1 Alpha, beta and gamma are types of nuclear radiation.

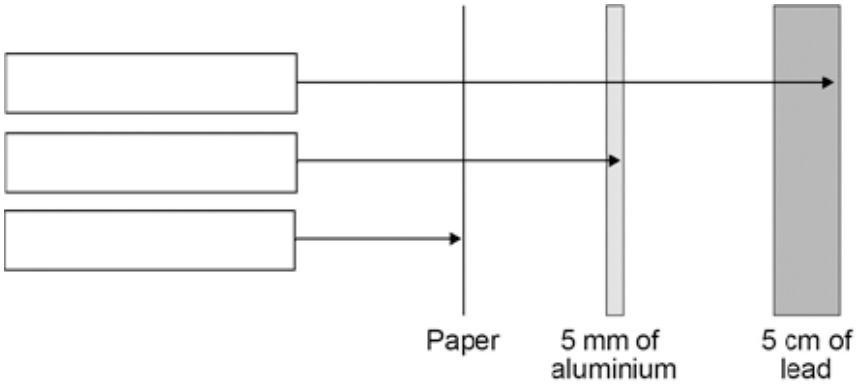
(a) Draw **one** line from each type of radiation to what the radiation consists of.

Type of radiation	What radiation consists of
	Electron from the nucleus
Alpha	
	Two protons and two neutrons
Beta	
	Electromagnetic radiation
Gamma	
	Neutron from the nucleus

(3)

(b) A teacher demonstrates the penetration of alpha, beta and gamma radiation through different materials.

The demonstration is shown in the figure below.



Complete the figure above by writing the name of the correct radiation in each box.

(2)

(c) Give **two** safety precautions the teacher should have taken in the demonstration.

1 .....

.....

2 .....

.....

(2)

(d) The table below shows how the count rate from a radioactive source changes with time.

Time in seconds	0	40	80	120	160
Count rate in counts / second	400	283	200	141	100

Use the table to calculate the count rate after 200 seconds.

.....

.....

(2)

(e) The half-life of the radioactive source used was very short.

Give **one** reason why this radioactive source would be much less hazardous after 800 seconds.

.....

.....

(1)

(Total 10 marks)

2 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)

(d) *In this question you will be assessed on using good English, organising information clearly and using specialist terms where appropriate.*

Some substances are radioactive. They may emit alpha or beta particles.

Describe the characteristics of alpha particles and beta particles in terms of their:

- structure
- penetration through air and other materials
- deflection in an electric field.

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(6)
(Total 13 marks)

3 Nuclear fission and nuclear fusion are two processes that release energy.

(a) (i) Use the correct answer from the box to complete each sentence.

Geiger counter	**nuclear reactor**	**star**

Nuclear fission takes place within a ..... .

Nuclear fusion takes place within a ..... .

(2)

(ii) State **one** way in which the process of nuclear fusion differs from the process of nuclear fission.

.....

.....

(1)

(b) The following nuclear equation represents the fission of uranium-235 (U-235).

$$^{1}_{0}n + {}^{235}_{92}U \longrightarrow {}^{236}_{92}U \longrightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3\,{}^{1}_{0}n + \text{energy}$$

Chemical symbols:

Ba - barium

Kr - krypton

(i) Use the information in the equation to describe the process of nuclear fission.

.....

.....

.....

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.....

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.....

(4)

(ii) An isotope of barium is Ba-139.
Ba-139 decays by beta decay to lanthanum-139 (La-139).

Complete the nuclear equation that represents the decay of Ba-139 to La-139.

$$^{139}Ba \longrightarrow \text{.....} \; ^{139}La + \text{.....}$$

(3)

(Total 10 marks)

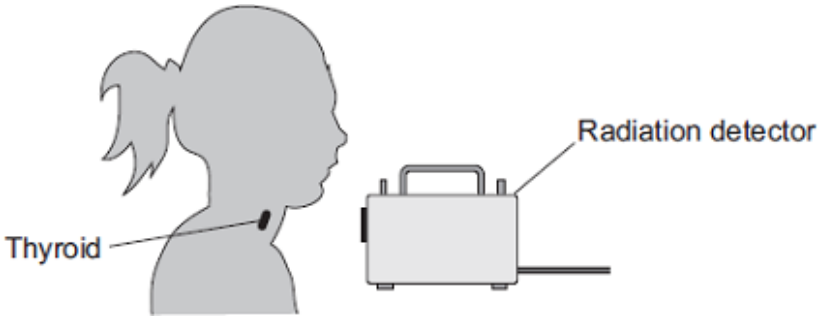
4 (a) The names of three types of radiation are given in **List A**. Some properties of these three types of radiation are given in **List B**.

Draw **one** line from each type of radiation in **List A** to its correct property in **List B**.

List A **Type of radiation**	**List B** **Property of radiation**
	will pass through paper but is stopped by thin metal
alpha	
	has the shortest range in air
beta	
	will not harm human cells
gamma	
	is very weakly ionising

(3)

(b) The radioactive isotope iodine-123 can be used by a doctor to examine the thyroid gland of a patient. The iodine, taken as a tablet, is absorbed by the thyroid gland. The gamma radiation emitted as the iodine atoms decay is detected outside the body.



The doctor uses an isotope emitting gamma radiation to examine the thyroid gland rather than an isotope emitting alpha or beta radiation.

Which **one** of the following gives a reason why gamma radiation is used?

Tick (✓) **one** box.

Gamma radiation will pass through the body. ☐

Gamma radiation is not deflected by a magnet. ☐

Gamma radiation has a long range in air. ☐

(1)

(c) Iodine-123 has a half-life of 13 hours.

Use a word from the box to complete the sentence.

all	**half**	**most**

After 13 hours ..... of the iodine-123 atoms the thyroid absorbed have decayed.

(1)

(d) Iodine-123 and iodine-131 are two of the isotopes of iodine.

Draw a ring around the correct answer to complete the sentence.

The nucleus of an iodine-123 atom has the same number of | electrons | neutrons | protons | as the

nucleus of an iodine-131 atom.

(1)

(Total 6 marks)

5 In 2011 an earthquake caused severe damage to a nuclear power station in Japan.

The damage led to the release of large amounts of radioactive iodine-131 ($^{131}_{53}I$) into the atmosphere.

(a) The table gives some information about an atom of iodine-131 ($^{131}_{53}I$).

Complete the table.

mass number	131
number of protons	53
number of neutrons	

(1)

(b) Complete the sentence.

The number of protons in an atom is called the proton number or

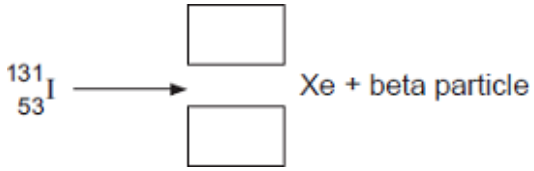
the ..... number.

(1)

(c) An atom of iodine-131 decays into an atom of xenon (Xe) by emitting a beta particle.

(i) The decay of iodine-131 can be represented by the equation below.

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



(2)

(ii) A sample of rainwater contaminated with iodine-131 gives a count rate of 1200 counts per second.

Calculate how many days it will take for the count rate from the sample of rainwater to fall to 75 counts per second.

Half-life of iodine-131 = 8 days

Show clearly how you work out your answer.

.....

.....

..... days

(2)

(iii) If people drink water contaminated with iodine-131, the iodine-131 builds up in the thyroid gland. This continues until the thyroid is saturated with iodine-131 and cannot absorb any more. The radiation emitted from the iodine-131 could cause cancer of the thyroid.

In Japan, people likely to be drinking water contaminated with iodine-131 were advised to take tablets containing a non-radioactive isotope of iodine.

Suggest why this advice was given.

.....

.....

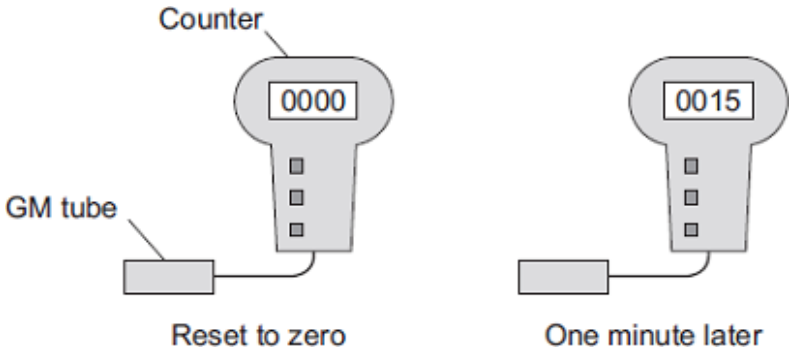
.....

.....

(2)
(Total 8 marks)

6 (a) A teacher used a Geiger-Műller (GM) tube and counter to measure the *background radiation* in her laboratory.

The teacher reset the counter to zero, waited one minute and then took the count reading. The teacher repeated the procedure two more times.



(i) Background radiation can be either from natural sources or from man-made sources.

Name **one man-made** source of background radiation.

.....

(1)

(ii) The three readings taken by the teacher are given in the table.

Count after one minute
15
24
18

The readings given in the table are correct.

Why are the readings different?

.....

.....

(1)

(b) Some scientists say they have found evidence to show that people living in areas of high natural background radiation are less likely to develop cancer than people living in similar areas with lower background radiation.

The evidence these scientists found does not definitely mean that the level of background radiation determines whether a person will develop cancer.

Suggest a reason why.

.....

.....

(1)

(c) An atom of the isotope radon-222 emits an alpha particle and decays into an atom of polonium.

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

$$^{4}_{2}\text{He}$$

(i) How many protons and how many neutrons are there in an alpha particle?

Number of protons = ...

Number of neutrons = ...

(2)

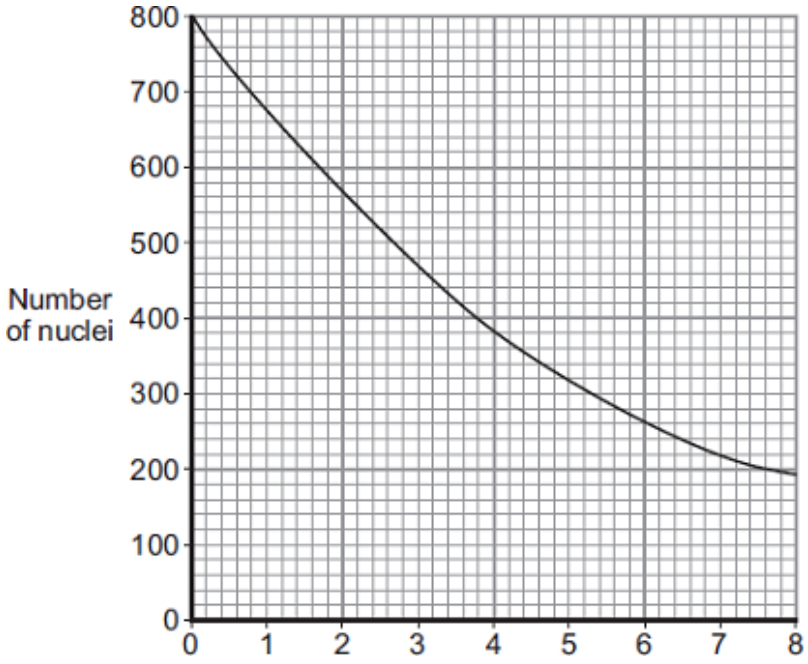
(ii) The decay of radon-222 can be represented by the equation below.

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

$$^{222}_{86}\text{Rn} \longrightarrow \square \quad \square \quad + \text{Po} + \text{alpha particle}$$

(2)

(d) The graph shows how, in a sample of air, the number of radon-222 nuclei changes with time.



Use the graph to find the half-life of radon-222.

Show clearly on the graph how you obtain your answer.

Half-life = ... days

(2)

(Total 9 marks)

7 Certain types of atom emit alpha, beta or gamma radiation. The radiation is emitted from the centre of the atom.

(a) What name is given to the centre of an atom?

.....

(1)

(b) The sign below is used to warn people that a radiation source is being used in a laboratory.

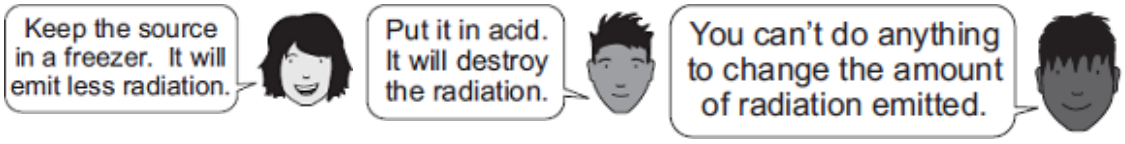
Why is it important to warn people that a radiation source is being used?

.....

.....

(1)

(c) Before using a radiation source, a teacher asked her class whether there was any way that she could reduce the amount of radiation that the source emitted. Three students each gave an answer to the teacher.



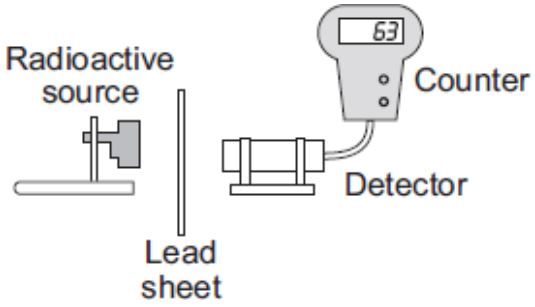
A **B** **C**

Which **one** of the students, **A**, **B** or **C**, is correct?

Write your answer in the box. ☐

(1)

(d) The diagram shows the apparatus used by the teacher to demonstrate how one type of radiation is able to pass through lead.



One lead sheet, 2 mm thick, was placed between the source and the detector and a count rate was taken. Extra lead sheets were added. For each extra lead sheet, a new count rate was taken and recorded in the table.

Number of lead sheets	Count rate in counts per minute
1	226
2	220
3	210
4	190
5	185

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

.....

Give the reason for your answer.

.....

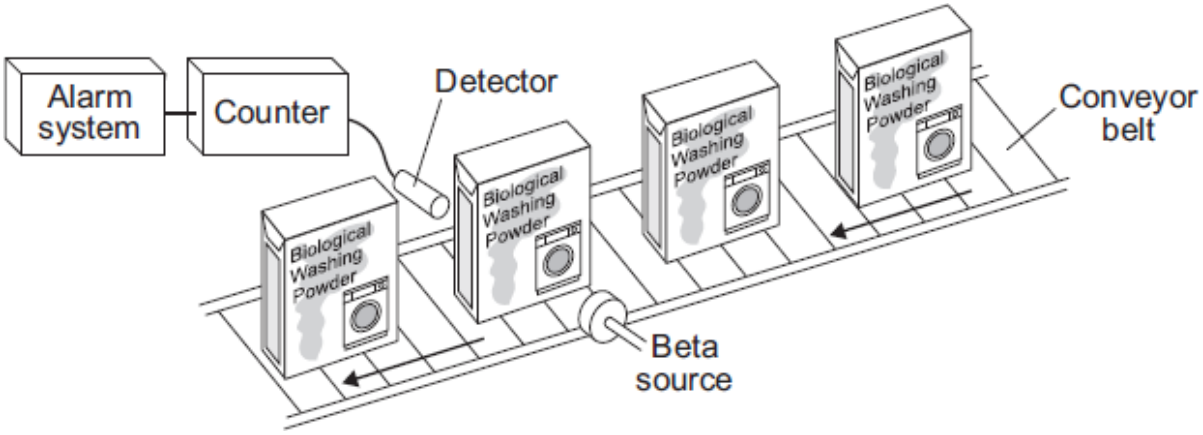
.....

.....

(2)

(e) The diagram shows how a company detects any boxes left empty by an automatic filler.

When an empty box passes between the beta source and the detector, a buzzer sounds. A worker then removes the box from the conveyor belt.



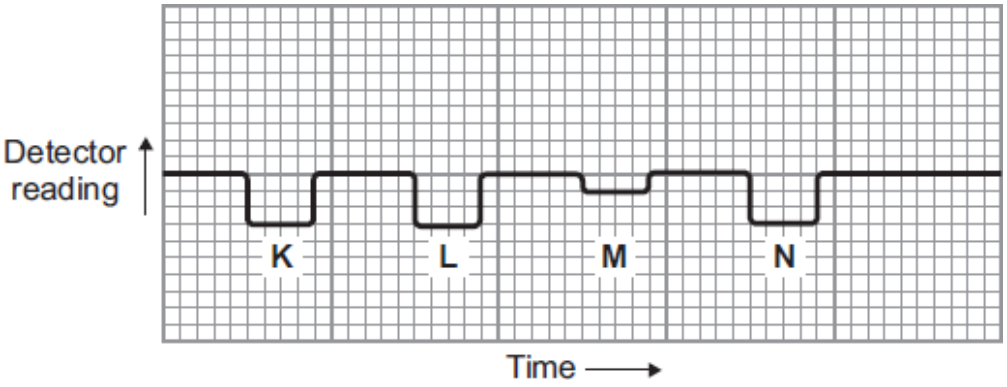
(i) Why would this system **not** work if an alpha source were used instead of the beta source?

.....

.....

(1)

(ii) The chart shows how the detector reading changes as boxes pass along the conveyor belt.



Which part of the chart, **K**, **L**, **M** or **N**, shows that an empty box is passing between the beta source and the detector?

