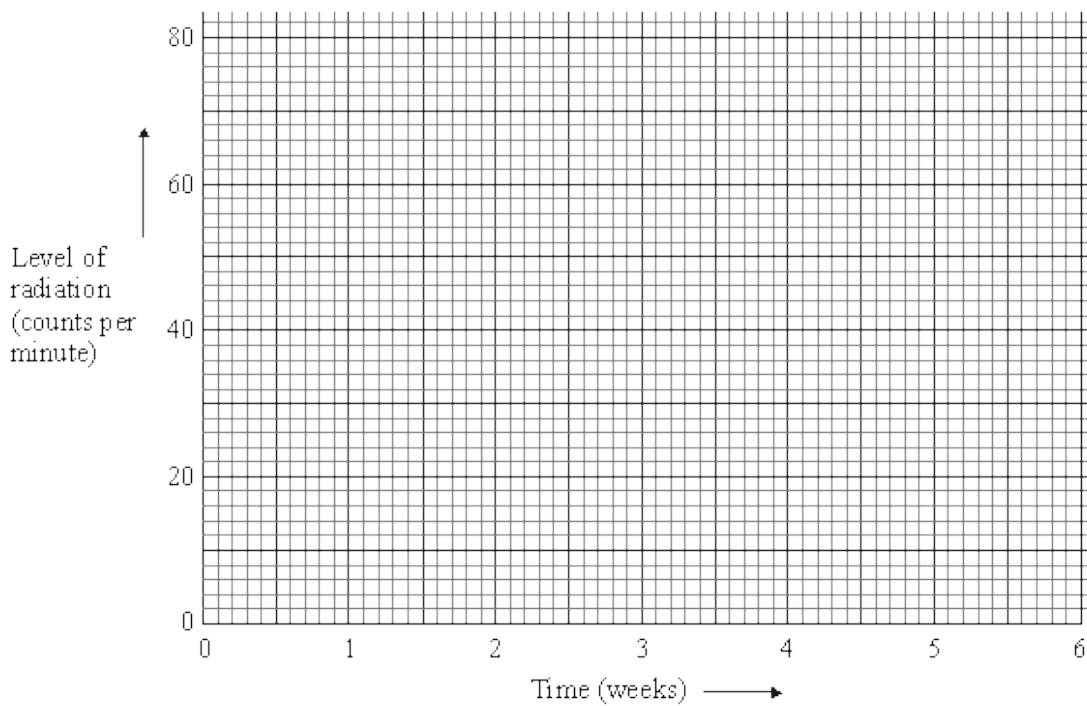
(5)

(b)   What overall pattern is there in the students' results?

....

....

....

(3)
(Total 8 marks)

30   The diagram shows a helium atom.
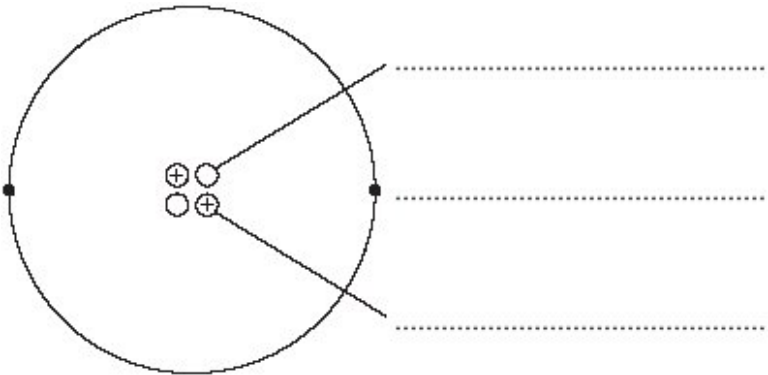
(a)   (i)   Use the words in the box to label the diagram.

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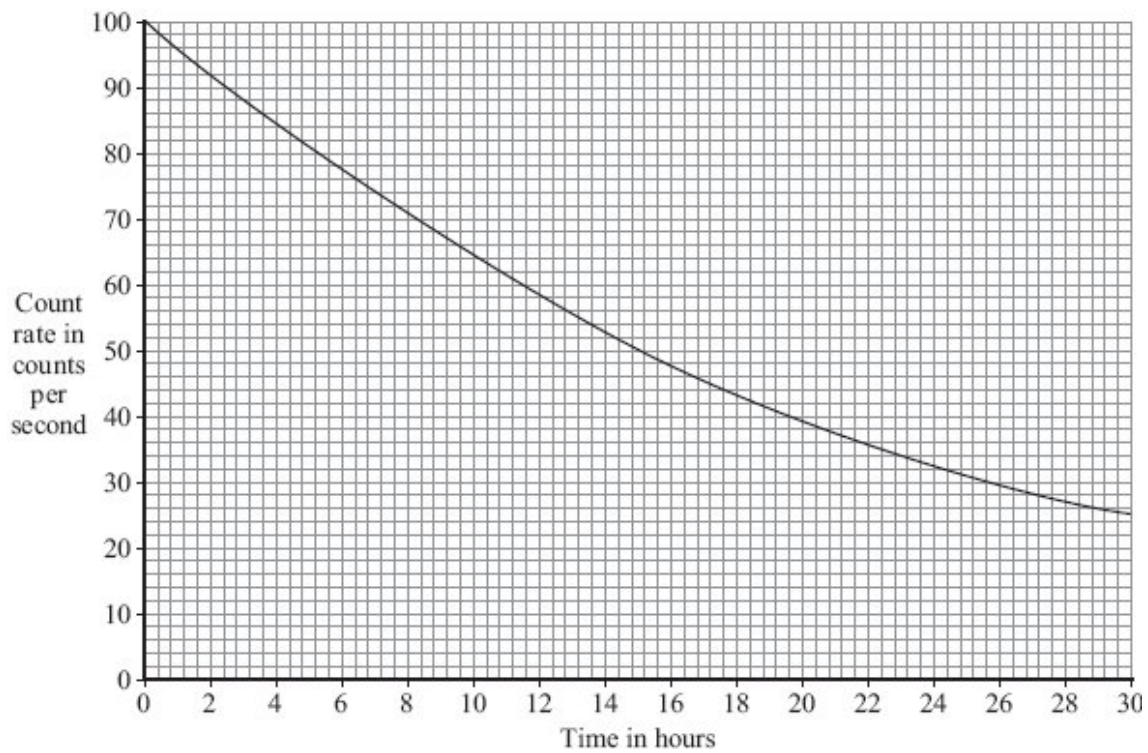
(i)   How many hours does it take for the count rate to fall from 100 counts per second to 50 counts per second?

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)

31 A teacher measured the amount of radiation from a radioactive source, during the same lesson each week, over a period of six weeks.

The results are shown on the graph.
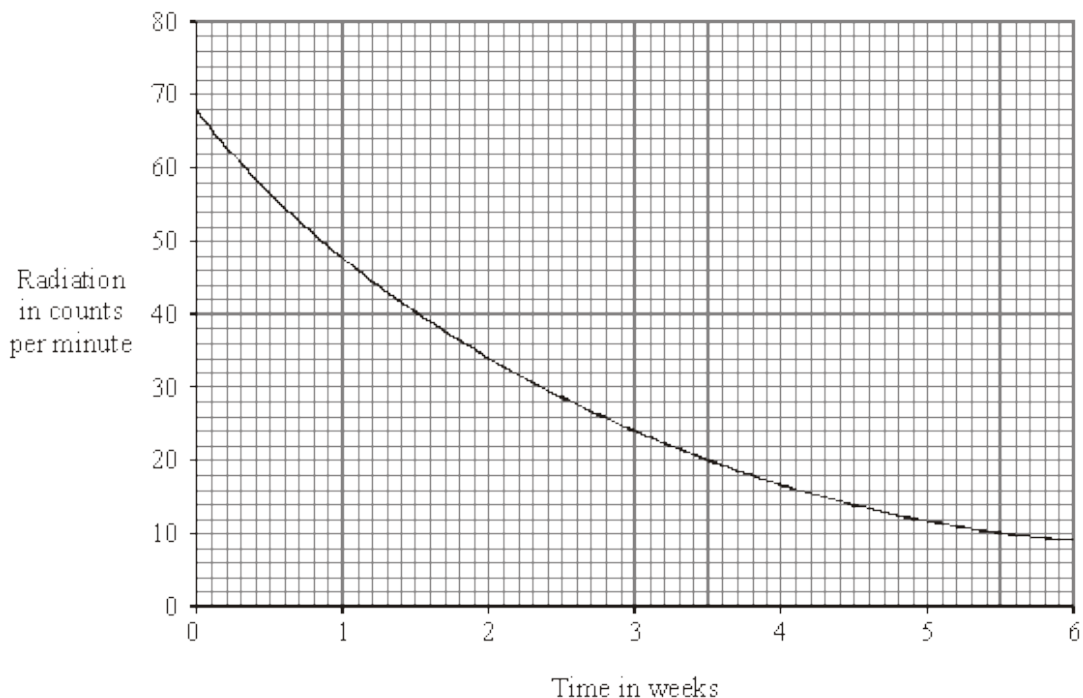
How long does it take for the radiation to fall from 68 counts per minute to half that value?

Show clearly how you work out your answer.

....

....

....

Time taken for radiation to halve ....

(Total 3 marks)

32 $^{99}_{43}Tc$ (technetium) is produced by the radioactive decay of $^{99}_{42}Mb$ (molybdenum).

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

....

....

(Total 1 mark)

33 The isotope of sodium with a mass number of 24 is radioactive. The following data were obtained in an experiment to find the half-life of sodium-24.

Time in hours	Count rate in counts per minute
0	1600
10	1000
20	600
30	400
40	300
50	150
60	100

(a) Draw a graph of the results and find the half-life for the isotope. On the graph show how you obtain the half-life.