.....

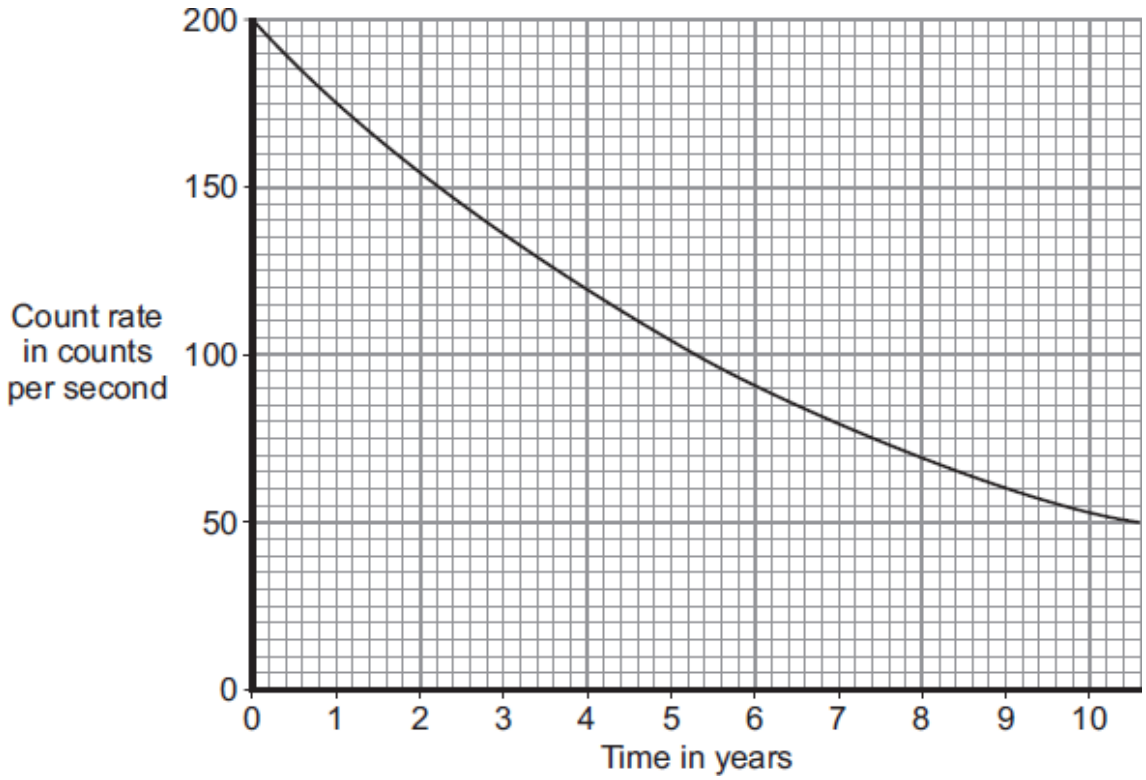
Give a reason for your answer.

.....

.....

(2)
(Total 8 marks)

8 (a) The graph shows how the count rate from a sample containing the radioactive substance cobalt-60 changes with time.



(i) What is the range of the count rate shown on the graph?

From ..... counts per second to ..... counts per second.

(1)

(ii) How many years does it take for the count rate to fall from 200 counts per second to 100 counts per second?

Time = ... years

(1)

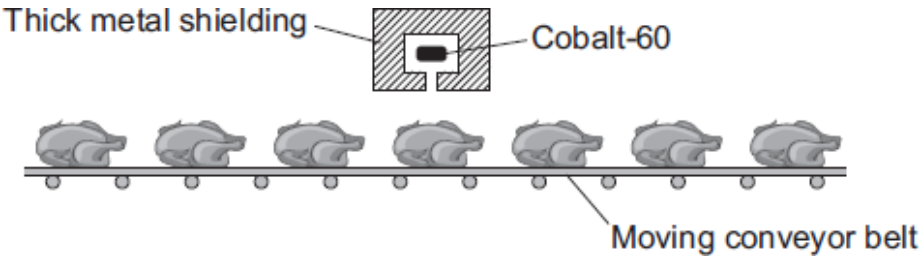
(iii) What is the half-life of cobalt-60?

Half-life = ... years

(1)

(b) The gamma radiation emitted from a source of cobalt-60 can be used to kill the bacteria on fresh, cooked and frozen foods. Killing the bacteria reduces the risk of food poisoning.

The diagram shows how a conveyor belt can be used to move food past a cobalt-60 source.



(i) Which **one** of the following gives a way of increasing the amount of gamma radiation the food receives?

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

Increase the temperature of the cobalt-60 source. ☐

Make the conveyor belt move more slowly. ☐

Move the cobalt-60 source away from the conveyor belt. ☐

(1)

(ii) To protect people from the harmful effects of the gamma radiation, the cobalt-60 source has thick metal shielding.

Which **one** of the following metals should be used?

Draw a ring around your answer.

aluminium **copper** **lead**

(1)

(c) A scientist has compared the vitamin content of food exposed to gamma radiation with food that has not been exposed.

The table gives the data the scientist obtained when she tested 1 kg of cooked chicken.

Vitamin	Food not exposed to gamma radiation	Food exposed to gamma radiation
	Mass in milligrams	Mass in milligrams
B6	1.22	1.35
B12	21.00	28.00
E	3.30	2.15
Niacin	58.00	55.50
Riboflavin	2.10	2.25

Considering only this data, which **one** of the following is a correct conclusion?

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

Vitamin content is not affected by gamma radiation. ☐

Gamma radiation completely destroys some types of vitamin. ☐

Exposure increased the content of some types of vitamin. ☐

(1)
(Total 6 marks)

9 Food irradiation is a process that exposes food to radiation. Irradiation can be used to kill the bacteria that cause food poisoning or to slow down the ripening of fresh fruit and vegetables. Frozen foods and food inside packaging can also be irradiated.

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

Isotope	Half-life	Radiation emitted
Caesium-134	2.1 years	beta
Cobalt-60	5.3 years	gamma
Curium-242	160 days	alpha
Strontium-90	28 years	beta
Technetium-99	6 hours	gamma

Which of these radioactive isotopes would be most suitable for irradiating food?

.....

Explain the reasons for your choice.

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(3)

(b) Many people think that food should not be irradiated. Consumer groups have said that they are worried about the nutritional value and safety of eating irradiated foods.

(i) Suggest **one** reason why some people may be concerned about the safety of eating irradiated food.

.....

.....

(1)

(ii) Independent scientific committees in several countries, including Sweden, Canada and the UK, have concluded that it is safe to eat irradiated food.

These scientific committees need to be independent from government influence.

Suggest why.

.....

.....

(1)

(iii) One group of scientists has compared the vitamin content of non-irradiated foods with irradiated foods.

The table below gives the data obtained for 1 kg of cooked chicken.

Vitamin	**Non-irradiated food in milligrams**	**Irradiated food in milligrams**
B6	1.22	1.35
B12	21.00	28.00
E	3.30	2.15
Niacin	58.00	55.50
Riboflavin	2.10	2.25

Considering only the data in the table, is it valid to conclude that irradiated food is less nutritional than non-irradiated food?

Explain your answer.

.....

.....

.....

.....

.....

(2)

(iv) In a restaurant, meals with ingredients that have been irradiated must be clearly identified on the menu.

It is important that people eating in a restaurant are given this information.

Suggest why.

.....

.....

(1)

(c) The isotope caesium-137 decays by emitting beta radiation.
Caesium-137 has a half-life of 30 years.

(i) What is a beta particle, and from which part of an atom is a beta particle emitted?

.....

.....

(1)

(ii) A sample containing caesium-137 has a count rate of 600 counts per minute.

Calculate how long it would take for the count rate from the sample to fall to 75 counts per minute.

Show clearly how you work out your answer.

.....

.....

.....

Time taken = ... years

(2)
(Total 11 marks)

10 (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.

$$^{212}_{83}\text{Bi} \longrightarrow {}^{212}_{84}\text{Po} + \text{beta particle}$$

(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)

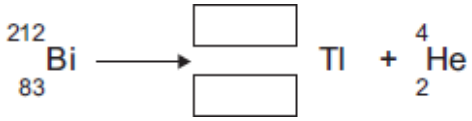
(b) When an atom of bismuth-212 emits an alpha particle, the atom decays into an atom of thallium.

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

$$^{4}_{2}He$$

(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)

11 (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**.

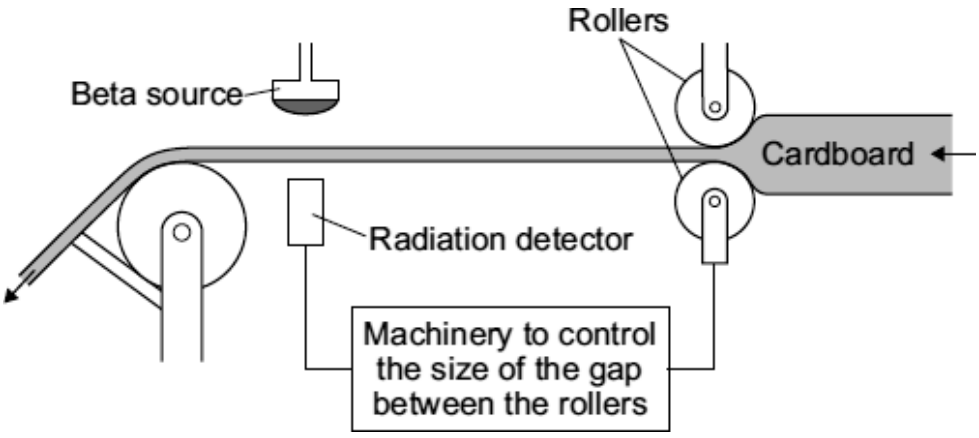
Draw a straight line to link each type of radiation in **List A** to its correct property in **List B**.

Draw only **three** lines.

List A **Type of nuclear radiation**	**List B** **Property of radiation**
	Has the same mass as an electron
Alpha	
	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.

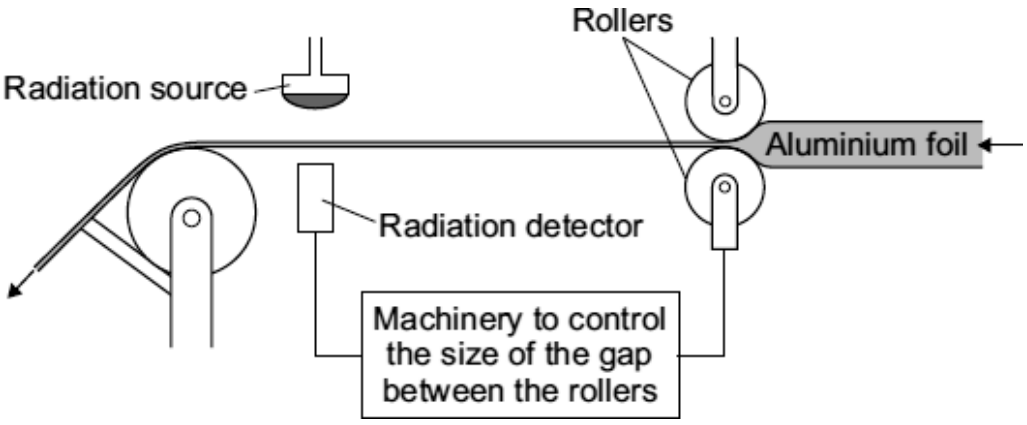
Why not?

.....

.....

(1)
(Total 7 marks)

12 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.

.....

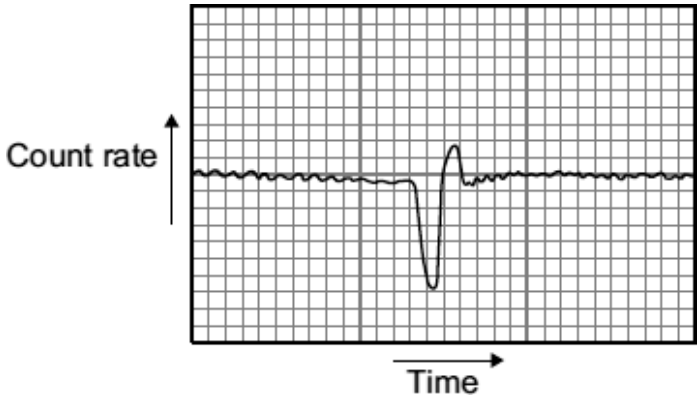
.....

.....

.....

(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.

.....

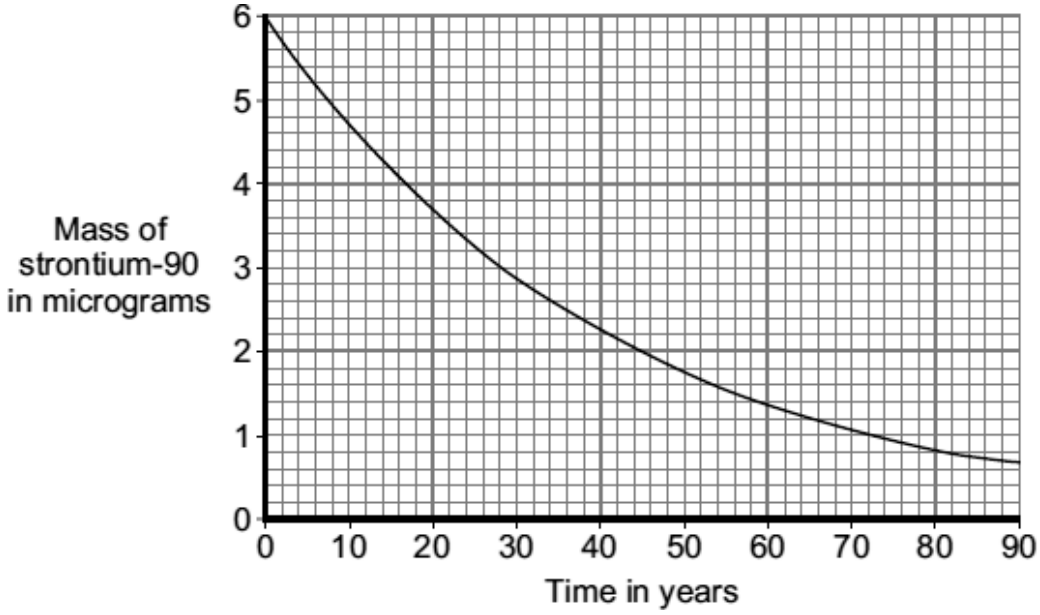
.....

.....

.....

(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.

.....

.....

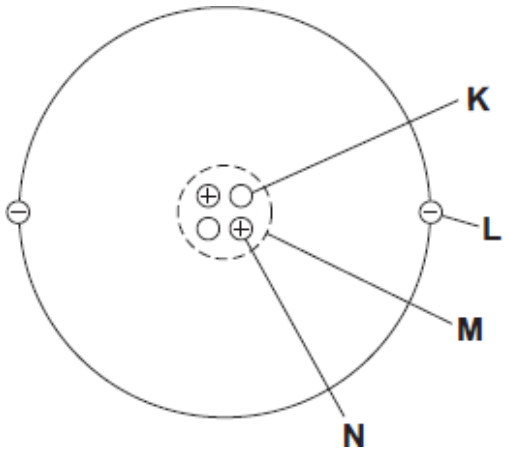
.....

Number of years = ...

(2)

(Total 7 marks)

13 (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.

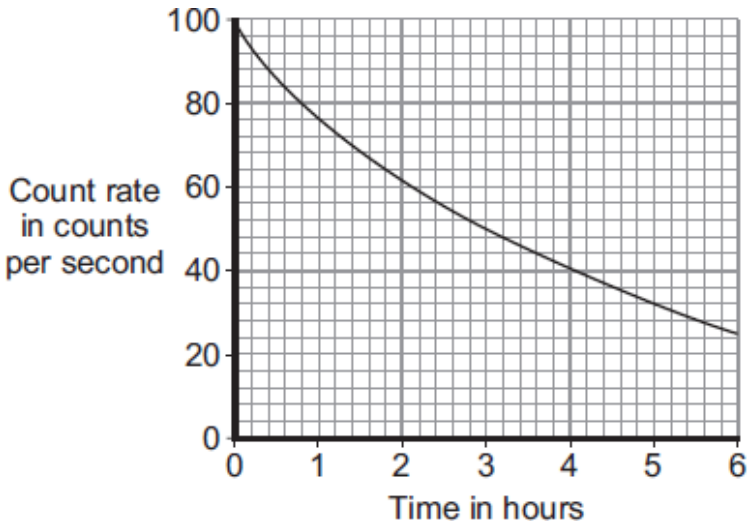
to monitor the thickness of aluminium foil as it is made in a factory ☐

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)

14 (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?

.....

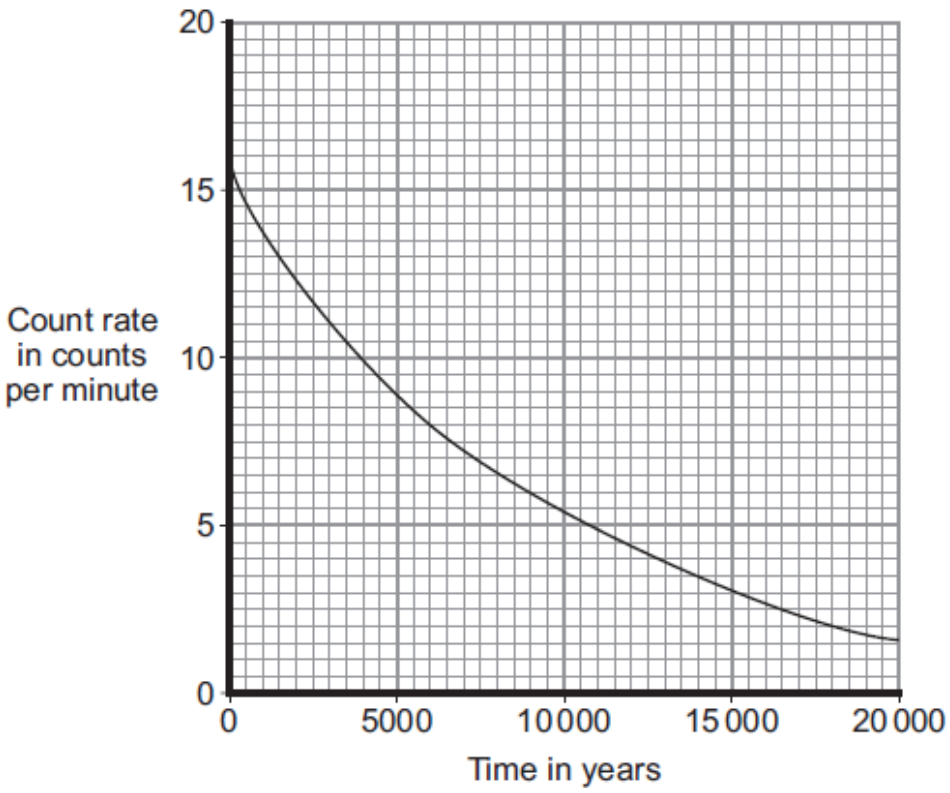
.....

(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**



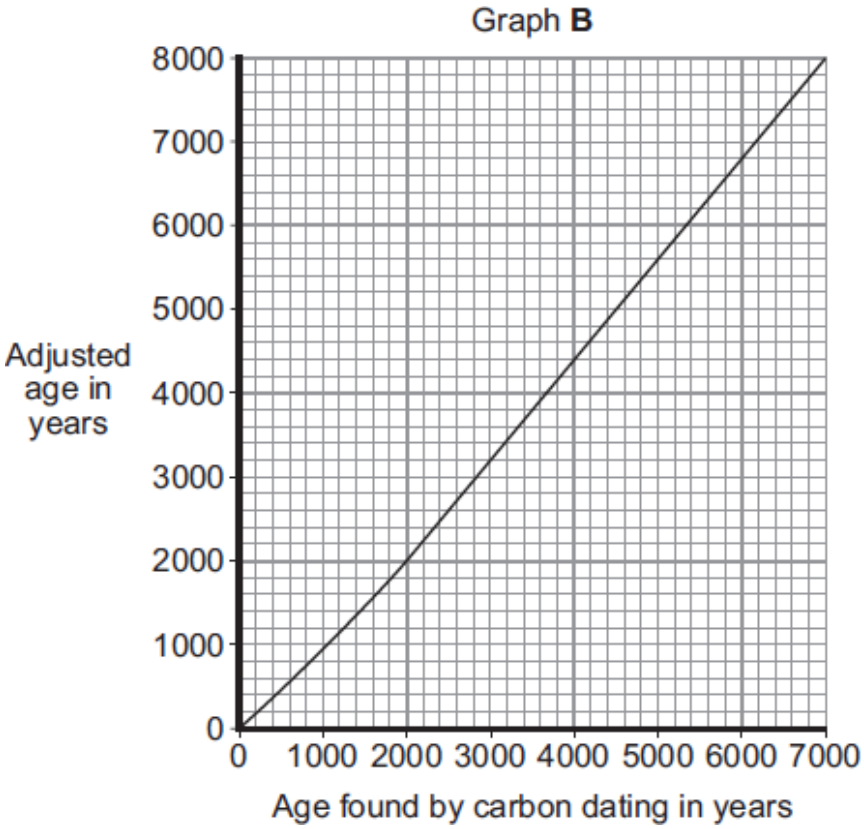
(i) Lake Cuicocha in Ecuador was formed after a volcanic eruption.
Carbon taken from a tree killed by the eruption was found to have a count rate of 10.5 counts per minute.
At the time of the eruption, the count rate would have been 16 counts per minute.

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** 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)

15 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.

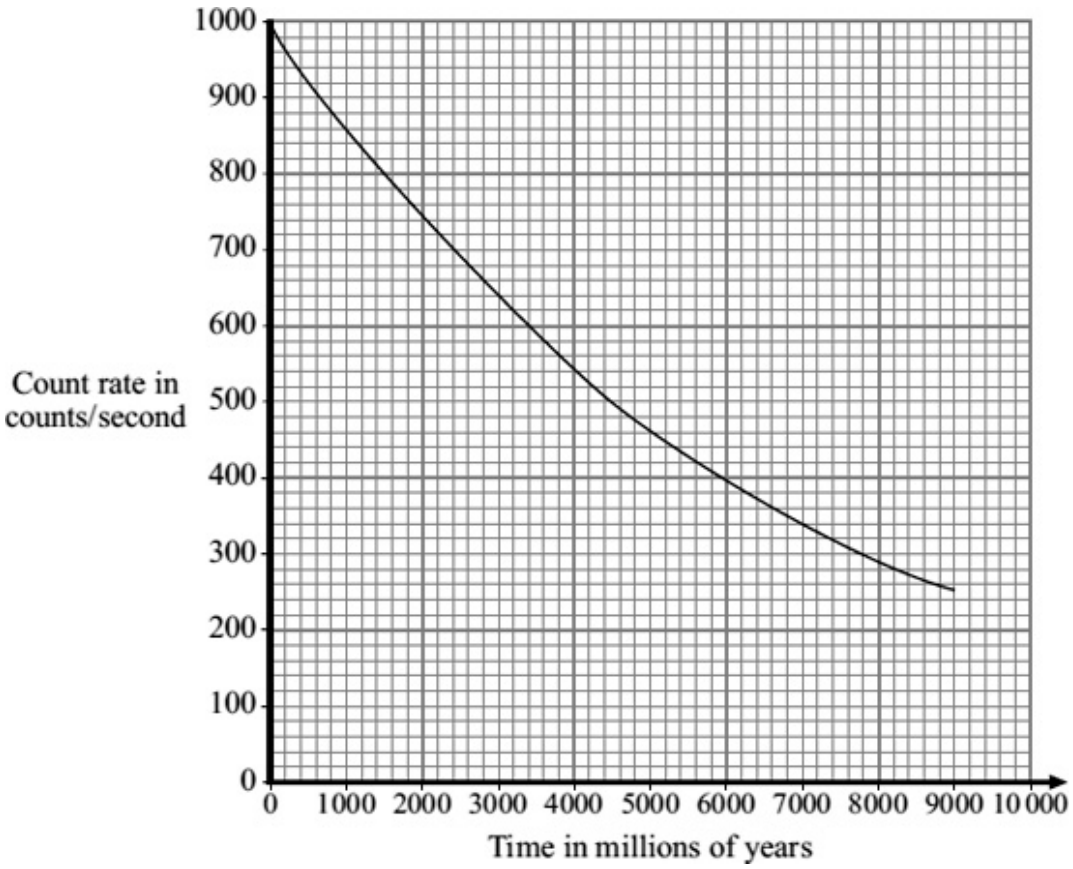
Write down your **new** statement.

.....

.....

(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.

.....

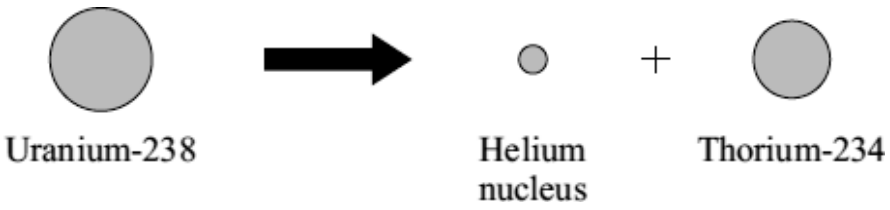
.....

.....

.....

(2)
(Total 5 marks)

16 (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.

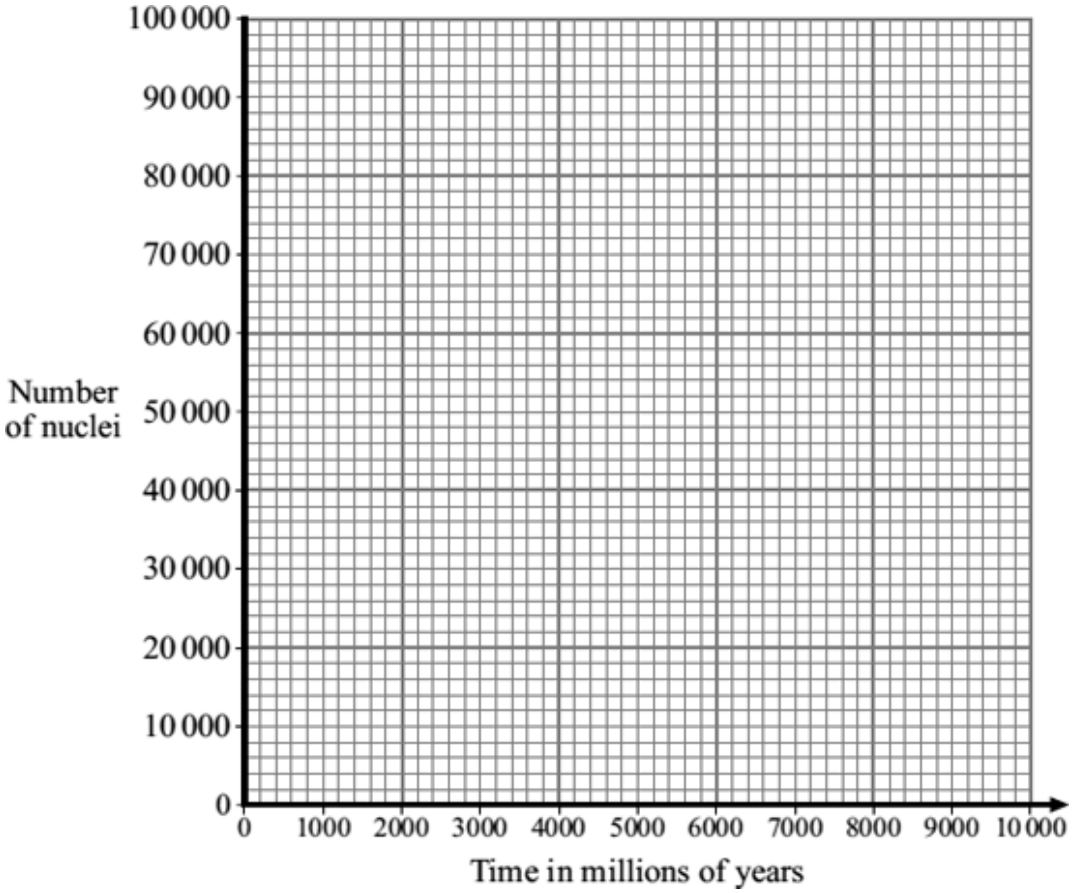
(i) When the Earth was formed, there was twice as much uranium-238 in the rocks as there is now.

What is the age of the Earth?

.....

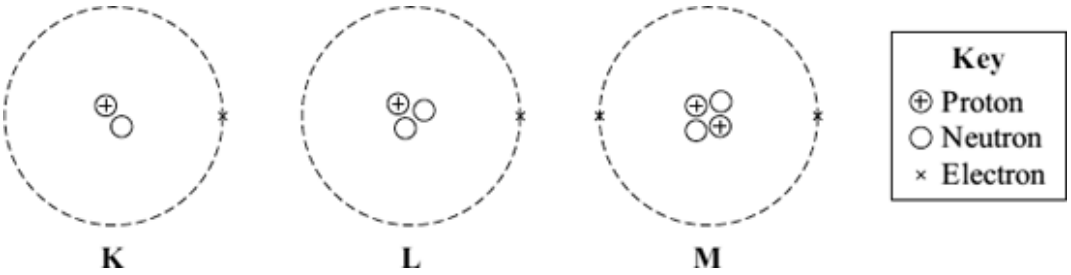
(1)

(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)

17 (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.

$$^{230}_{90}\text{Th} \longrightarrow {}^{226}_{88}\text{Ra} + \boxed{\text{Radiation}}$$

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

.....

Explain the reason for your answer.

.....

.....

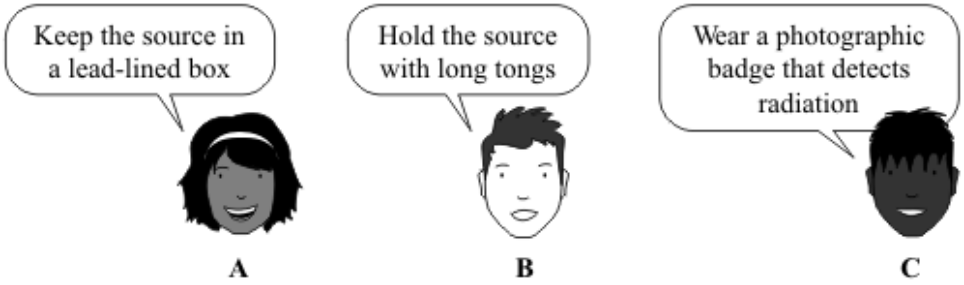
.....

.....

.....

(3)
(Total 8 marks)

18 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

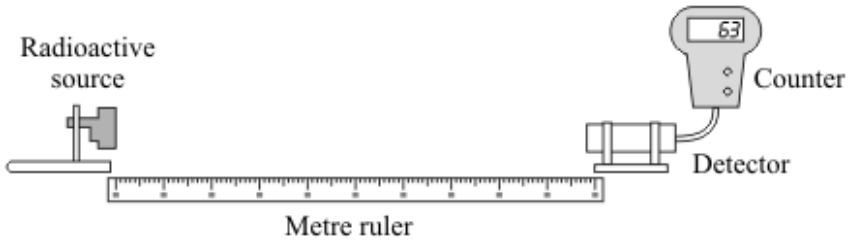


(a) Which suggestion, **A**, **B** or **C**, would **not** reduce the exposure of the teacher to radiation?

.....

(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.



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.

.....

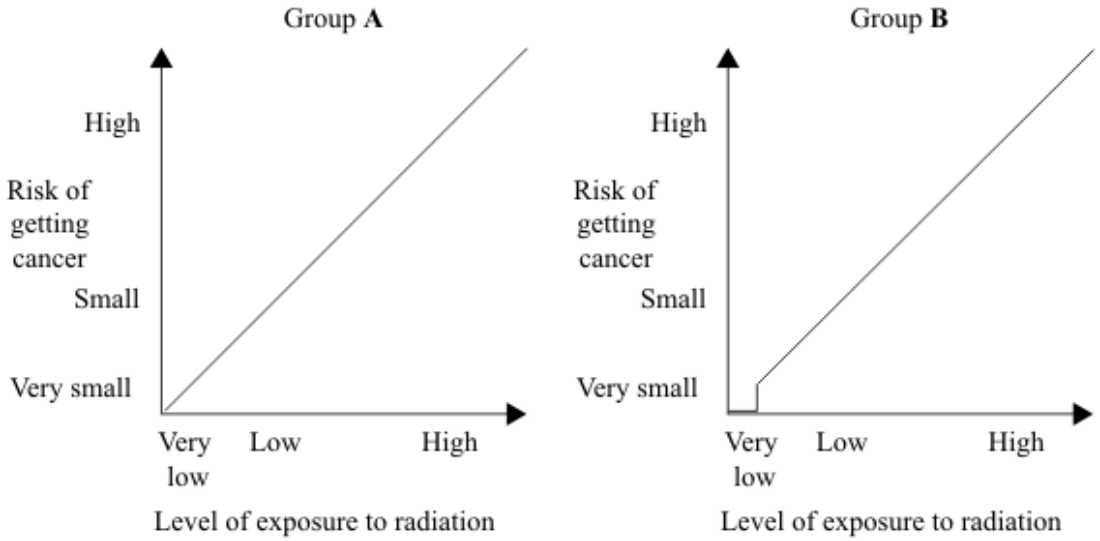
.....

.....

.....

(3)

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



(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)

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

(a) What is meant by the terms:

(i) *isotopes*

.....

.....