Count rate in counts per minute

Time in hours
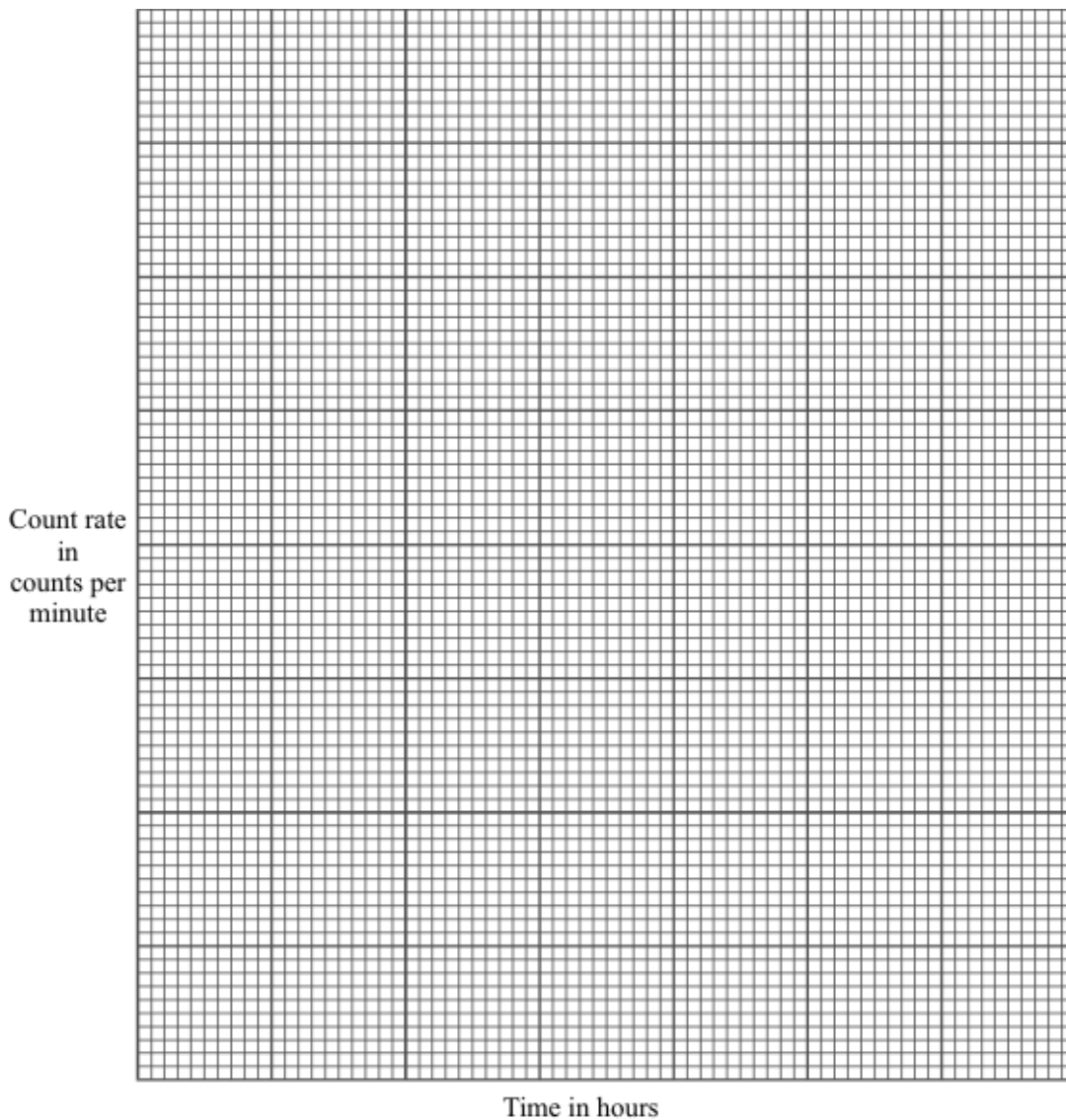
Half-life = ... hours

(4)

(b) Sodium-24 decays by beta emission. The G.M. tube used in the experiment is shown in the diagram. Each beta particle which gets through the glass causes a tiny electric current to pass in the circuit connected to the counter.

Solution containing sodium-24

Thin glass wall of G.M. tube

Anode   Cathode
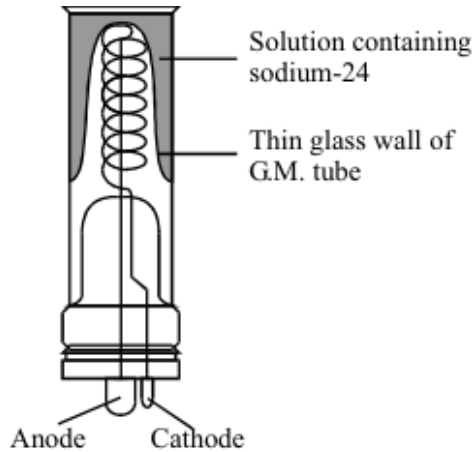
(i) Why must the glass wall of the G.M. tube be very thin?

....

....

(1)

(ii) Why is this type of arrangement of no use if the radioactive decay is by alpha emission?

....

....

(1)

(c) Sodium chloride solution is known as saline. It is the liquid used in 'drips' for seriously-ill patients. Radioactive sodium chloride, containing the isotope sodium-24, can be used as a tracer to follow the movement of sodium ions through living organisms.

Give **one** advantage of using a sodium isotope with a half-life of a few hours compared to using an isotope with a half-life of:

(i) five years; ....

....

(1)

(ii) five seconds. ....

....

(1)
(Total 8 marks)

34 A simple spark counter can be used to detect charged particles. It is made by having two wires close together with a large voltage across them. When a charged particle passes through the gap between the wires a spark is seen.

(a)   Give the names and symbols of **two** particles which will cause a spark.

(i)   Name ....   Symbol ....

(2)

(ii)   Name ....   Symbol ....

(2)

(b)   A radioactive source was placed within 2 cm of the spark counter and lots of sparks were seen. A piece of paper was slid between the source and the counter. The sparking stopped.

(i)   What type of radiation was being given off?

....

(1)

(ii)   The paper was removed and the source slowly moved away from the spark counter. Describe what will happen to the sparking.

....

....

....

(2)

(c)   A radioactive source gave a high reading using a Geiger-Müller tube and counter, but did not cause sparking when brought near to the spark counter. Why?

....

....

(1)
(Total 8 marks)

35

Some rocks contain the radioactive isotope uranium–235 (^{235}U).

^{235}U has a half-life of 700 million years and, as it decays, lead–207 (^{207}Pb) is eventually formed.

(a)   Draw a decay curve for ^{235}U on the graph below.

Proportion of uranium –235 remaining

Time (millions of years)
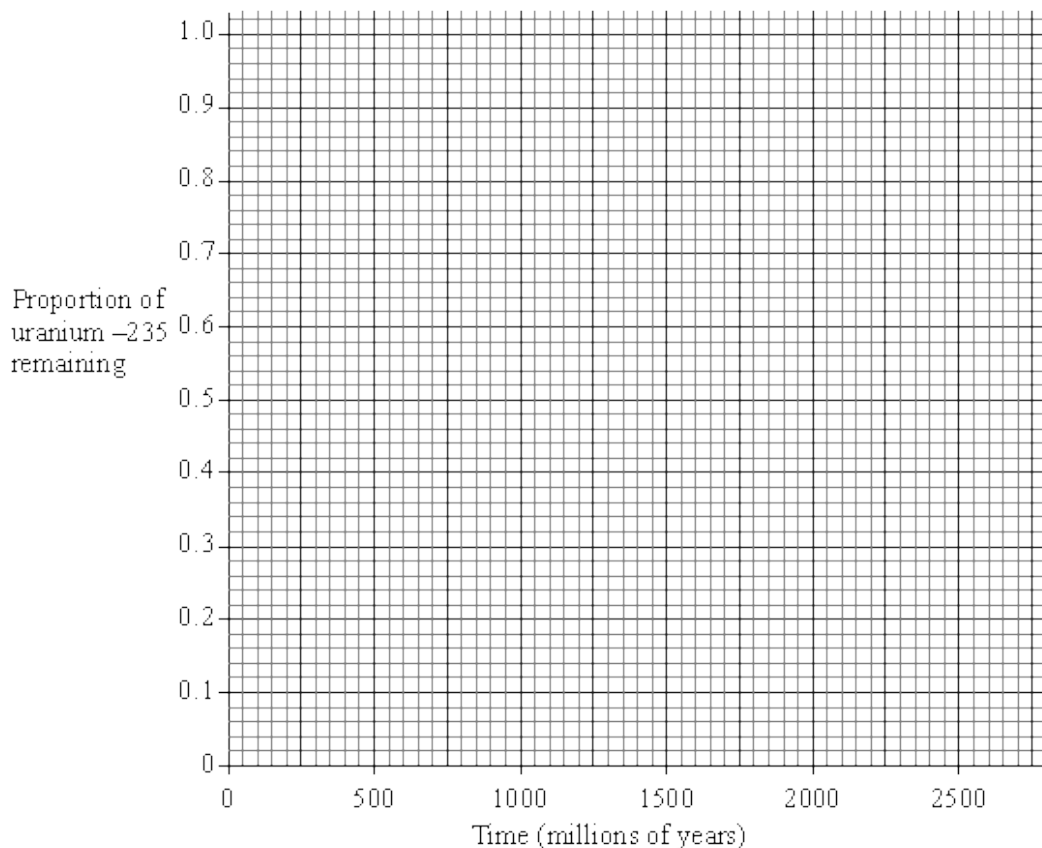
(4)

(b)   Samples of an igneous rock gave an average ratio of 70 atoms of ^{235}U to 30 atoms of 207 Pb.