(1)

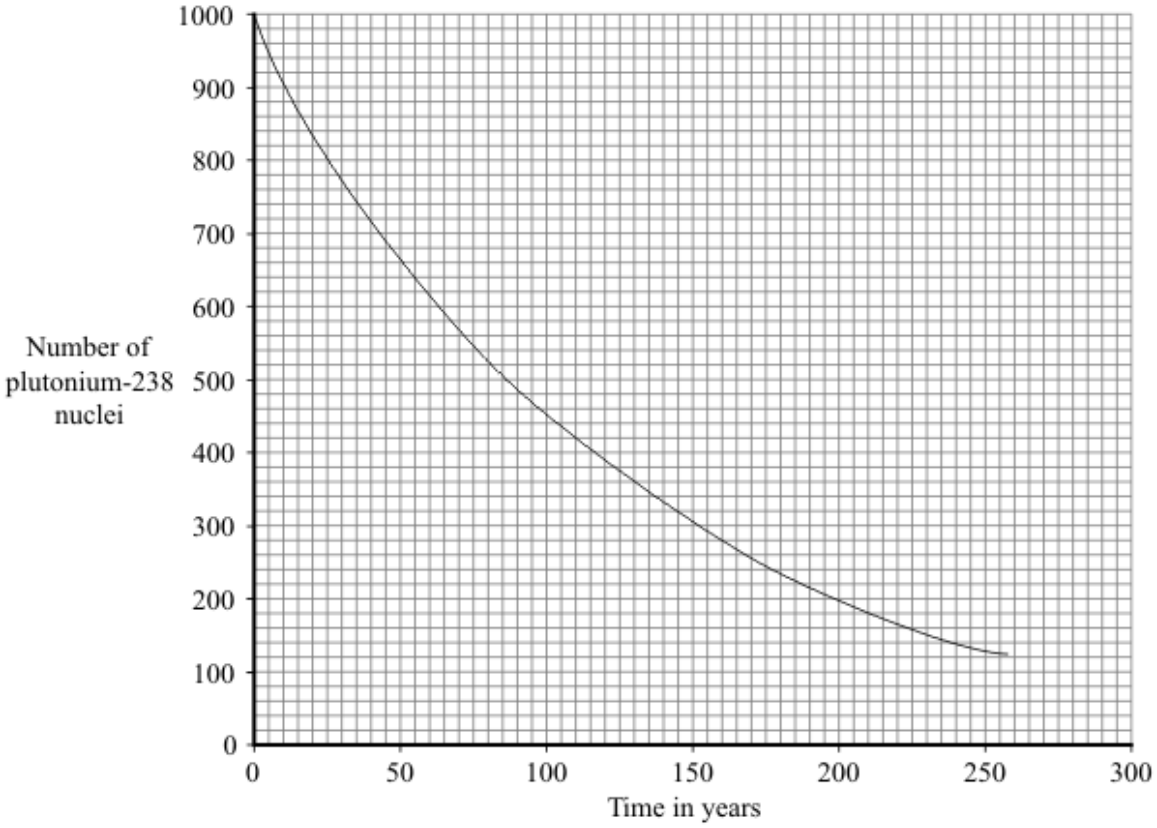
(ii) *radioactive*?

.....

.....

(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)

20 (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)

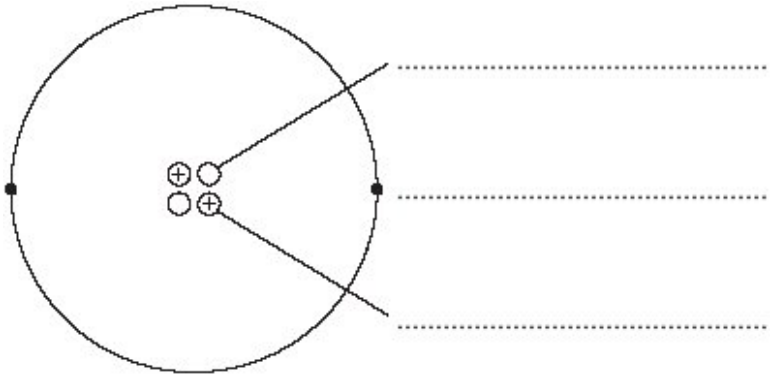
(ii) Why does an atom that decays by emitting alpha or beta radiation become an atom of a different element?

.....

.....

(1)
(Total 4 marks)

21 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.

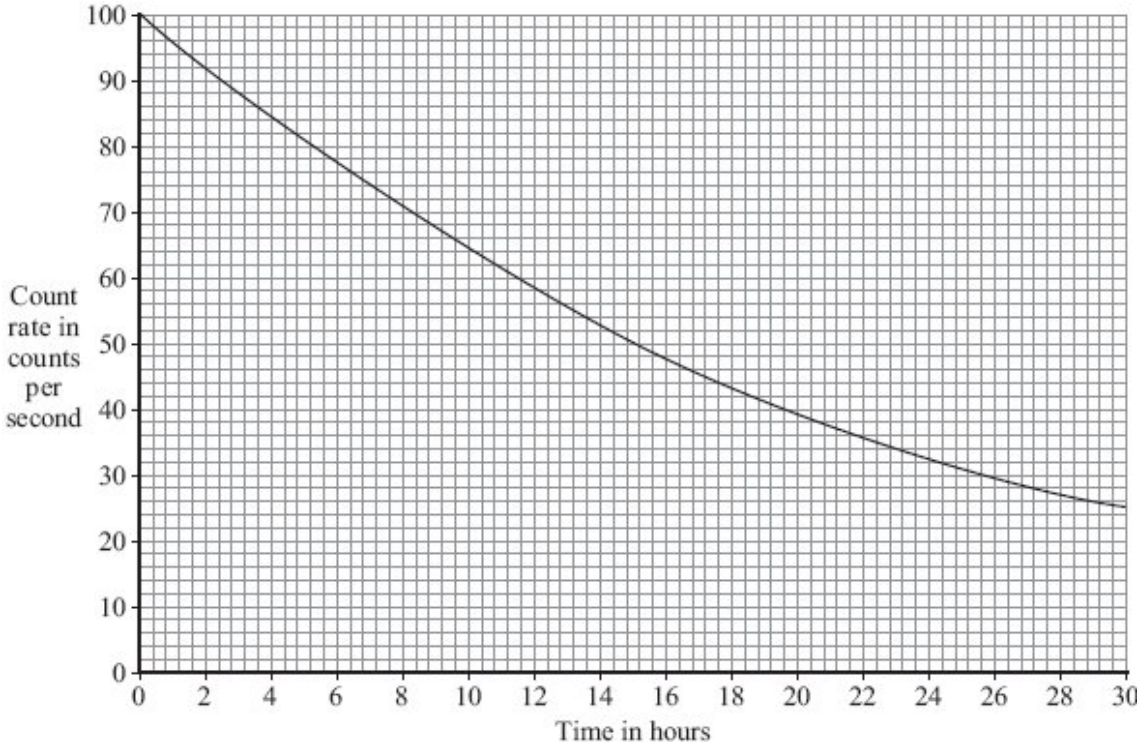
How is an alpha particle different from a helium atom?

.....

.....

(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?

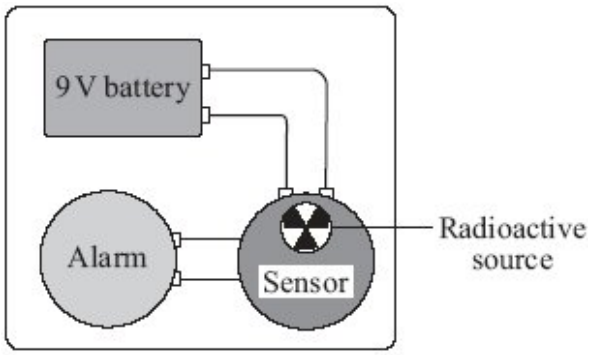
.....

.....

(1)

(Total 7 marks)

22 (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.

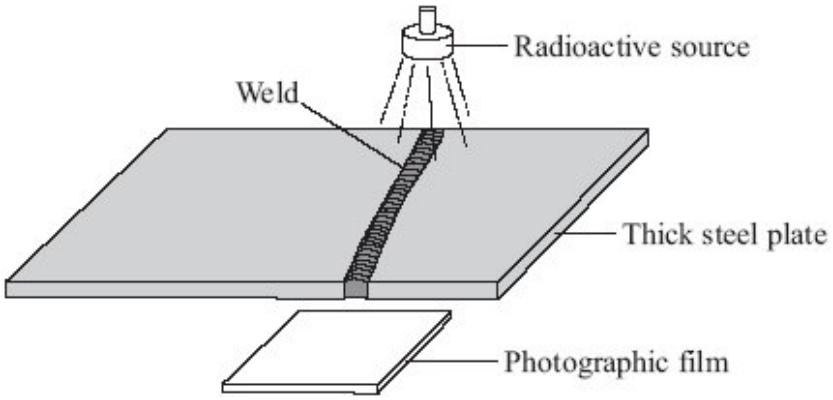
How is an atom of curium-242 different from an atom of curium-244?

.....

.....

(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.

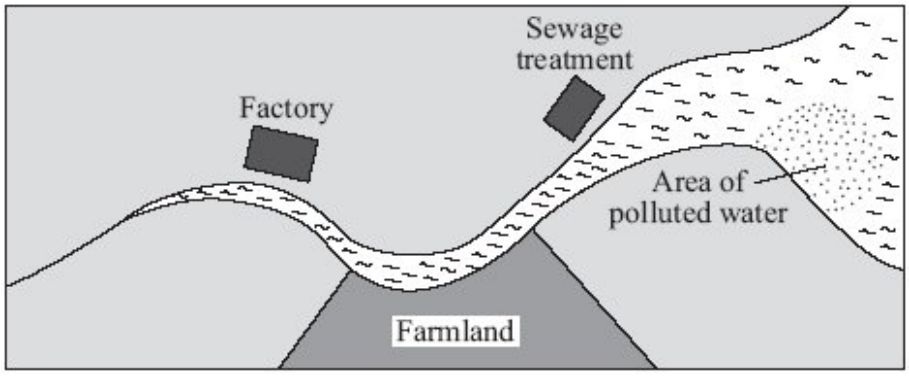
.....

.....

(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.

.....

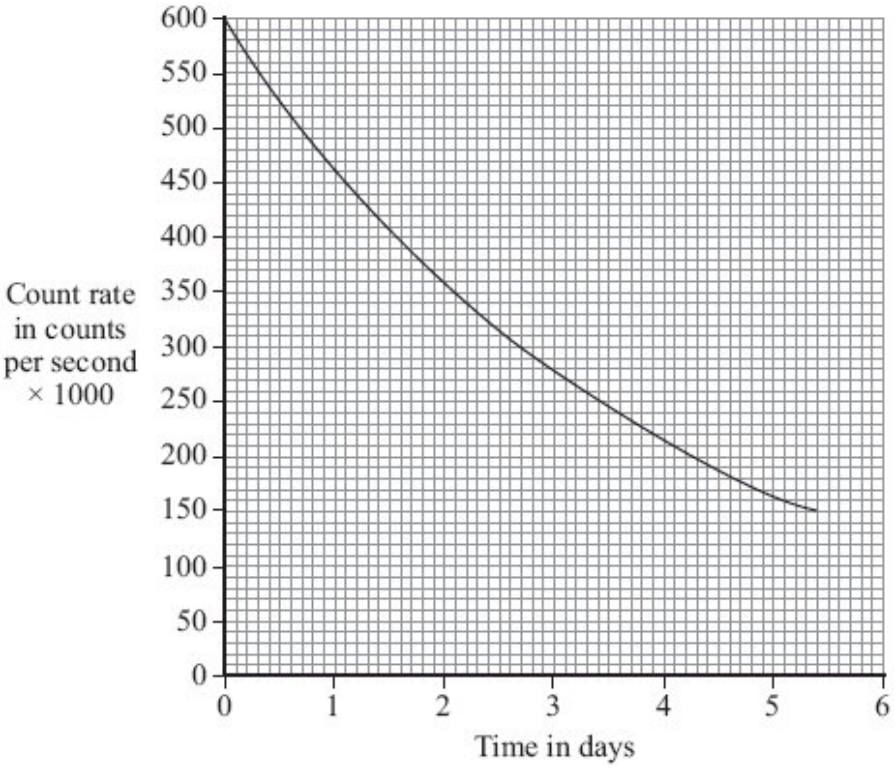
.....

.....

.....

(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.

.....

.....

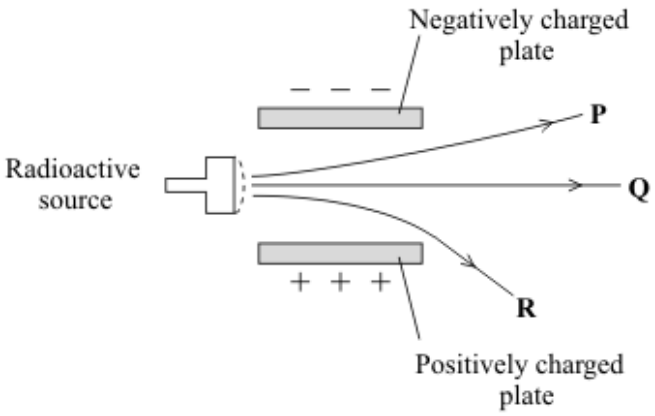
Half-life = ... days

(2)

(Total 9 marks)

23 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:

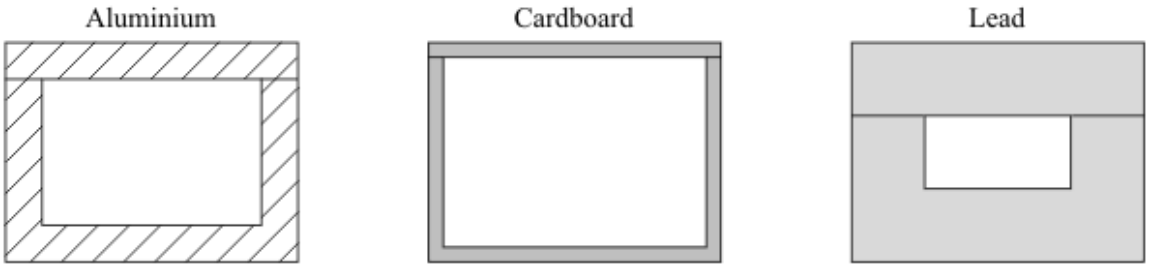
(i) alpha radiation .....

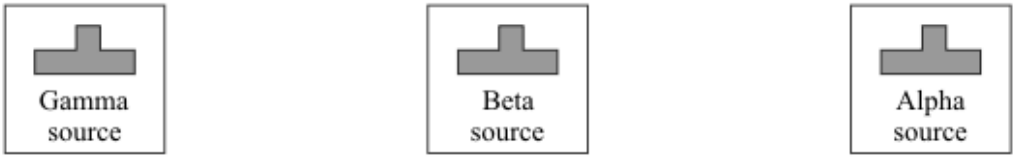
(1)

(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.

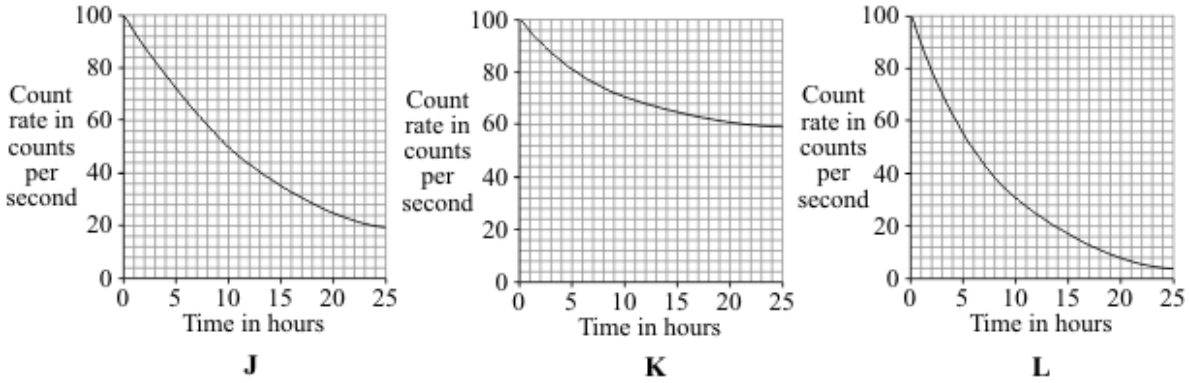




Draw **three** lines to show which source should be stored in which box so that the minimum amount of radiation gets into the air.

(2)

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



(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)

24 (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.

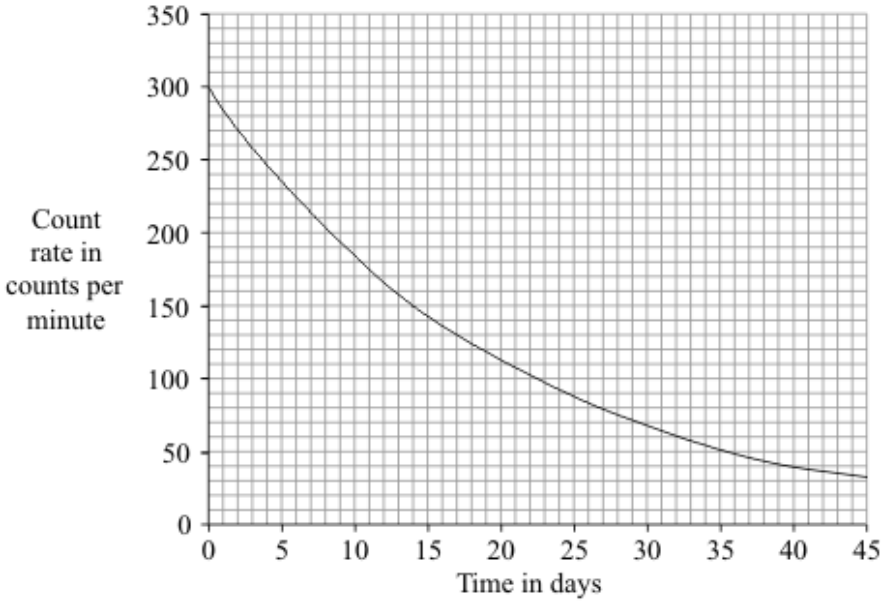
(i) How is an atom of phosphorus-32 different from an atom of the stable isotope phosphorus-31?