Use the decay curve you have drawn to estimate the age of the igneous rock.

Answer .... million years.

(1)

(c)   A sandstone rock which lies above the igneous rock contains traces of uranium-235 and of lead-207.

Why might it be unsatisfactory to use this uranium for dating the sandstone?

....

....

....

....

(2)
(Total 7 marks)

36 (a) When an atom of thorium-232 decays, an alpha (α) particle is emitted from the nucleus. An atom of radium is left behind.

An alpha particle consists of two protons and two neutrons.

We can represent this radioactive decay in a special kind of equation:

$$^{232}_{90}Th \longrightarrow \ ^{4}_{2}a \ + \ ^{228}_{88}Ra$$

◄- - - number of nucleons (protons + neutrons)

◄- - - number of protons
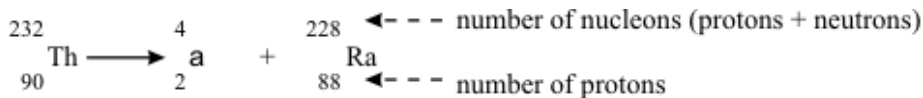
Thorium-228 is also radioactive.

Atoms of this isotope also decay by emitting an alpha particle and producing an isotope of radium.

Complete the equation for this decay.

$$^{228}_{90}Th \longrightarrow$$
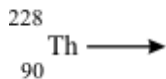
(4)

(b) An atom of radium-228 decays by emitting a beta (β) particle from the nucleus.

A beta particle is in fact an electron (symbol $^{0}_{-1}e$).

The effect of this is to change a neutron into a proton.

An atom of actinium remains.

This type of decay can also be represented by an equation:

$$^{228}_{88}Ra \longrightarrow \ ^{0}_{-1}e \ + \ ^{228}_{89}Ac$$

◄- - - number of nucleons (protons + neutrons)

◄- - - number of protons
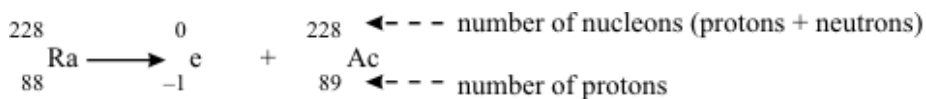
This isotope of actinium is radioactive.

An atom of actinium-228 also decays by emitting a beta particle.

An isotope of thorium is left behind.

Complete the equation for this decay.

$$^{228}_{89}\text{Ac} \longrightarrow$$
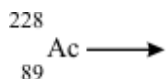
(4)

(c)   Thorium-232 eventually decays to the stable isotope lead-208.

All the steps in this process can be shown on a diagram.
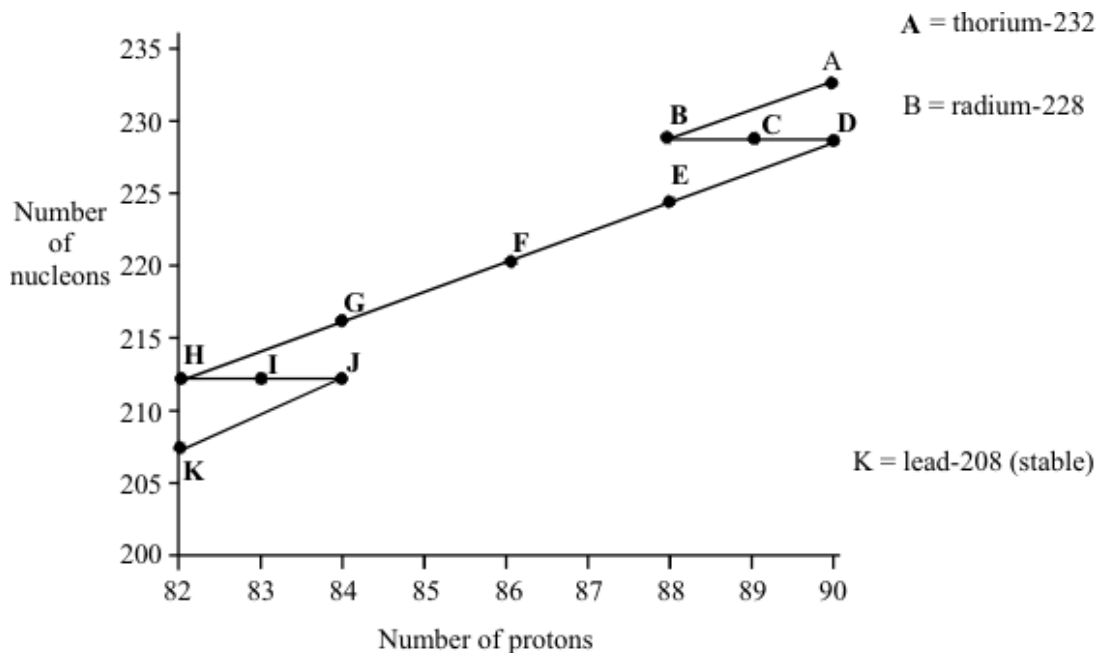
(i)   Complete the sentences:

During the decay from (A) to (B) a .... particle is emitted.

During the decay from (B) to (C) a .... particle is emitted.

During the decay from (E) to (F) a .... particle is emitted.

During the decay from (I) to (J) a .... particle is emitted.

(2)

(ii)   The table shows how long it takes for half of the atoms of each isotope to decay.

ISOTOPE	TIME FOR HALF TO DECAY
A	billions of years
B	7 years
C	6 years
D	2 years
E	4 days
F	1 minute
G	0.4 seconds
H	10 hours
I	1 hour
J	0.3 microseconds

A rock sample contains:

- many atoms of thorium-232

- even more atoms of lead-208

- hardly any atoms of any of the other isotopes shown on the diagram

Explain this as fully as you can.

....

....

....

....

....

(3)
(Total 13 marks)

37 Doctors sometimes need to know how much blood a patient has.

They can find out by using a radioactive solution.

After measuring how radioactive a small syringe-full of the solution is they inject it into the patient's blood.

YOUR BLOOD CIRCULATION
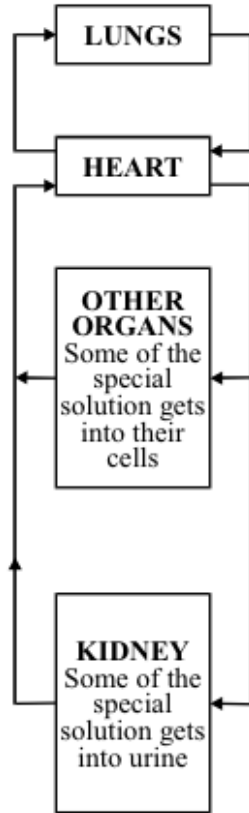
They then wait for 30 minutes so that the solution has time to become completely mixed into the blood.

Finally, they take a syringe-full of blood and measure how radioactive it is.

Example:

If the doctor injects 10 cm^3 of the radioactive solution and this is diluted 500 times by the blood there must be 10 × 500 = 5000 cm^3 of blood.

(a) After allowing for background radiation:

- 10 cm^3 of the radioactive solution gives a reading of 7350 counts per minute;

- a 10 cm^3 sample of blood gives a reading of 15 counts per minute.

Calculate the volume of the patient's blood.
(Show your working.)

....

....

....

....

(4)

As time passes, the solution becomes less radioactive **on its own.**

LEVEL OF RADIATION

TIME (h)
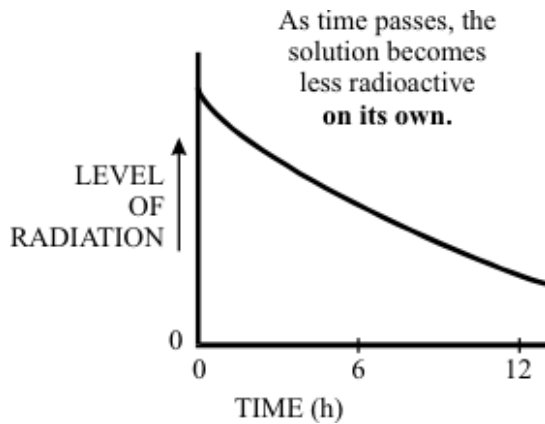
Radiation from radioactive substances can harm your body cells.

(b) The doctor's method of estimating blood volume will not be completely accurate. Write down **three** reasons for this.

1 ....

2 ....

3 ....

(3)

(c) The doctors use a radioactive substance which loses half of its radioactivity every six hours. Explain why this is a suitable radioactive substance to use.

....

....

(2)
(Total 9 marks)

38 The diagram shows what happens to the radiation from three radioactive substances when different materials are put in the way.
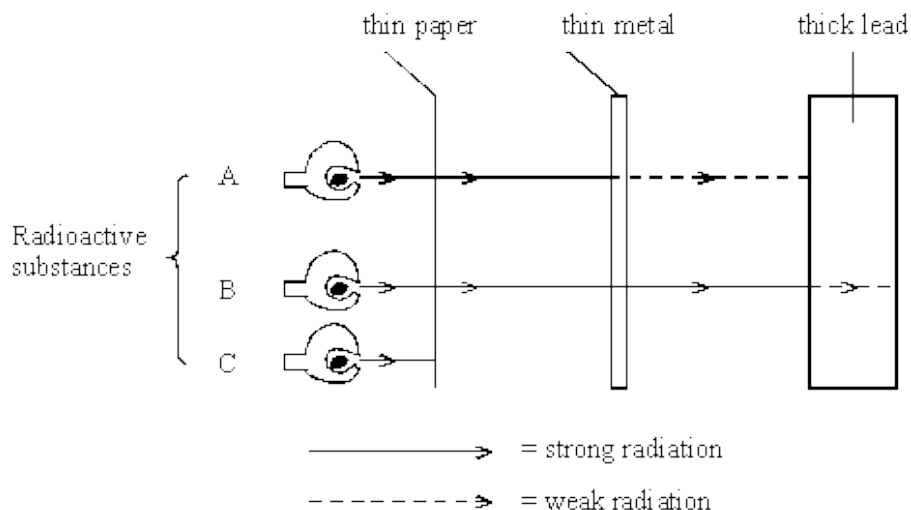
Choose types of radiation from this list to complete the table below.