.....

.....

(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.

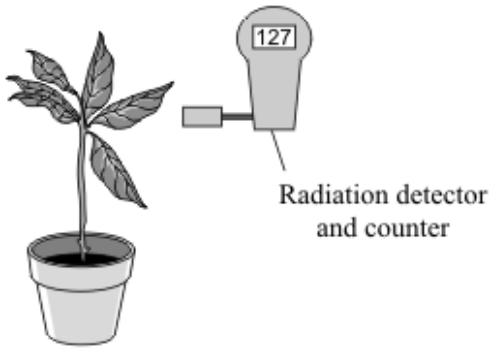
.....

.....

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.



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

.....

.....

.....

.....

(2)
(Total 9 marks)

25 (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	not deflected by an electric field
beta	stopped by thin metal but not paper
gamma	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.

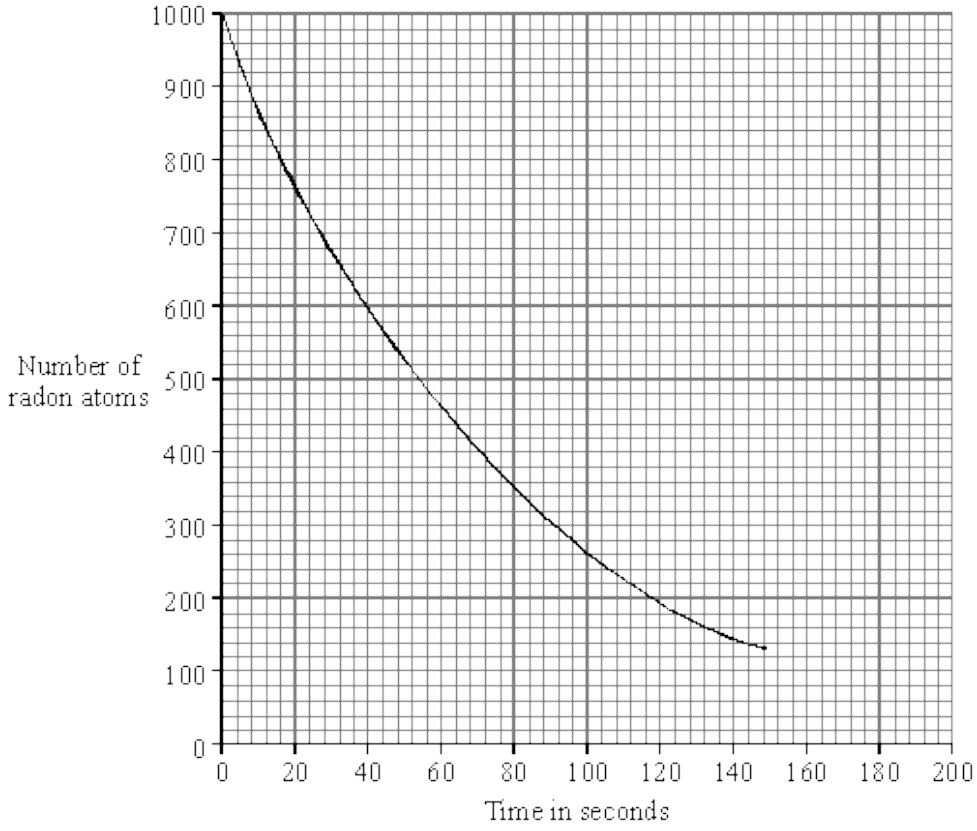
.....

.....

(1)

(Total 8 marks)

26 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

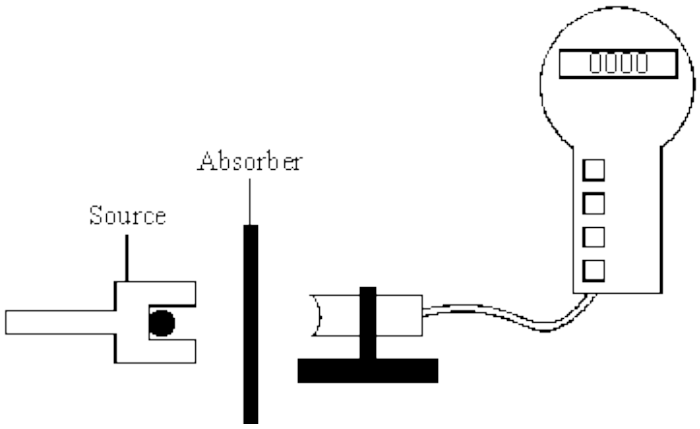
less
a constant level of
more

radiation per second.

(1)

(Total 3 marks)

27 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)

28 (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.

.....

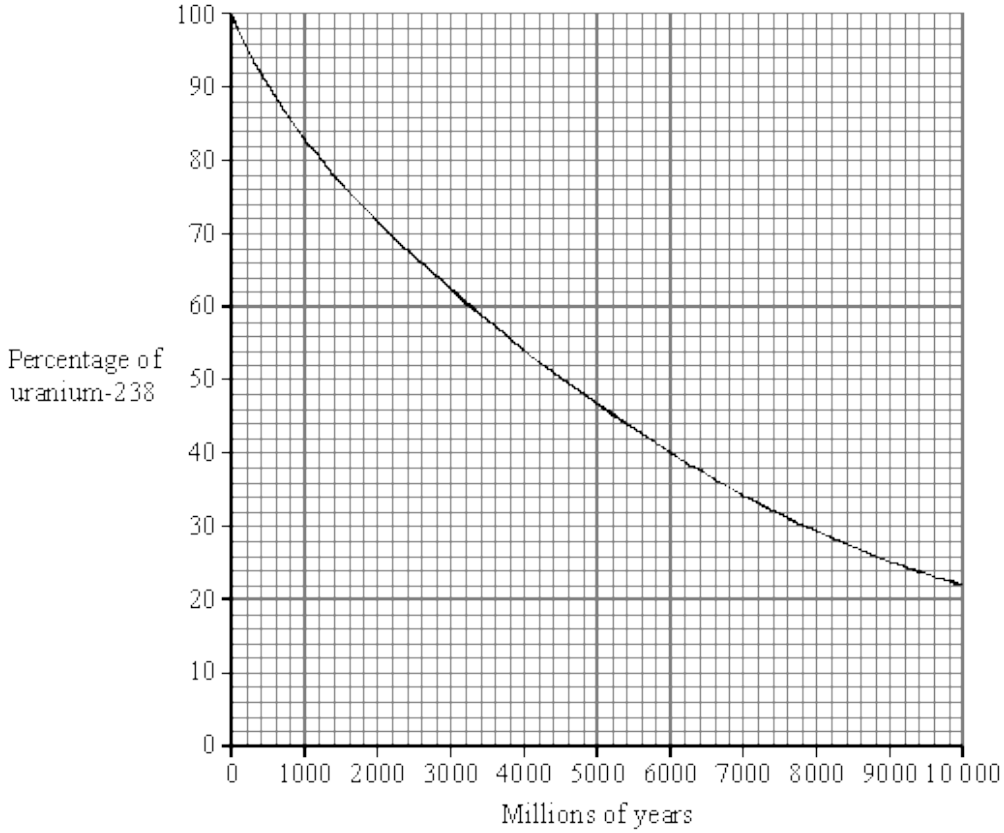
.....

.....

.....

(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)

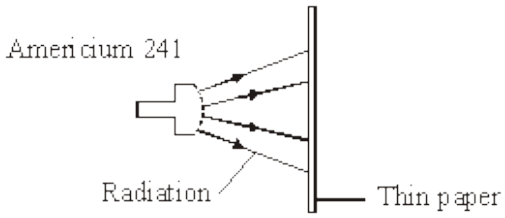
29 A smoke detector fitted inside a house contains a radioactive source, americium 241.

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

Number ofneutrons	146
Number ofprotons	95
Number ofelectrons	

(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)

30 A beta particle is a high-energy electron.

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

.....

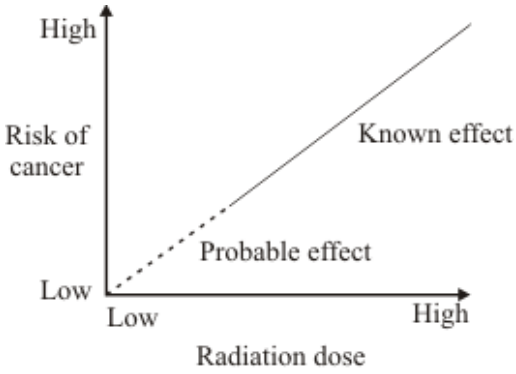
(1)

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

.....

(1)
(Total 2 marks)

31 (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.

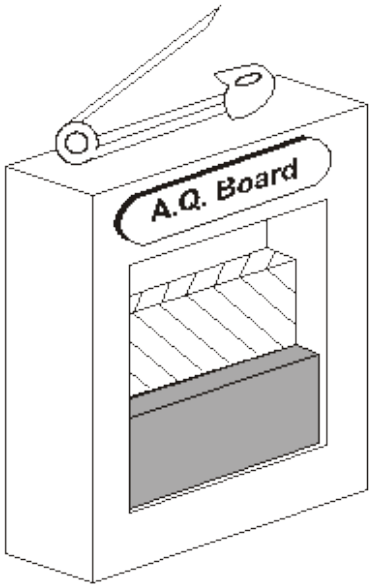


Diagram 1

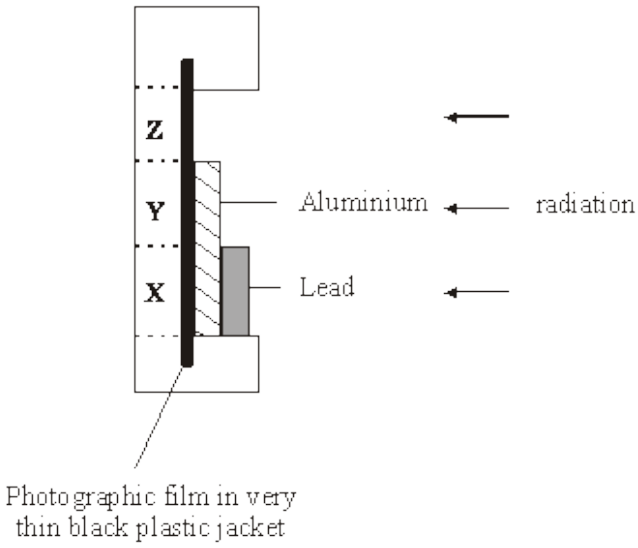


Diagram 2

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.

.....

.....

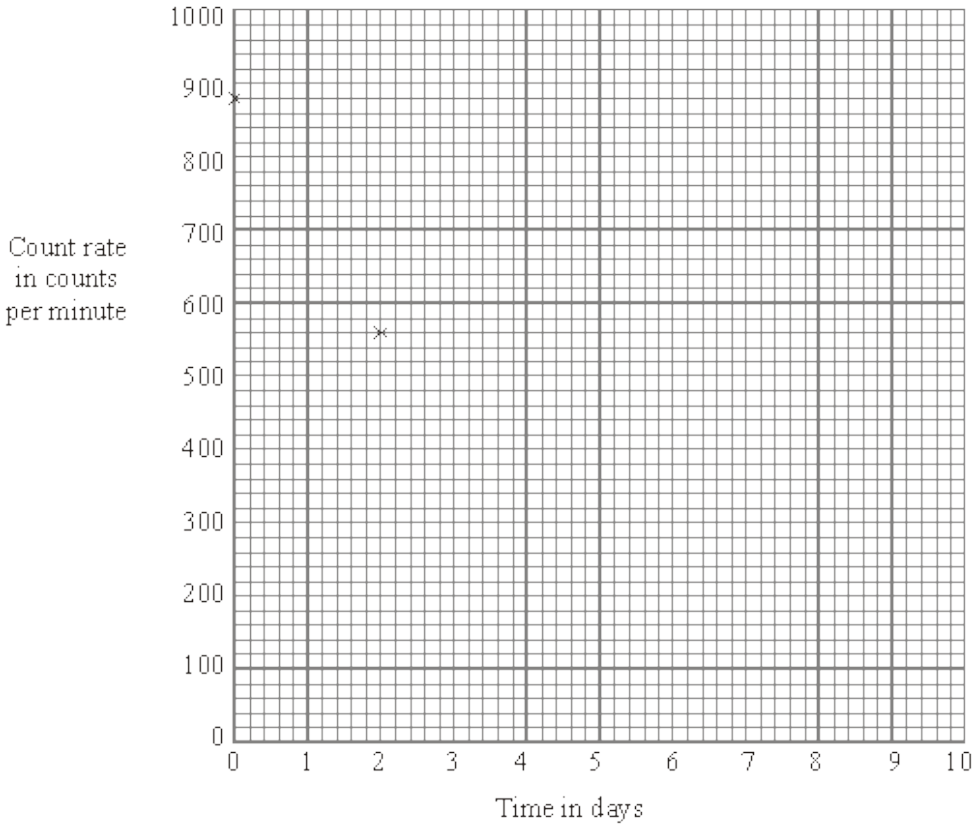
(2)
(Total 3 marks)

32 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)

33 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?

.....

(1)

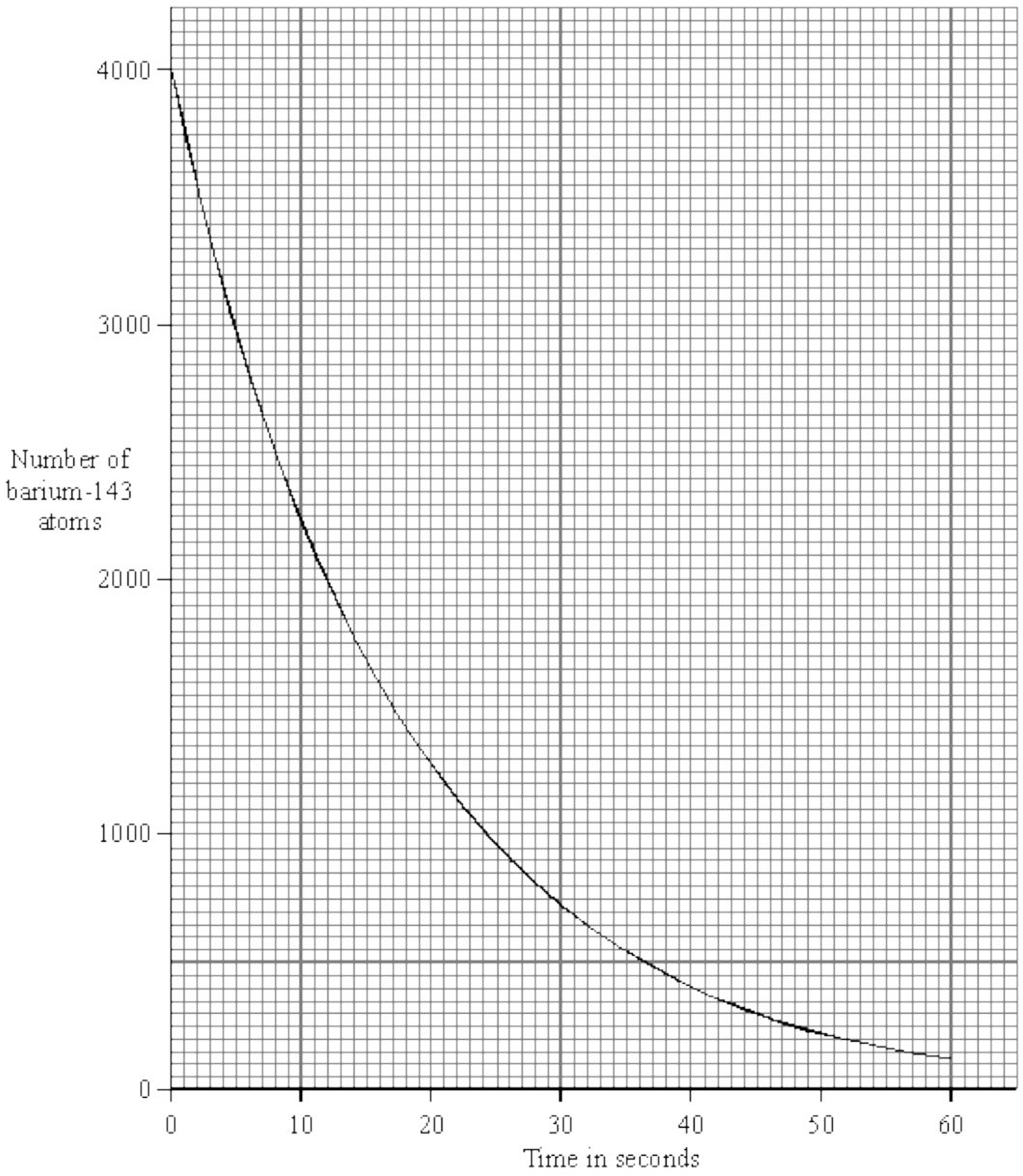
(ii) Calculate the age of the rock.

.....

Age of rock = ... million years

(1)
(Total 2 marks)

34 (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)

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

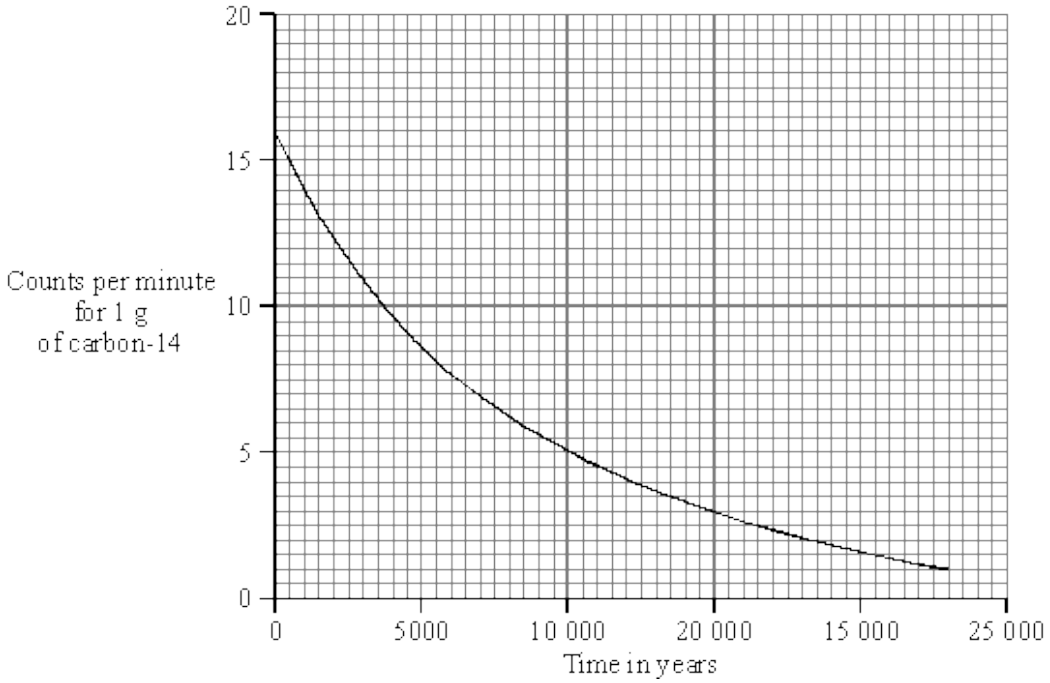
(a) What is a beta (β) particle?

.....

.....

(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)

36 (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.

.....

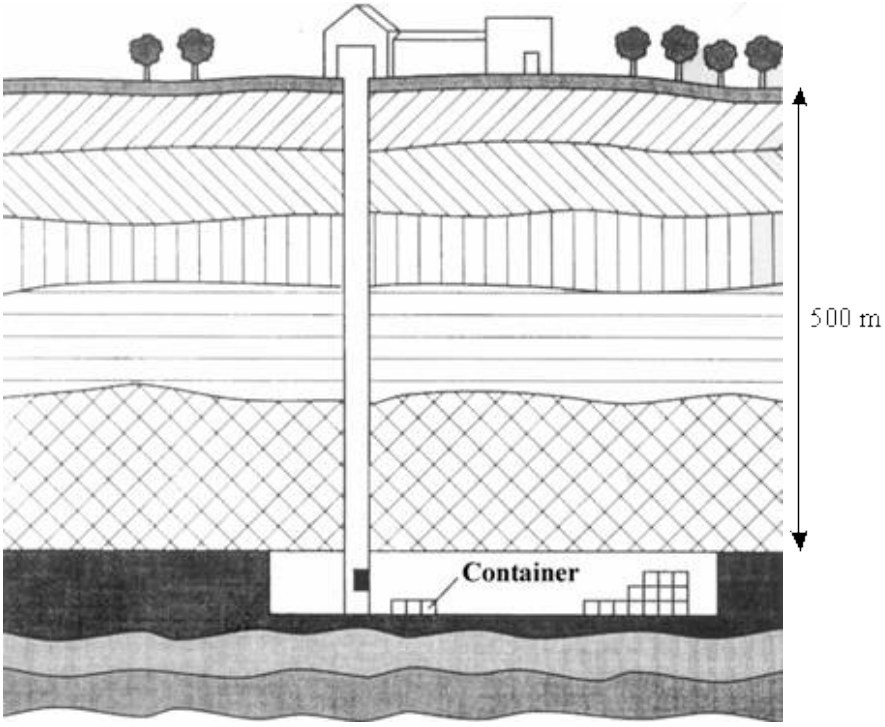
.....

.....

.....

(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.



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)

37 (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 .....

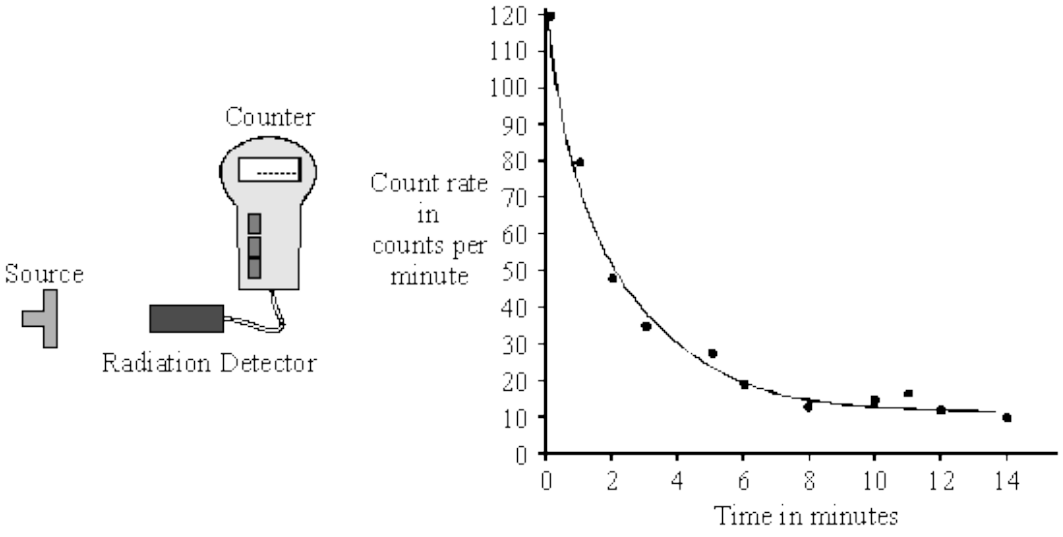
(1)

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

(1)

(Total 3 marks)

38 (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)

39 (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.

.....

.....

.....

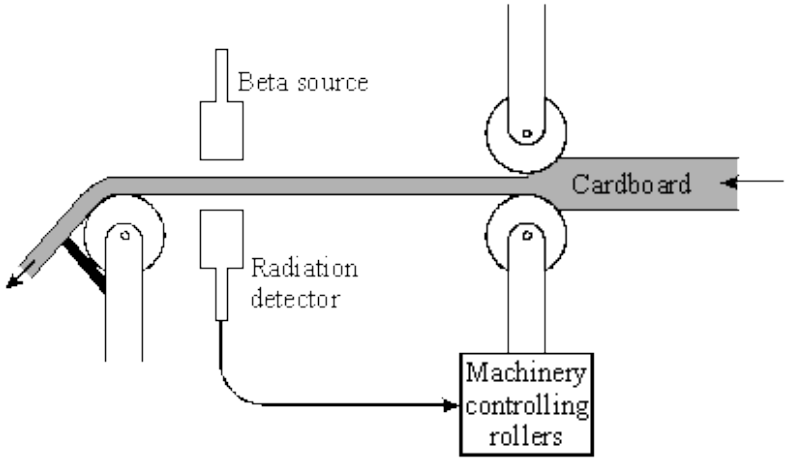
.....

.....

.....

(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)

40 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*?

.....

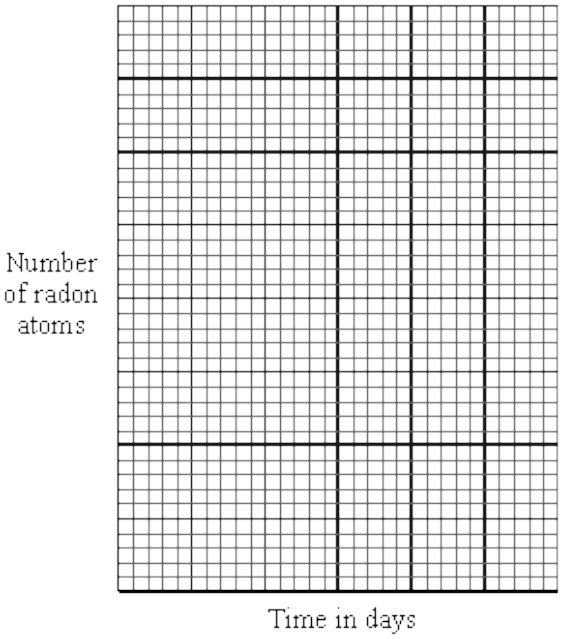
(1)

(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.

.....

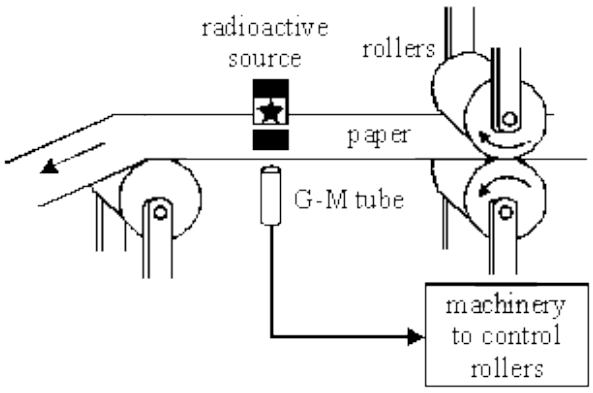
.....

.....

.....

(2)
(Total 11 marks)

41 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?

.....

.....

.....

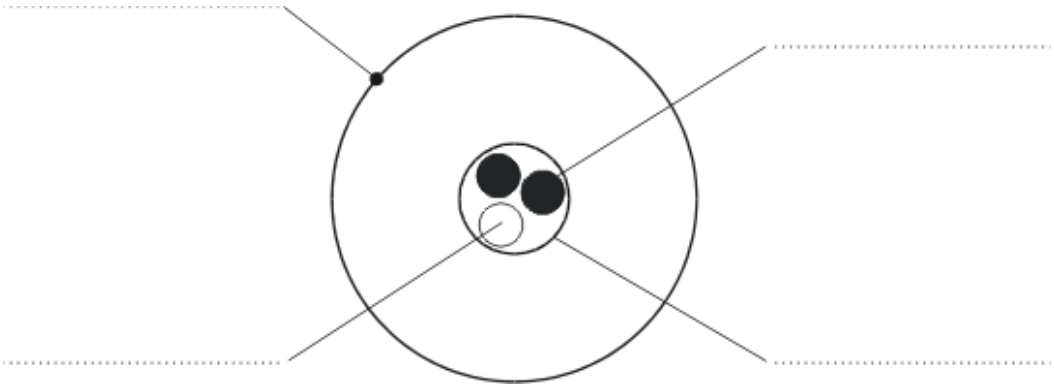
Answer = ...

(3)

(Total 8 marks)

42 (a) Tritium ($^{3}_{1}H$) 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 ($^{1}_{1}H$) have a mass number of 1.

.....

.....

.....

(2)

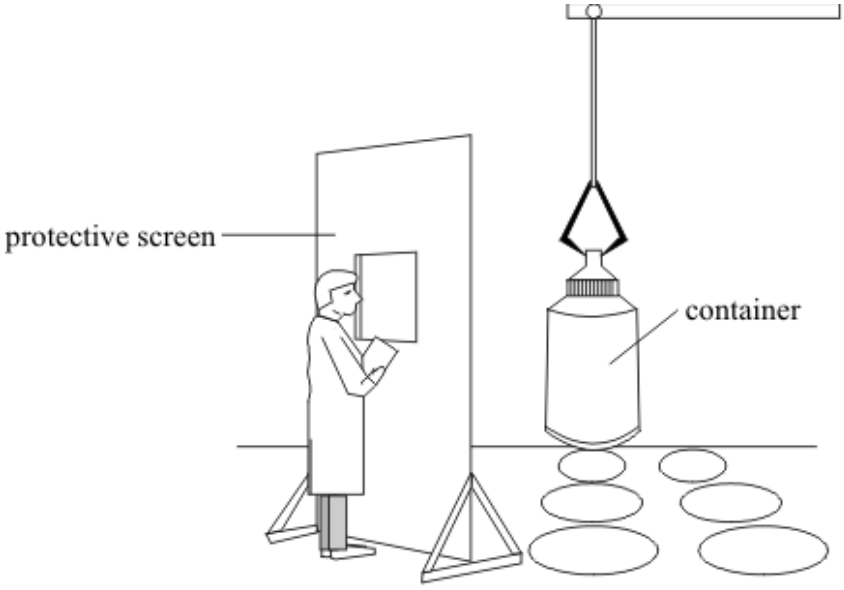
(iii) Tritium is a radioactive substance which emits beta (β) radiation.
Why do the atoms of some substances give out radiation?

.....

.....

(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)

43 (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)

44 (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.

.....

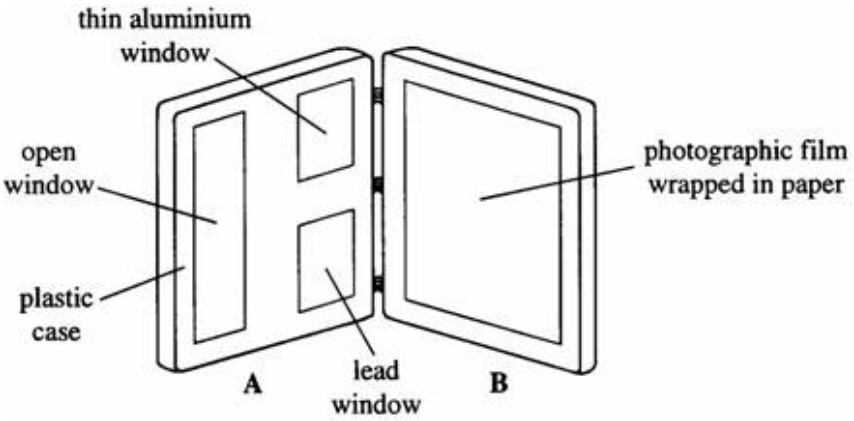
.....

.....

.....

(2)
(Total 4 marks)

45 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.

.....

.....

.....

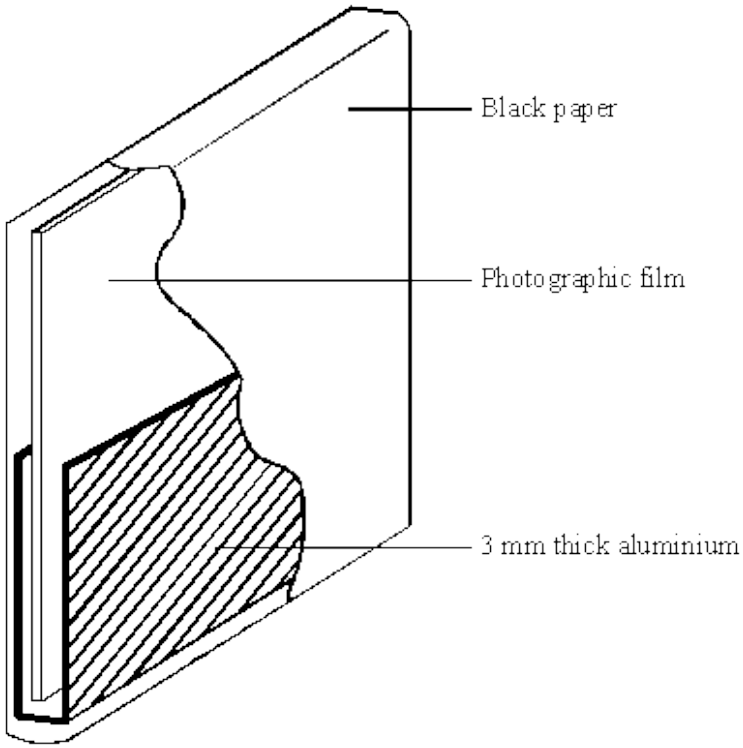
Age ..... million years

(2)

(Total 10 marks)

46 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.

.....

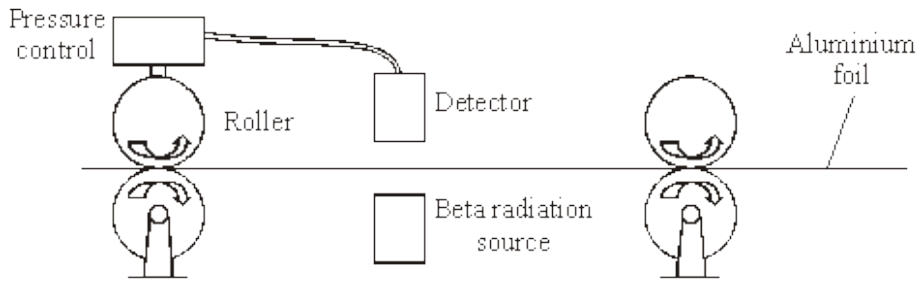
.....

.....

.....

(Total 2 marks)

47 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)

48 (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.