α (**alpha**)   β (**beta**)   γ (**gamma**)   UV **(ultraviolet)**

RADIOACTIVE SUBSTANCE	TYPE OF RADIATION IT EMITS
A	
B	
C	

(Total 3 marks)

39 The graph shows how the amount of radiation emitted by a sample of the radionuclide uranium 238 (U^{238}) changes as time passes.
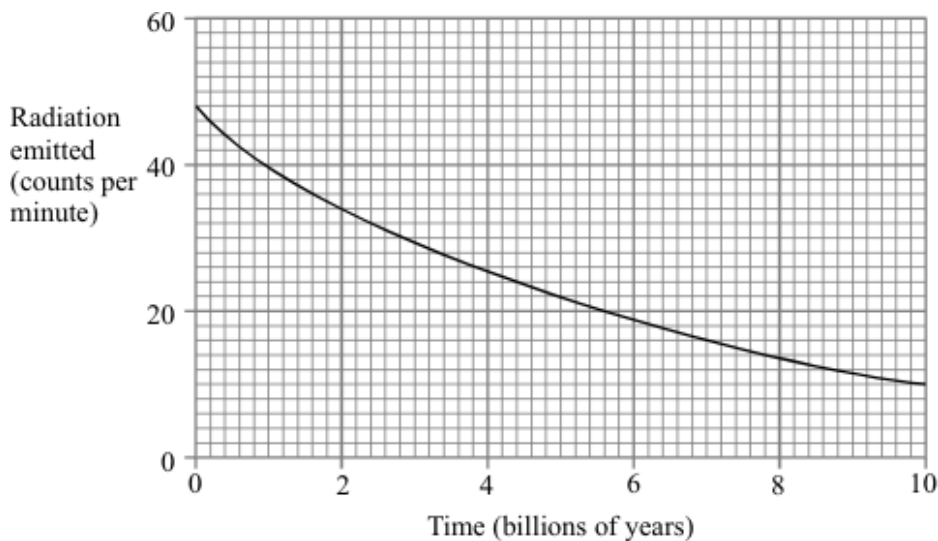
(a)   What is the half-life of uranium 238 (U^{238})?
        (You should show how you obtained your answer. You may do this on the graph
        if you wish.)

        ....

        ....

                                        Answer ....

                                                                                                            (3)

(b)   What fraction (or percentage) of the uranium 238 (U^{238}) atoms will have decayed after
        9 billion years?

        ....

                                                                                                            (1)

(c)   Uranium 238 (U^{238}) decays through a long series of intermediate radionuclides to stable
        atoms of the isotope lead 206 (Pb).

        A sample of igneous rock contains 3 atoms of uranium 238 (U^{238}) for every atom of lead
        206 (Pb^{206}).

        (i)   The intermediate radionuclides are not important when estimating the age of the rock.
                Explain why.

                ....

                ....

                                                                                                            (1)

        (ii)   Estimate the age of the rock.
                (You should explain how you obtained your answer.)

                ....

                ....

                ....

                                        Answer .... billion years

                                                                                                            (3)
                                                                                            (Total 8 marks)

40 When atoms of uranium 238 (U^{234}) decay they produce another radionuclide called thorium 234 (Th^{234})

Thorium 234 (Th^{234}) decays by emitting beta radiation.

(i) What does beta radiation consist of?

....

(1)

(ii) Thorium 234 (Th^{238}) decays to form protactinium 234 (Pa^{234}).

What differences are there between the nucleus of a protactinium 234 (Pa^{234}) atom and the nucleus of a thorium 234 (Th^{234}) atom?

....

....

(2)
(Total 3 marks)

41 (a) The diagram shows the parts of a smoke detector. The radioactive source emits alpha particles.
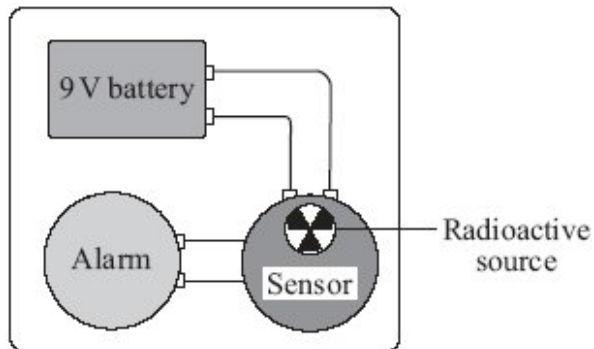
The alpha particles ionise the air inside the sensor which causes a small electric current. Any smoke getting into the sensor changes the current. The change in current sets the alarm off.

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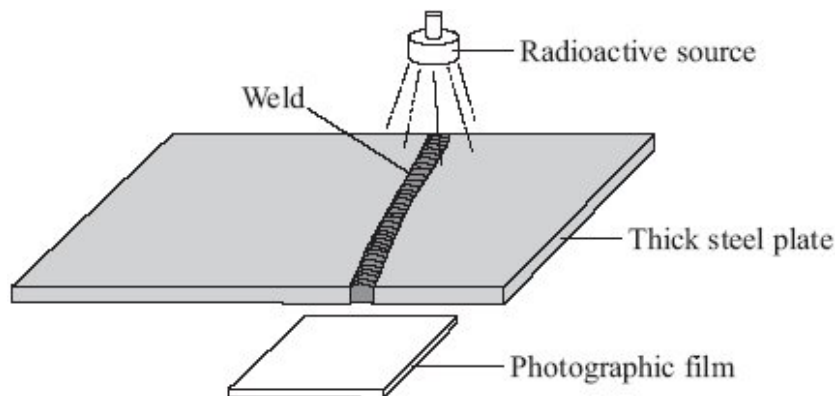
Cracks in the weld will be shown up on the photographic film below the thick steel plate.

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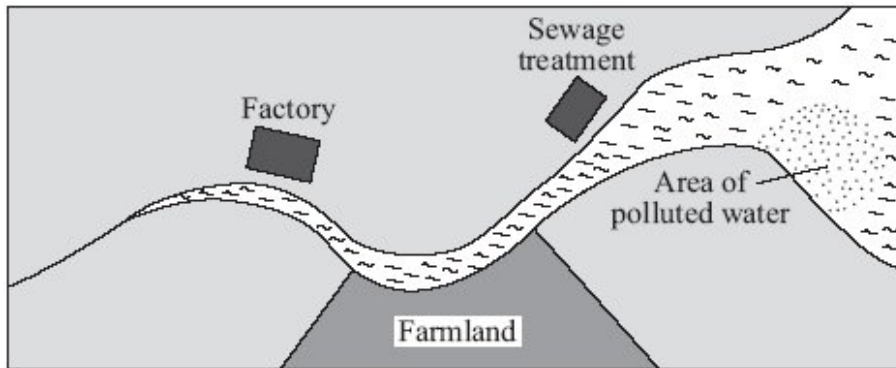
(i) Explain how the gold-198 is used to find where the pollution is coming from.

....

....

....

....

(2)

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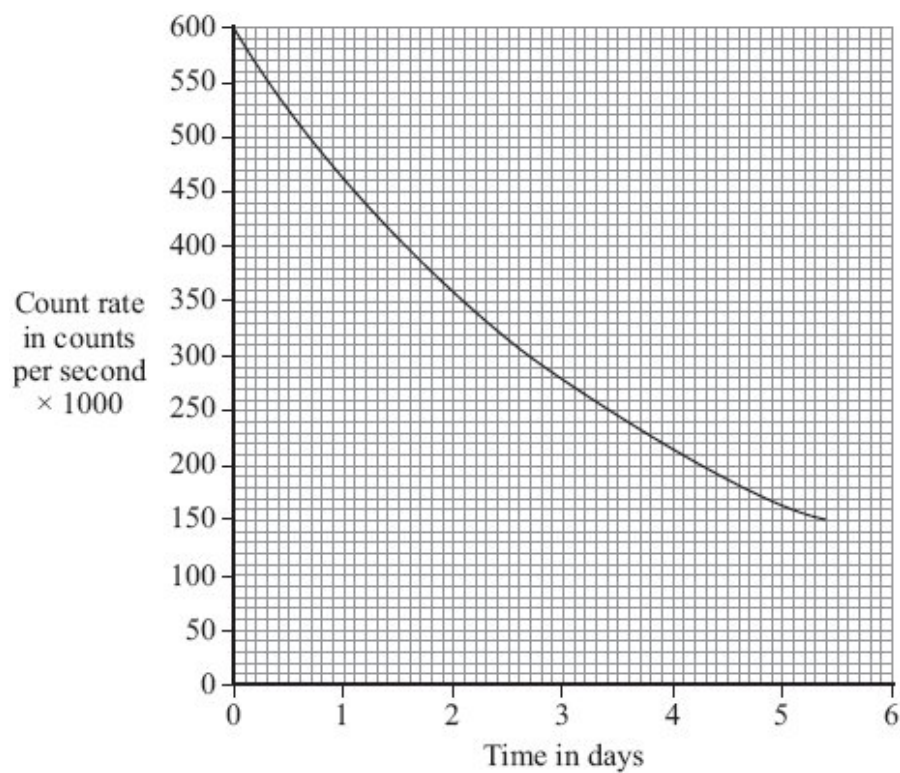
Use the graph to calculate the half-life of gold-198.

Show clearly on the graph how you obtain your answer.

....

....

Half-life = ... days

(2)
(Total 9 marks)

42 (a) The names of the three types of nuclear radiation are given in **List A**.
Some properties of these types of radiation are given in **List B**.

Draw a straight line to link each type of radiation in **List A** to its correct property in **List B**.

Draw only **three** lines.

List A
Type of nuclear radiation

List B
Property of radiation

| Alpha |

| Has the same mass as an electron |

| Very strongly ionising |

| Beta |

| Passes through 10 cm of aluminium |

| Gamma |

| Deflected by a magnetic field but not deflected by an electric field |

(3)

(b)   The diagram shows a system used to control the thickness of cardboard as it is made.
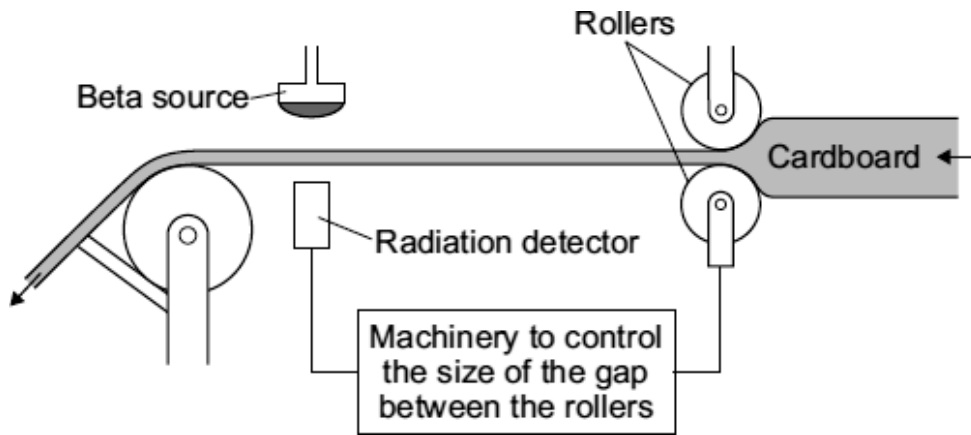
The cardboard passes through a narrow gap between a beta radiation source and a radiation detector.

The table gives the detector readings over 1 hour.

Time	Detector reading
08:00	150
08:15	148
08:30	151
08:45	101
09:00	149

(i)   Between 08:00 and 08:30, the cardboard is produced at the usual, correct thickness.

Explain how you can tell from the detector readings that the cardboard produced at 08:45 is thicker than usual.

....

....

....

....

(2)

(ii)   Which would be the most suitable half-life for the beta source?

Draw a ring around your answer.

                    six days   six months   six years

(1)

(iii)   This control system would **not** work if the beta radiation source was replaced by an alpha radiation source.

Why not?

....

....

43   The diagram shows a system used to control the thickness of aluminium foil as it is being rolled. A radiation source and detector are used to monitor the thickness of the foil.
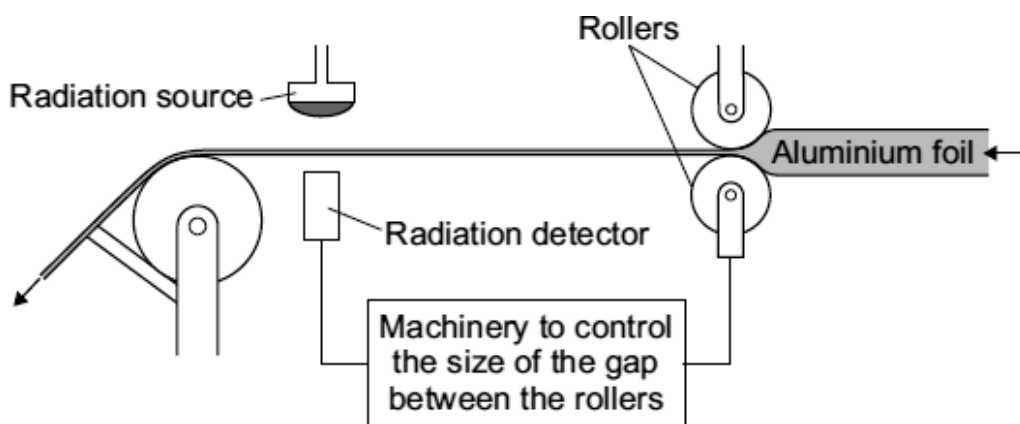
(a)   Which type of source, alpha, beta or gamma, should be used in this control system?

....

Explain why each of the other two types of source would **not** be suitable.

....

....

....

....

(3)

(b)   The chart shows how the count rate recorded by the detector varies over a short period of time.
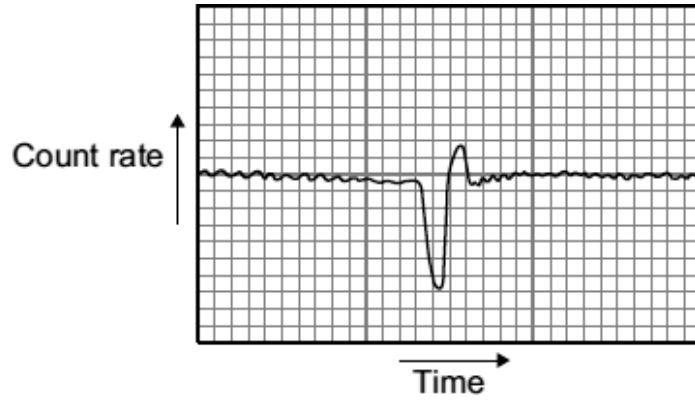
Use the graph to explain how the thickness of the foil changes, and how the control system responds to this change.

....

....

....

....

(2)

(c)   When first used, the radiation source contains 6 micrograms of strontium-90.
      The graph shows how the mass of the strontium-90 will decrease as the nuclei decay.
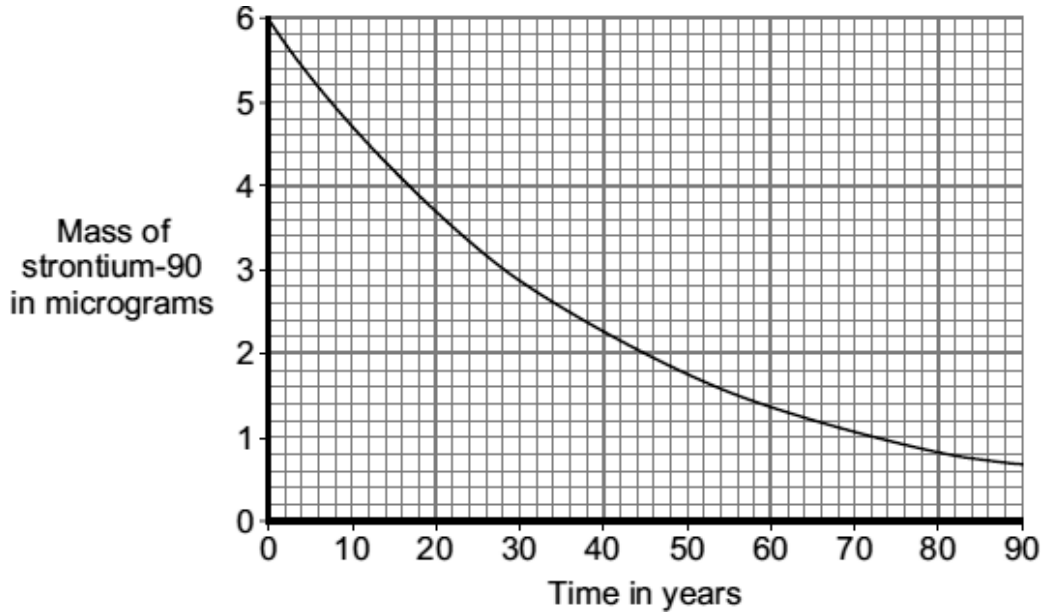
The control system will continue to work with the same source until 75 % of the original strontium-90 nuclei have decayed.

After how many years will the source need replacing?

Show clearly your calculation and how you use the graph to obtain your answer.

....

....

....

                          Number of years = ...

(2)
(Total 7 marks)

44 (a)   The diagram represents a helium atom.
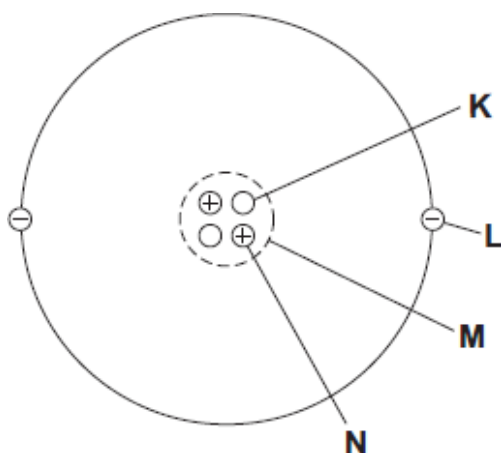
(i)   Which part of the atom, **K**, **L**, **M** or **N**, is an electron?