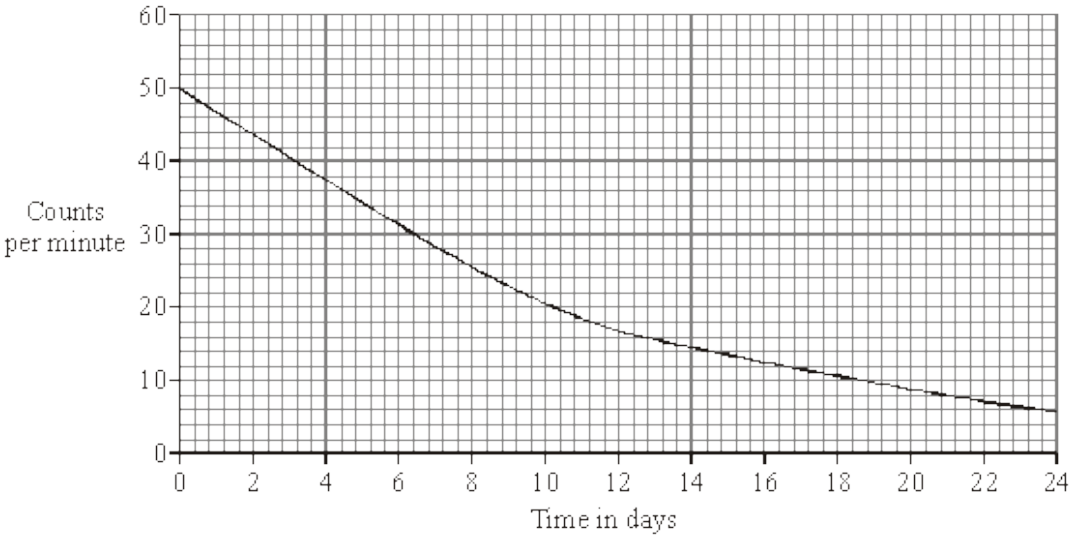
.....

.....

(1)
(Total 4 marks)

49 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)

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

.....

.....

.....

.....

(2)

(ii) What are beta particles?

.....

.....

.....

(1)

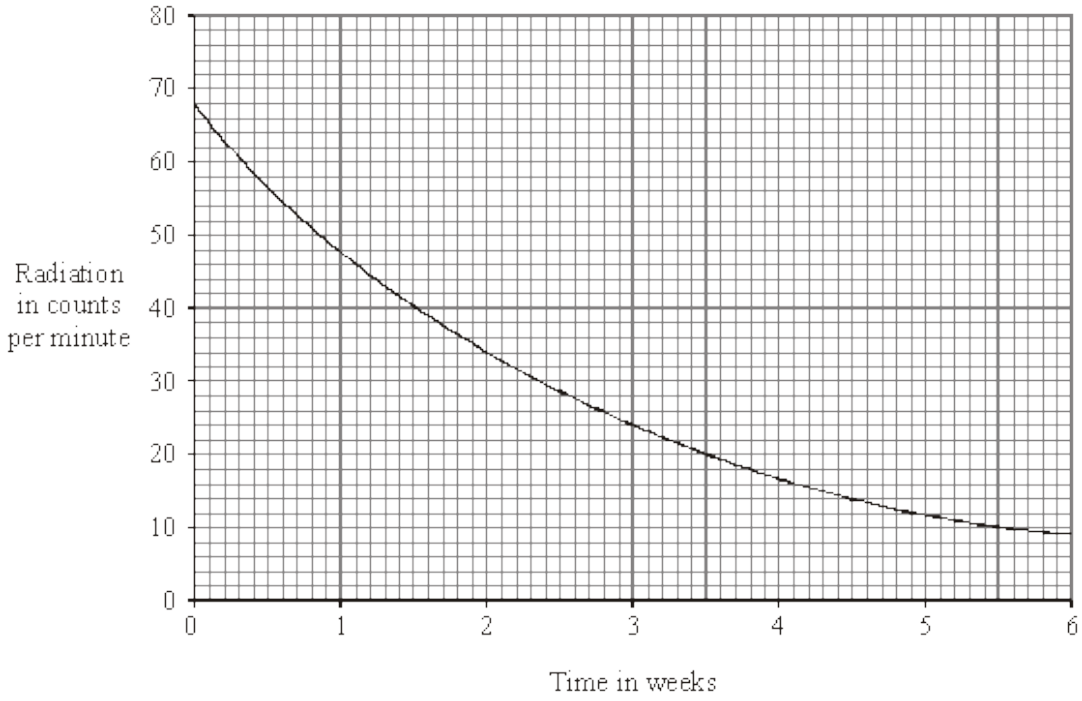
(b) Describe how beta radiation is produced by a radioactive isotope.

.....

(1)
(Total 4 marks)

51 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)

52 $^{99}_{43}Tc$ (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?

.....

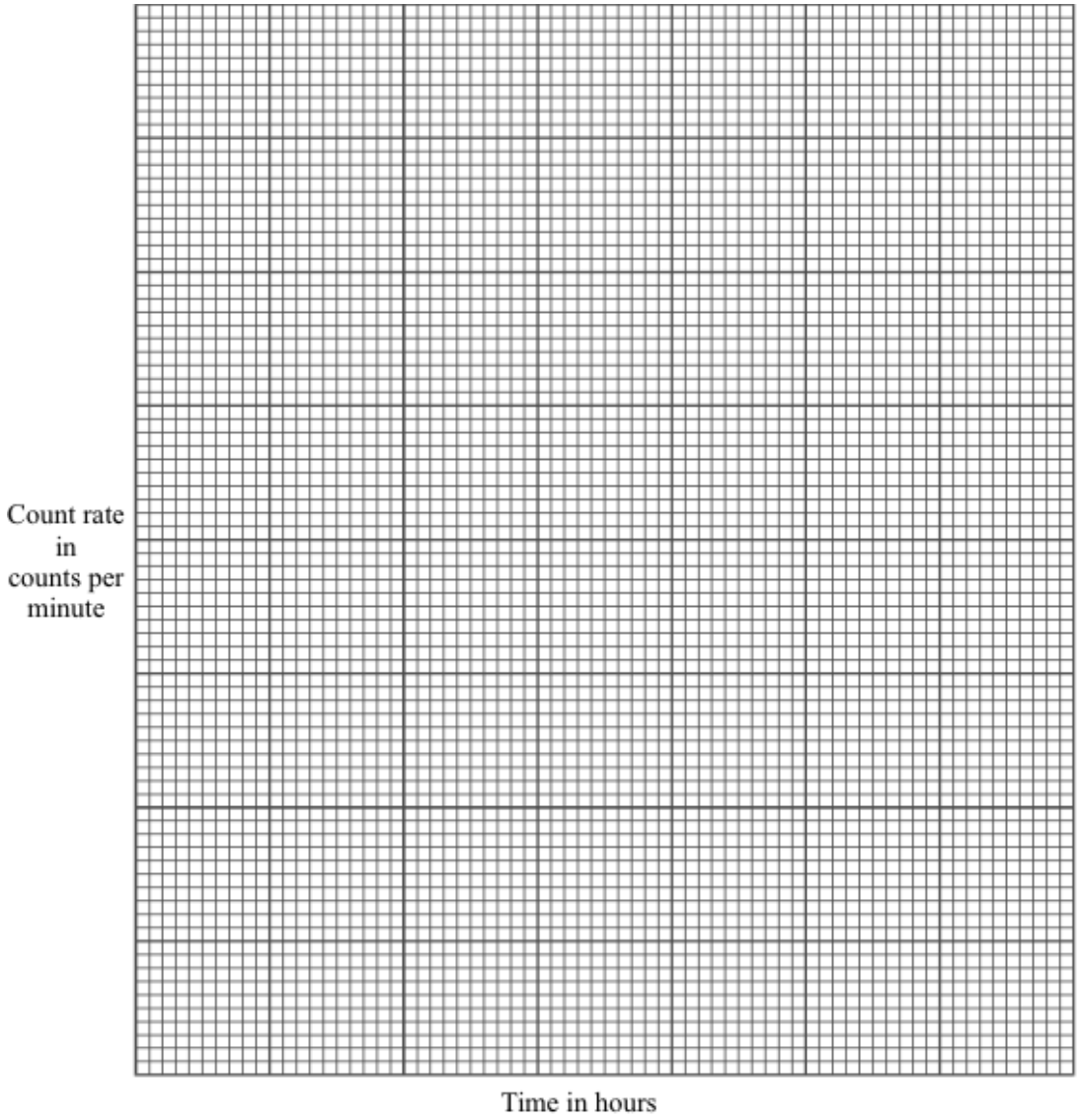
.....

(Total 1 mark)

53 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

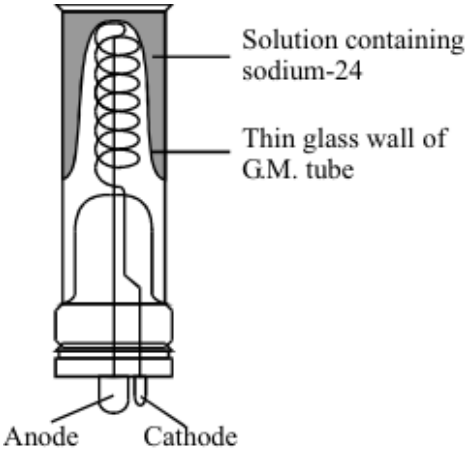
(a) Draw a graph of the results and find the half-life for the isotope. On the graph show how you obtain the half-life.



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.



(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)

54 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)

55 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?

.....

.....

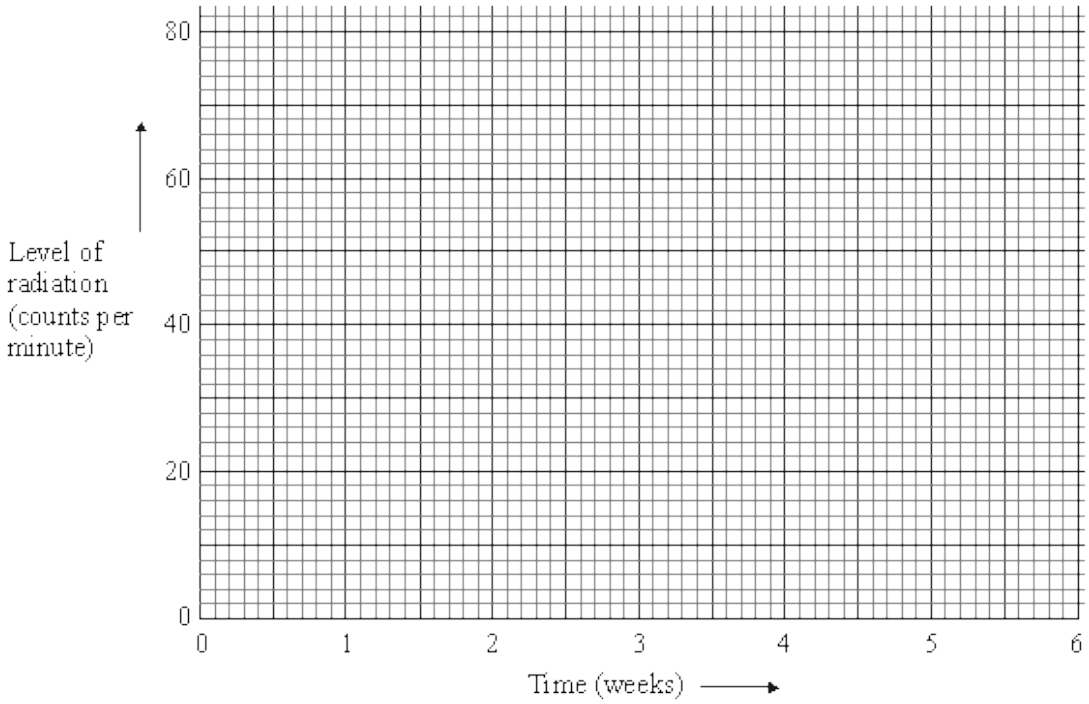
(1)
(Total 8 marks)

56 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?

.....

.....

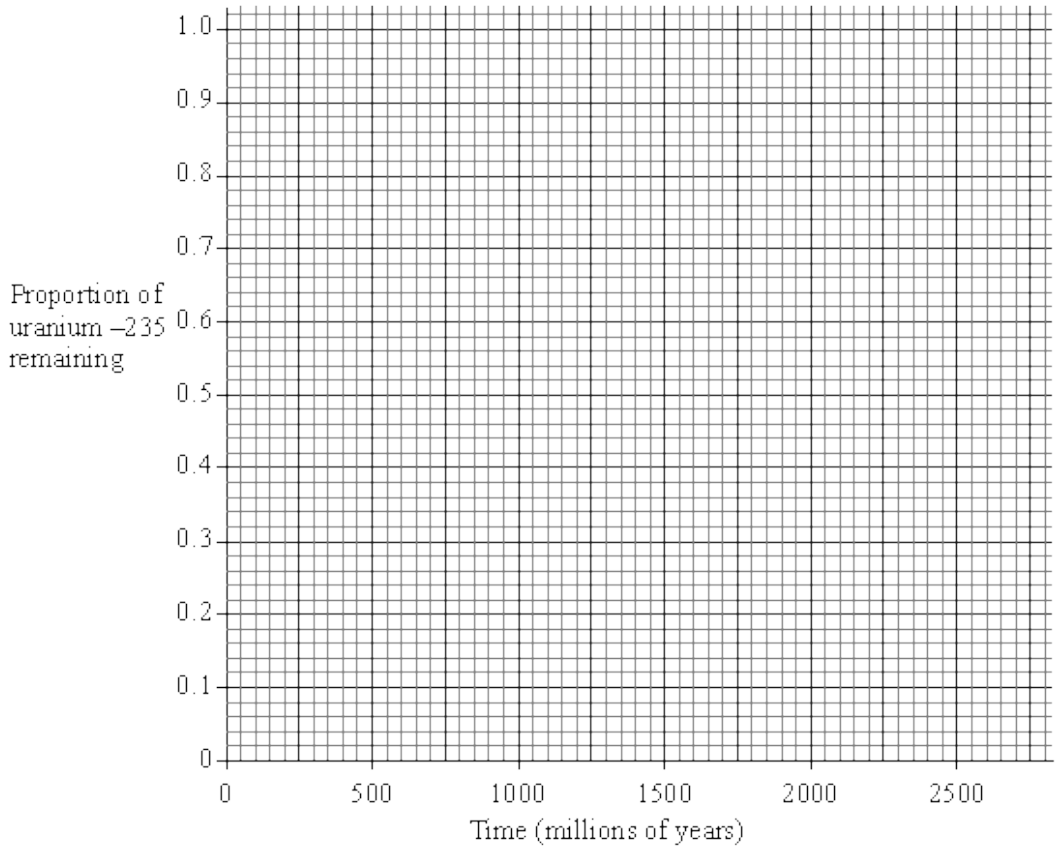
.....

(3)
(Total 8 marks)

57 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.



(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)

58 (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:

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

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

88 ◄- - - 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.

$$^{228}_{89}\text{Ac} \longrightarrow$$

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

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:

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

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

89 ◄- - - 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.

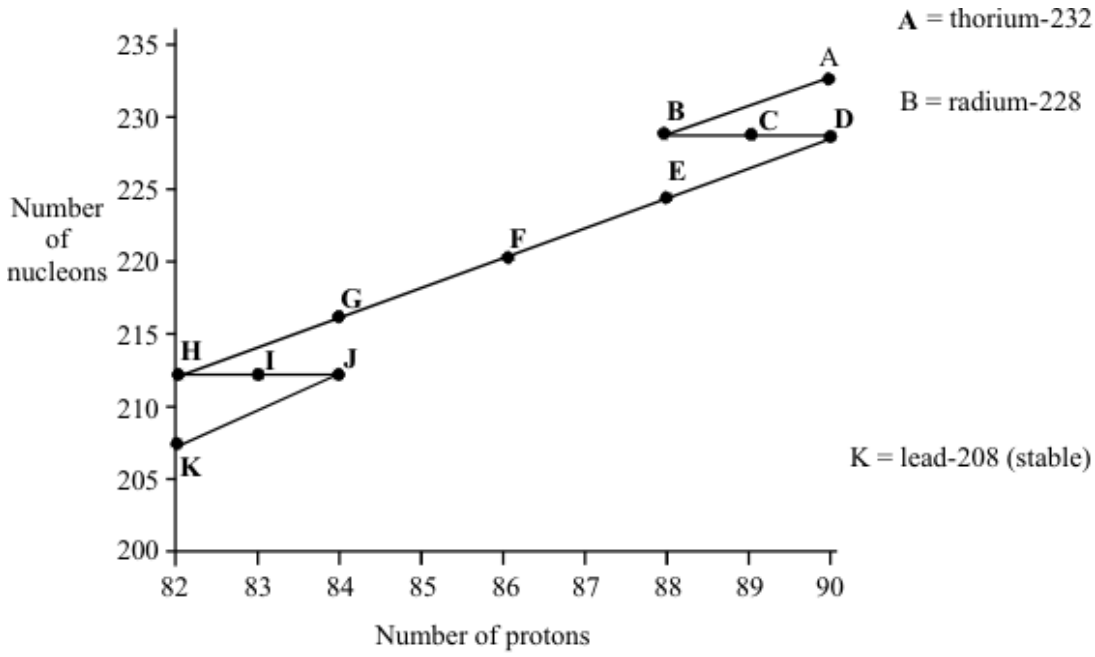
Complete the equation for this decay.

$$^{228}_{89}\text{Ac} \longrightarrow$$

(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.