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.
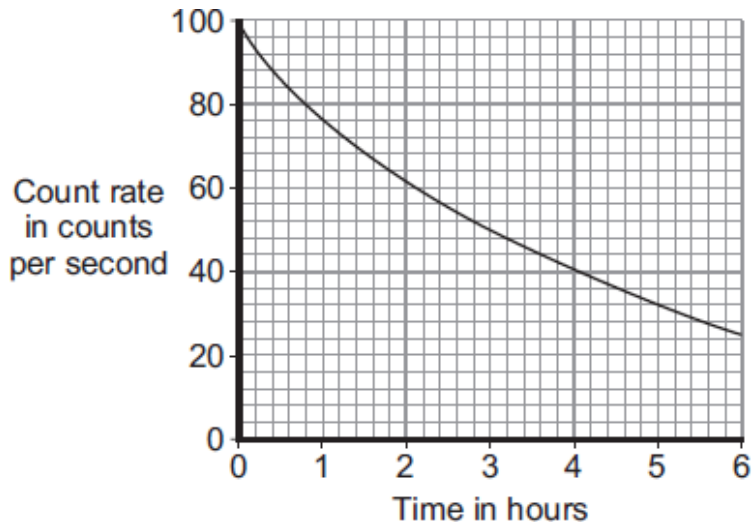
What is the count rate after 4 hours?

.... counts per second

(1)
(Total 4 marks)

45   (a)   Carbon has three naturally occurring isotopes. The isotope, carbon-14, is radioactive.
        An atom of carbon-14 decays by emitting a beta particle.

(i)   Complete the following sentences.

The atoms of the three carbon isotopes are the same as each other because

....

The atoms of the three carbon isotopes are different from each other because

....

(2)

(ii)   What is a beta particle and from what part of an atom is it emitted?

....

....

(1)

(b) Carbon-14 is constantly being made in the atmosphere, yet for most of the last million years, the amount of carbon-14 in the atmosphere has not changed.

How is this possible?

....

....

(1)

(c) Trees take in carbon-12 and carbon-14 from the atmosphere. After the tree dies, the proportion of carbon-14 that the tree contains decreases.

Graph **A** shows the decay curve for carbon-14.

Graph **A**
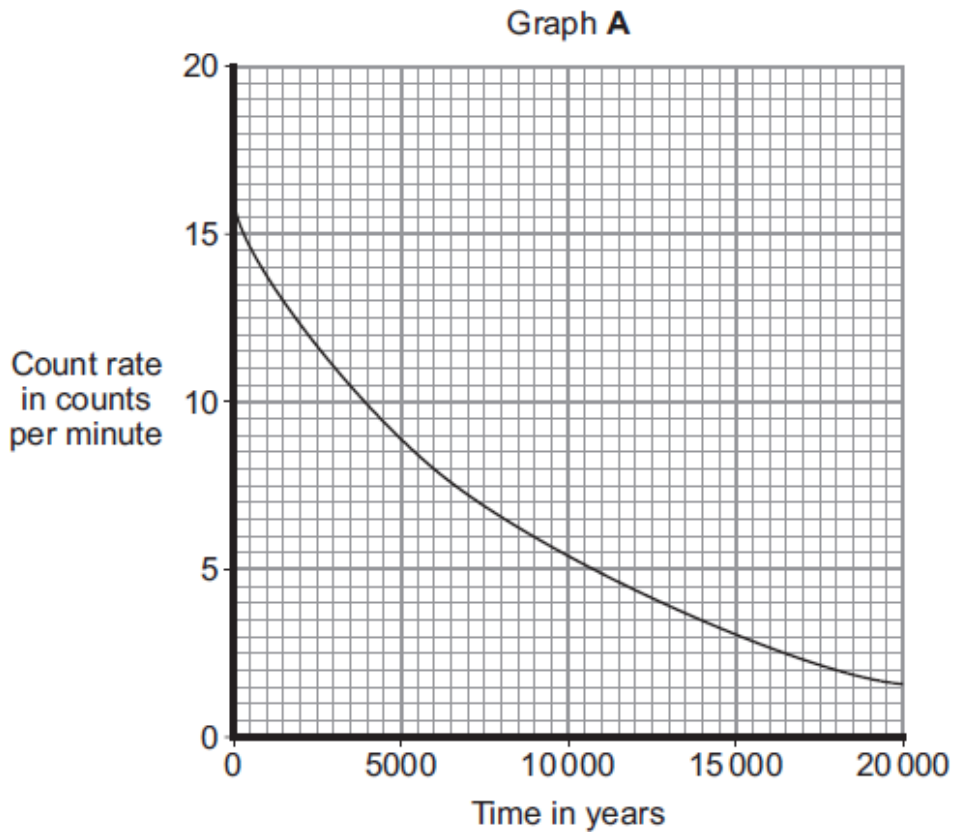
(i) Lake Cuicocha in Ecuador was formed after a volcanic eruption.
Carbon taken from a tree killed by the eruption was found to have a count rate of 10.5 counts per minute.
At the time of the eruption, the count rate would have been 16 counts per minute.

Use graph **A** to find the age of Lake Cuicocha.

Age of Lake Cuicocha = ... years

(1)

(ii) Finding the age of organic matter by measuring the proportion of carbon-14 that it contains is called carbon dating. This technique relies on the ratio of carbon-14 to carbon-12 in the atmosphere remaining constant. However, this ratio is not constant so the age found by carbon dating needs to be adjusted.
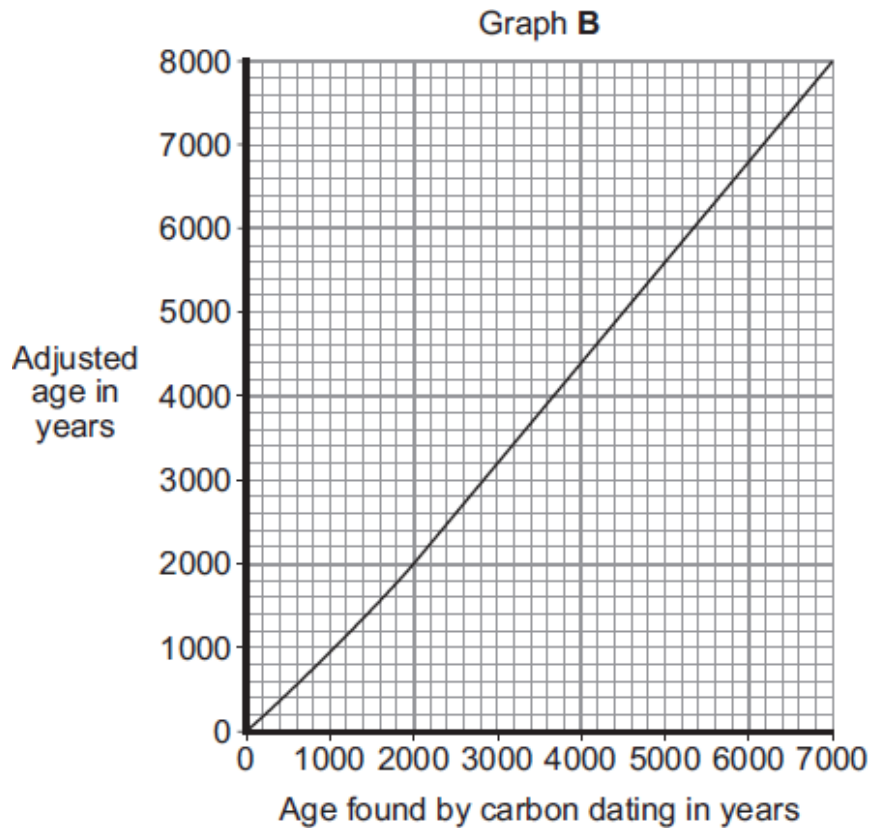
Graph **B**

Graph **B** is used to adjust the age of an object found by carbon dating.
The value obtained from graph **B** will be no more than 50 years different to the true age of the object.

Use graph **B** and the information above to find the maximum age that Lake Cuicocha could be.

Show clearly how you obtain your answer.

....

....

Maximum age of Lake Cuicocha = ... years

(2)
(Total 7 marks)

46 Some rocks inside the Earth contain a radioactive element, uranium-238. When an atom of uranium-238 decays, it gives out an alpha particle.

(a) The following statement about alpha particles was written by a student.
The statement is **not** correct.

> *Alpha particles can pass through a very thin sheet of lead.*

Change **one** word in the statement to make it correct.

Write down your **new** statement.

....

....

(1)

(b) The graph shows how the count rate from a sample of uranium-238 changes with time.
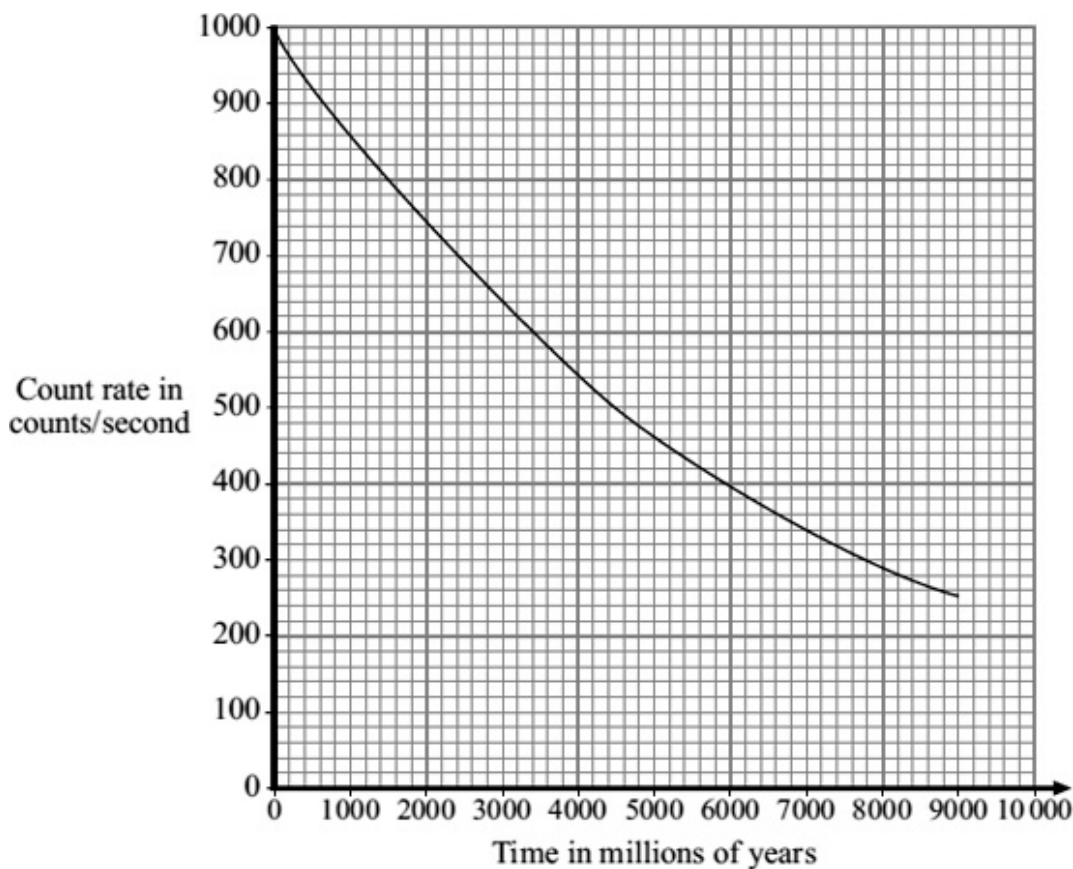
The graph can be used to find the half-life of uranium-238. The half-life is 4 500 million years.

(i) Draw on the graph to show how it can be used to find the half-life of uranium -238.

(1)

(ii)   There is now half as much uranium-238 in the rocks as there was when the Earth was formed.

How old is the Earth?

Draw a ring around your answer.

2250 million years   4500 million years   9000 million years

(1)

(iii)   If a sample of uranium-238 were available, it would not be possible to measure the half-life in a school experiment.

Explain why.

....

....

....

....

(2)
(Total 5 marks)

47   (a)   Some rocks inside the Earth contain uranium-238, a radioactive isotope of uranium. When an atom of uranium-238 decays, it gives out radiation and changes into a thorium-234 atom.
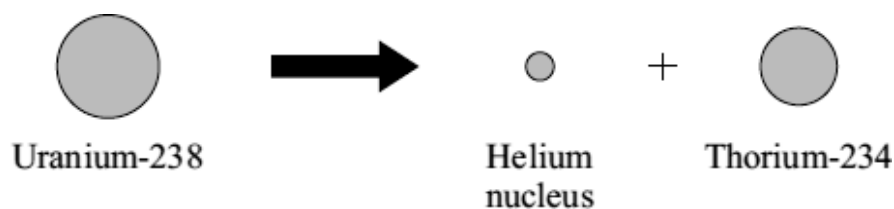
(i)   What type of radiation is emitted when a uranium-238 atom decays?

....

(1)

(ii)   From which part of a uranium-238 atom is the radiation emitted?

....

(1)

(iii)   Uranium-235 is another isotope of uranium.

How is an atom of uranium-235 similar to an atom of uranium-238?

....

(1)

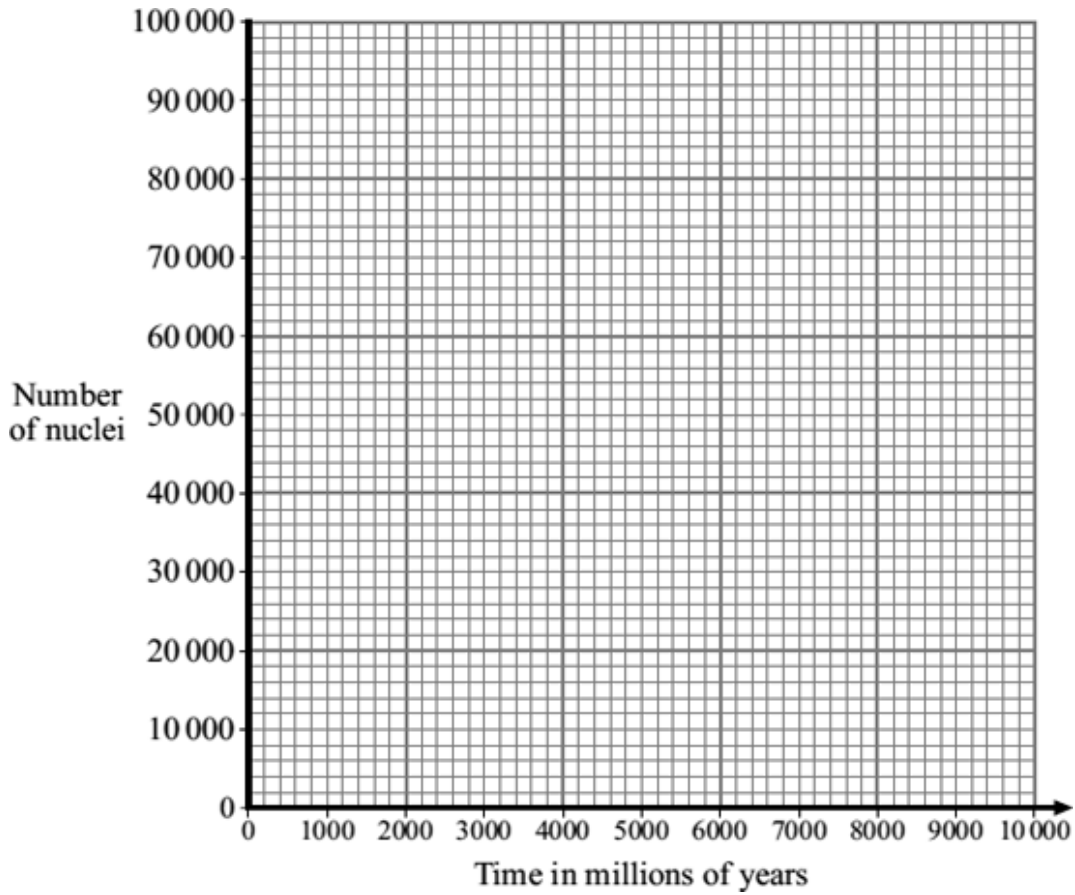(b)   Uranium-238 has a half-life of 4500 million years.

    (i)   When the Earth was formed, there was twice as much uranium-238 in the rocks as there is now.

        What is the age of the Earth?

        ....

(1)

    (ii)   Complete the graph to show how the number of nuclei in a sample of uranium-238 will change with time.
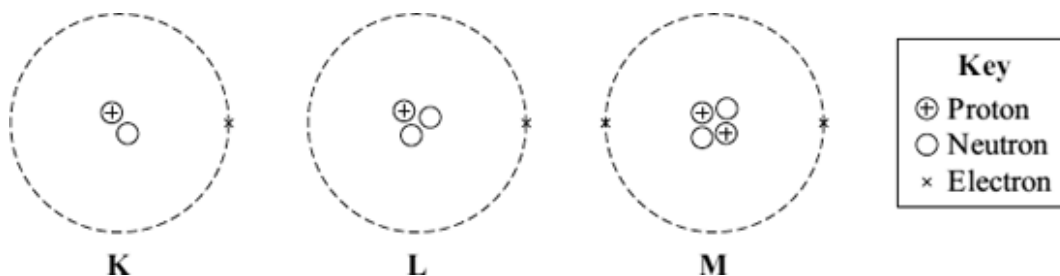Initially, there were 100 000 nuclei in the sample.

(2)
(Total 6 marks)

48

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

Key
⊕ Proton
○ Neutron
× Electron

K   L   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.

$$^{230}_{90}\text{Th} \longrightarrow {}^{226}_{88}\text{Ra} + \boxed{\text{Radiation}}$$
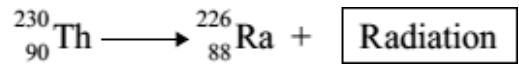
What type of radiation, alpha, beta or gamma, is emitted by thorium-230?

....

Explain the reason for your answer.

....

....

....

....

....

(3)
(Total 8 marks)

49 Before using a radioactive source, a teacher asked her students to suggest safety procedures that would reduce her exposure to the radiation. The students made the following

Keep the source in a lead-lined box

Hold the source with long tongs

Wear a photographic badge that detects radiation

A   **B**   **C**
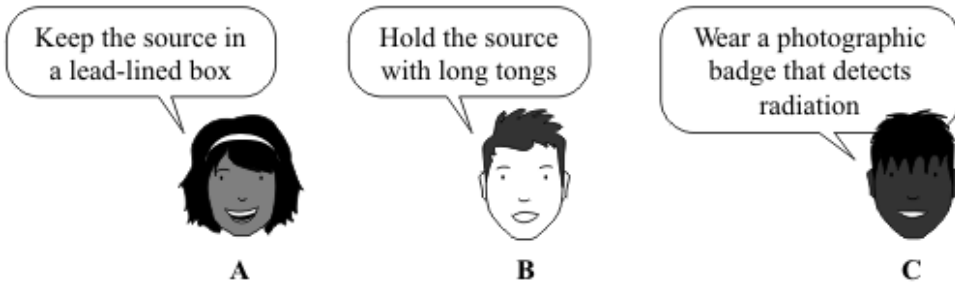
(a)   Which suggestion, **A**, **B** or **C**, would **not** reduce the exposure of the teacher to radiation?

....

(1)

(b)   The diagram shows how the teacher measured the distance that the radiation traveled from the source. The count-rate at different distances from the source was measured and recorded in the table.

Metre ruler
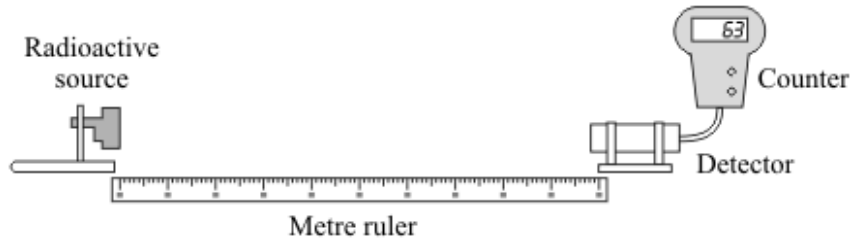
Distance from source to detector in cm	Count-rate in counts per minute
20	85
40	81
60	58
80	53
100	23

What type of radiation was the source emitting, alpha, beta or gamma?

....

Explain the reasons for your choice.

....

....

....

....

(3)

(c)   The graphs show how two groups of scientists, **A** and **B**, link exposure to radiation and the risk of getting cancer.
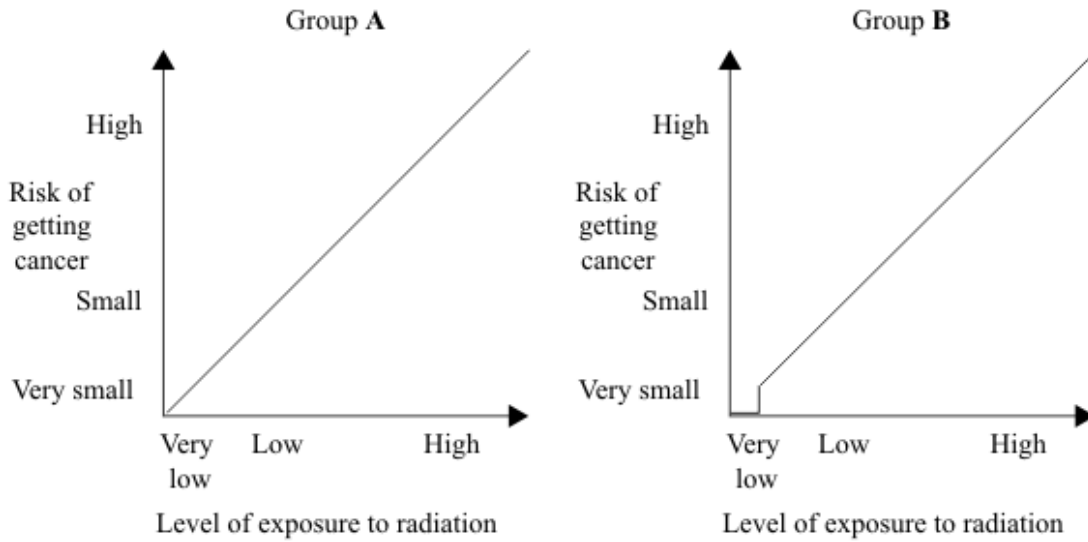
Group A

Group B

(i)   Complete the following sentence using a word or phrase from the box.

decreases	has no effect on	increases

Both groups of scientists agree that a high level of exposure to radiation

.... the risk of getting cancer.

(1)

(ii)   Use the graphs to describe carefully how the two groups of scientists disagree when the level of exposure to radiation is very low.

....

....

....

....

(2)
(Total 7 marks)

50

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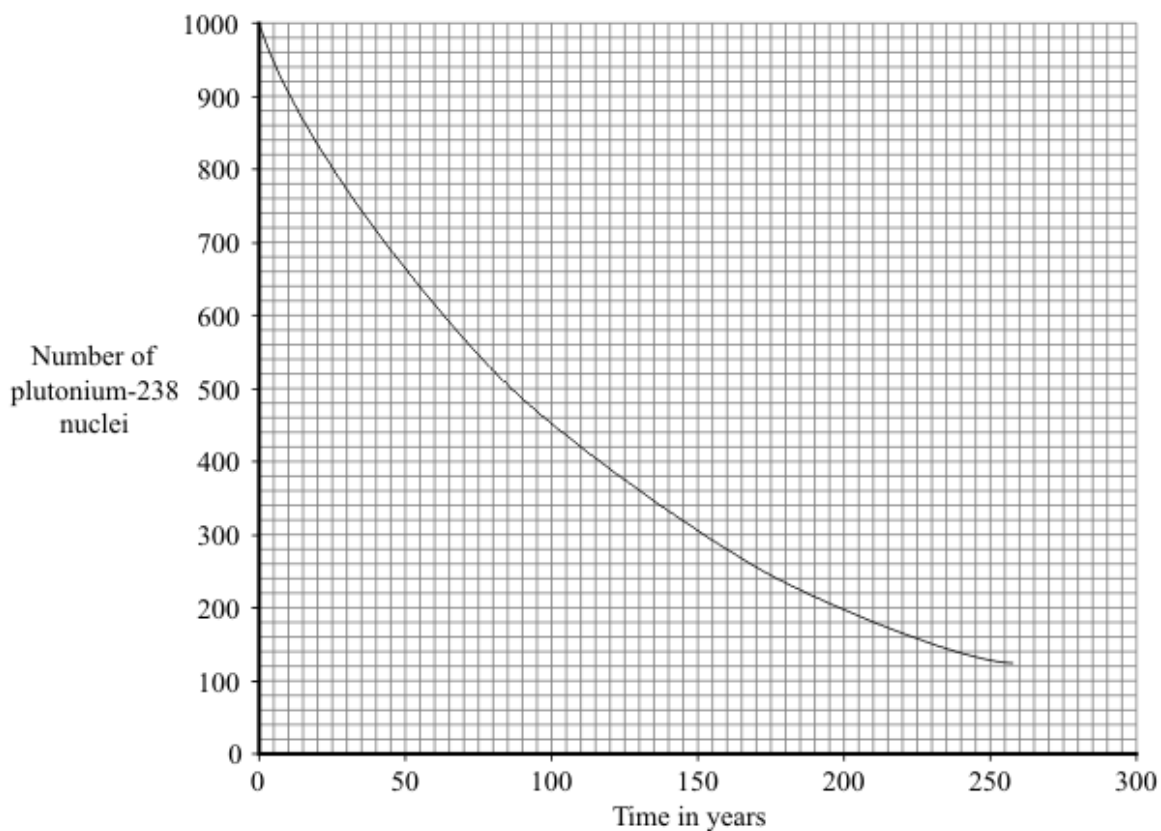
Use the graph to find the half-life of plutonium-238.

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)

51

(a)   Complete the following table for an atom of uranium-238 ($^{238}_{92}$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 ($^{238}_{92}$U) decays to form an atom of thorium-234 ($^{234}_{90}$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)

52 A radioactive source emits alpha (α), beta (β) and gamma (γ) radiation. The diagram shows what happens to the radiation as it passes between two charged metal plates.
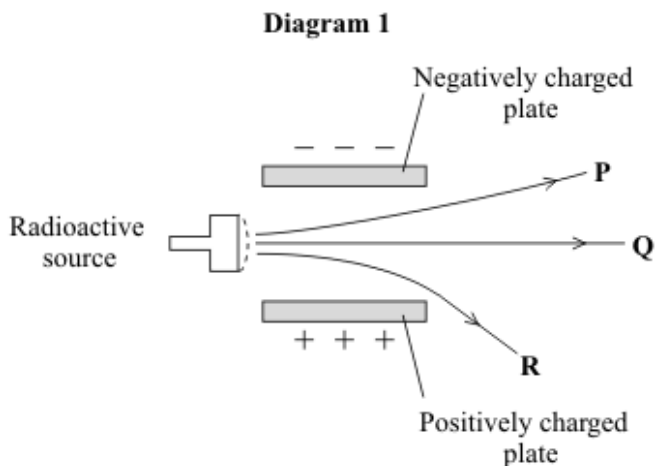
Diagram 1

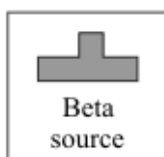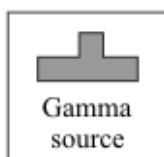(a) Which line **P**, **Q** or **R** shows the path taken by:

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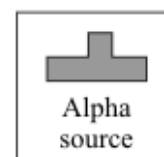
Draw **three** lines to show which source should be stored in which box so that the minimum amount of radiation gets into the air.

(2)

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

J

K

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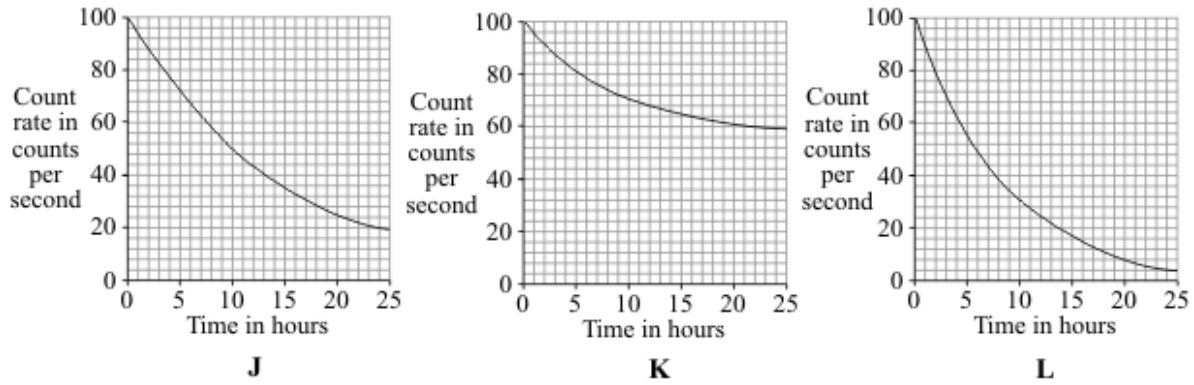
(i)   Which source, **J, K**, or **L**, has the highest count rate after 24 hours?

....

(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)