.....

.....

.....

.....

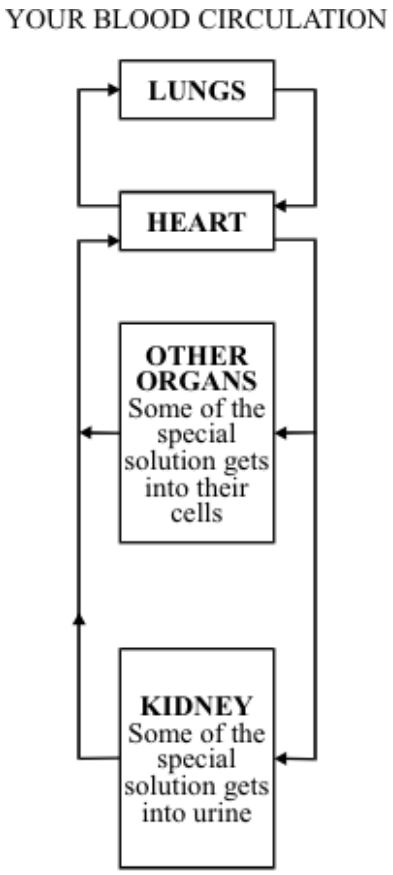
.....

(3)
(Total 13 marks)

59 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.



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 $10 \times 500 = 5000$ 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.)

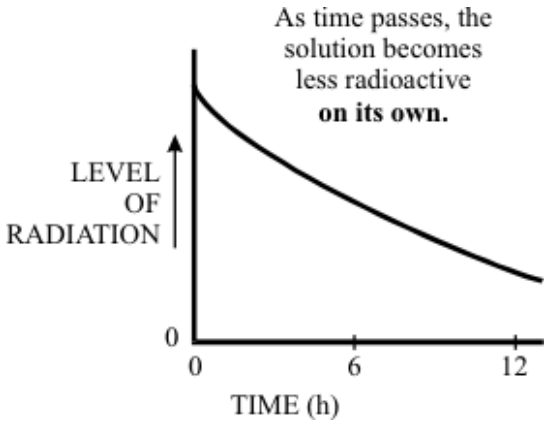
.....

.....

.....

.....

(4)



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)

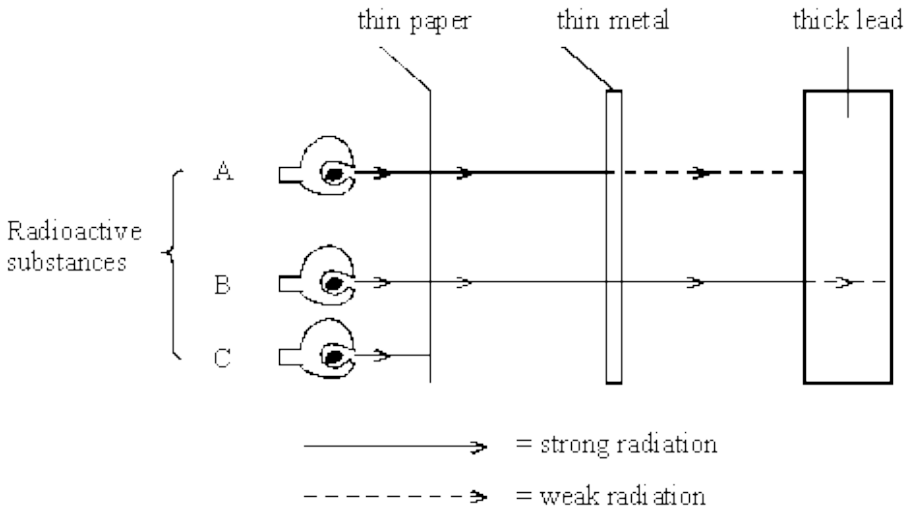
(c) The doctors use a radioactive substance which loses half of its radioactivity every six hours. Explain why this is a suitable radioactive substance to use.

.....

.....

(2)
(Total 9 marks)

60 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)

1

(a) Alpha – two protons and two neutrons

1

Beta – electron from the nucleus

1

Gamma – electromagnetic radiation

1

(b) Gamma

Beta

Alpha

*allow **1** mark for 1 or 2 correct*

2

(c) any **two** from:

- (radioactive) source not pointed at students
- (radioactive) source outside the box for minimum time necessary
- safety glasses **or** eye protection **or** do not look at source
- gloves
- (radioactive) source held away from body
- (radioactive) source held with tongs / forceps

accept any other sensible and practical suggestion

2

(d) half-life = 80 s

1

counts / s after 200 s = 71

accept an answer of 70

1

(e) very small amount of radiation emitted

accept similar / same level as background radiation

1

[10]

2

(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

6

[13]

3 (a) (i) nuclear reactor

1

star

1

(ii) nuclei are joined (not split)

accept converse in reference to nuclear fission

*do **not** accept atoms are joined*

1

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

- neutron
- (neutron) absorbed by U (nucleus)

  ignore atom

  *do **not** accept reacts*

  *do **not** accept added to*
- forms a larger nucleus
- (this larger nucleus is) unstable
- (larger nucleus) splits into two (smaller) nuclei / into Ba and Kr
- releasing three neutrons and energy

  accept fast-moving for energy

4

(ii) 56 (Ba)

1

57 (La)

*if proton number of Ba is incorrect allow **1** mark if that of La is 1 greater*

1

$^{0}_{-1}\beta$

accept e for β

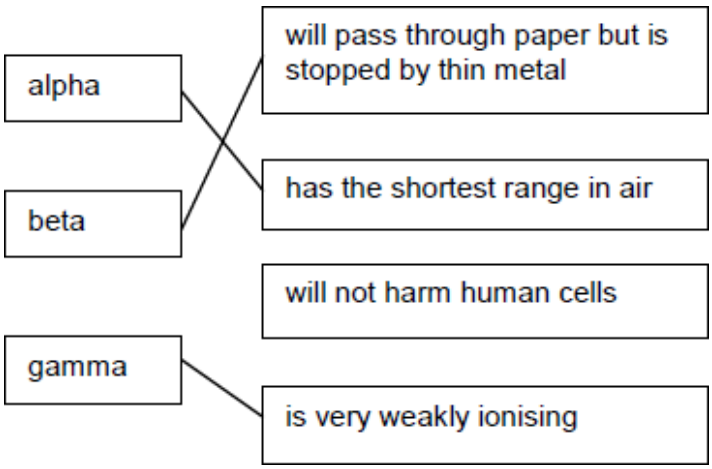
$^{139}_{56}Ba \longrightarrow {}^{139}_{57}La + {}^{0}_{-1}\beta$

*scores **3** marks*

1

[10]

4 (a) 3 lines correct



*allow **1** mark for each correct line*

if more than one line is drawn from any type of radiation box then all of those lines are wrong

3

(b) Gamma radiation will pass through the body

1

(c) half

1

(d) protons

1

[6]

5 (a) 78

1

(b) atomic

1

(c) (i) 131

correct order only

1

54

1

(ii) 32 (days)

*allow **1** mark for showing 4 half-lives provided no subsequent step*

2

(iii) limits amount of iodine-131 / radioactive iodine that can be absorbed

accept increases level of non-radioactive iodine in thyroid

*do **not** accept cancels out iodine-131*

1

so reducing risk of cancer (of the thyroid)

accept stops risk of cancer (of the thyroid)

1

[8]

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

- nuclear power (stations)

  accept nuclear waste
  accept coal power stations

- nuclear weapons (testing)

  accept nuclear bombs / fallout

- nuclear accidents

  accept named accident, eg Chernobyl or Fukushima

  accept named medical procedure which involves a radioactive source
  accept radiotherapy
  accept X-rays
  accept specific industrial examples that involve a radioactive source

  nuclear activity / radiation is insufficient

  smoke detectors is insufficient

1

(ii) (radioactive decay) is a random process

accept an answer in terms of background / radiation varies (from one point in time to another)

1

(b) any **one** from:

- (maybe) other factors involved

  accept a named 'sensible' factor, eg smoking

- evidence may not be valid

  accept not enough data

- may not have (a complete) understanding of the process (involved)

1

(c) (i) 2

1

2

1

(ii) 218

correct order only

1

84

1

(d) 3.8 (days)

*allow **1** mark for showing correct method using the graph provided no subsequent steps*

*correct answers obtained using numbers other than 800 and 400 gain **2** marks provided the method is shown*

2

[9]

7 (a) nucleus

*do **not** accept core / centre / middle*

1

(b) radiation damages our cells

accept radiation is dangerous / poisonous / harmful / toxic

accept radiation can cause cancer / kills cells / change DNA / cause mutations / harm health

accept so precautions can be taken

accept so they know they may be exposed to / harmed by radiation it refers to radiation (source)

to stop people being harmed is insufficient

1

(c) **C**

1

(d) gamma

1

gamma will pass through the lead

reason only scores if gamma chosen

or

alpha and beta will not pass through lead

accept correct symbols for alpha, beta and gamma

1

(e) (i) range of alpha too short

accept alpha would not reach detector

or

alpha absorbed whether box is full or empty

accept alpha (always) absorbed by box / card

accept alpha will not pass through the box / card

alphas cannot pass through objects / solids is insufficient

alpha not strong enough is insufficient

1

(ii) **M**

*reason only scores if **M** chosen*

1

less radiation / beta (particles) absorbed

accept more radiation / beta particles pass through

or

more radiation absorbed by full boxes

accept reading is higher

1

[8]

8 (a) (i) 200 to 50

accept either order

1

(ii) 5.3

accept values between 5.2 and 5.4 inclusive

1

(iii) 5.3

accept values between 5.2 and 5.4 inclusive

or

their (a)(ii)

1

(b) (i) Make the conveyor belt move more slowly

1

(ii) lead

1

(c) Exposure increased the content of some types of vitamin.

1

[6]

9 (a) cobalt-(60)

1

gamma (radiation) will pass through food / packaging

this can score if technetium chosen

1

long half-life so level of radiation (fairly) constant for (a number) of years

this can score if strontium / caesium is chosen

accept long half-life so source does not need frequent replacement

accept answers in terms of why alpha and beta cannot be used

gamma kills bacteria is insufficient

1

(b) (i) people may link the use of radiation with illness / cancer

accept (they think) food becomes radioactive

accept (they think) it is harmful to them

'it' refers to irradiated food

1

(ii) not biased / influenced (by government views)

1

(iii) any **two** from:

- data refers only to (cooked) chicken
- data may not generalise to other foods
- the content of some vitamins increases when food / chicken is irradiated
- no vitamins are (completely) destroyed
- (only) two vitamins decrease (but not significantly)

accept irradiated chicken / food contains a higher level of vitamins

marks are for the explanation only

2

(iv) so can choose to eat / not eat that (particular) food

accept irradiated food may cause health problems (for some people)

accept people may have ethical issues (over eating irradiated food)

1

(c) (i) electron
from nucleus / neutron

***both** parts required*

1

(ii) 90 years

*allow **1** mark for showing 3 half-lives*

2

[11]

10 (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

1

(ii) number of neutrons decreases by one

1

number of protons increases by one

accept for both marks a neutron changes into a proton

1

(b) (i) $^{208}_{81}Th$

1

correct order only

1

(ii) the number of protons determines the element

accept atomic number for number of protons

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

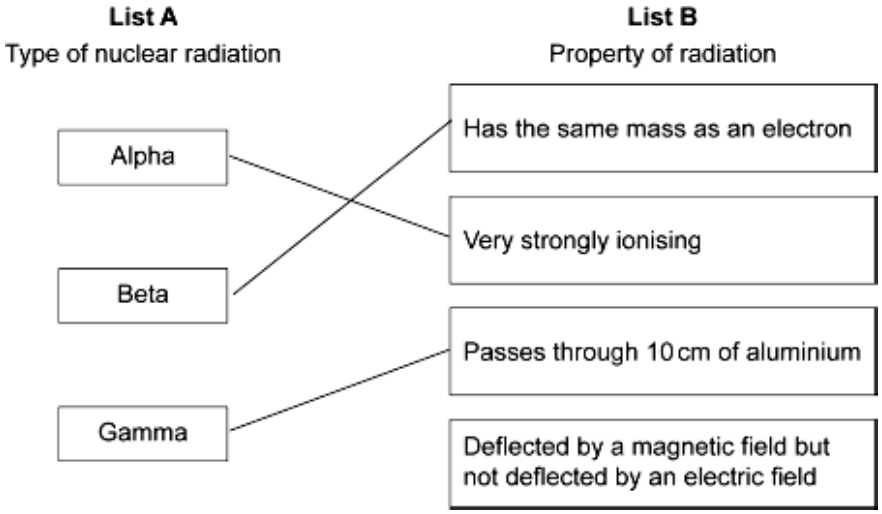
alpha and beta decay produce different atomic numbers

ignore correct reference to mass number

1

[7]

11 (a) **1** mark for each correct line



*if more than 1 line is drawn from any box in List **A**, none of those lines gain any credit*

3

(b) (i) (the detector) reading had gone down

'it' equals detector reading

accept the reading in the table is the smallest

accept 101 is (much) lower than other readings / a specific value eg 150

*do **not** accept this answer if it indicates the readings are the thickness*

1

more beta (particles / radiation) is being absorbed / stopped

accept radiation for beta particles / radiation

accept fewer particles being detected

1

(ii) six years

1

(iii) alpha would not penetrate the cardboard

accept the basic property – alpha (particles) cannot pass through paper / card

accept alpha (particles) are less penetrating (than beta)

range in air is neutral

1

[7]

12 (a) beta

1

alpha: would not pass through (the aluminium / foil)

1

gamma: no change in count rate when thickness changes

must be a connection between detection / count rate / passing through and change in thickness

1

(b) foil thickness increases then decreases (then back to normal / correct thickness)

a description of count rate changes is insufficient

1

gap between rollers decreases, then increases (then back to correct size)
or
pressure from rollers increases then decreases

accept tightness for pressure

answers may link change in thickness and gap width for full credit ie:

foil thickness increases so gap between rollers decreases (1)

foil thickness decreases so gap between rollers increases (1)

1

(c) 56 (years)

accept any value between 55-57 inclusive

*allow **1** mark for correct calculation of mass remaining as 1.5 (micrograms)*

*allow **1** mark for a mass of 4.5 micrograms plus correct use of graph with an answer of 12*

*maximum of **1** compensation mark can be awarded*

2

[7]

13 (a) (i) **L**

1

(ii) **M**

1

(b) To make a smoke detector work.

1

(c) **40**

no tolerance

1

[4]

14 (a) (i) number of protons are the same

accept atomic number / number of electrons for number of protons

1

number of neutrons are different

accept mass numbers are different – only if the first mark is awarded

1

(ii) an electron from the nucleus

both parts needed

1

(b) decays at the same rate as it is made

accept decays as fast as it is made

accept absorbed / used by plants (in CO_2) at same rate as it is being made

1

(c) (i) 3500

no tolerance

1

(ii) adjusted age correctly obtained from the graph

accept values between 3700–3800 inclusive

accept their (c)(i) used correctly to obtain an adjusted age from the graph

1

adjusted age +50

second mark can only be scored if first mark awarded

if no working shown an answer between 3750–3850 inclusive scores both marks

note: any line or mark made on the graph counts as working out

1

[7]

15 (a) alpha particles **cannot** pass through…

*do **not** accept gamma particles…*

or

alpha particles can pass through a very thin sheet of **paper** / **card**

credit answers where correct amendments are made to boxed statement

1

(b) (i) horizontal and vertical line drawn at correct positions on the graph

accept a cross drawn at 4500 / 500 on the curve

or

two pairs of lines drawn, for example, at 600 and 300

accept a horizontal line drawn at 500 on its own

*do **not** accept vertical lines only*

1

(ii) 4500 million years

1

(iii) half-life too long

*do **not** accept simply its half-life is 4500 million years*

1

no (measurable) change in count rate

*do **not** accept have not got the equipment*

*do **not** accept it's harmful (to children)*

*if neither of the above points scored, accept not enough time to measure it for **1** mark*

1

[5]

16 (a) (i) alpha (particle)

1

(ii) (unstable) nucleus

accept (unstable) nuclei

*do **not** accept middle*

*do **not** accept helium nucleus*

1

(iii) same number of protons

accept same number of electrons

accept same atomic / proton number

accept they both have 92 protons

same number of neutrons negates answer

1

(b) (i) 4500 million years

*do **not** accept 4500 years*

1

(ii) curve starting at 100 000 with a correct general shape

1

passing through (4500, 50 000) and (9000, 25 000)

*allow **1** mark for points plotted*

or

line passing through (4500, 50 000) and (9000, 25 000)

1

[6]

17 (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 $^{4}_{2}He$ or $^{4}_{2}\alpha$ for **1** mark*

an alpha particle is a helium nucleus is insufficient for this mark

1

[8]

18 (a) **C**

1

(b) beta

accept gamma

if answer alpha can still gain marks for saying why not beta or gamma

1

any **two** from:

*must have at least one quantitative statement to get **2** marks*

- range in air for beta is (at least) 50cm
- count-rate does not drop (much) in first 40cm
- count-rate does not fall much until distance is 60cm
- alphas cannot travel more than 5cm in air / alphas could not travel 100cm in air

  accept alphas cannot travel that far
- alphas would not be detected
- gammas not absorbed by 100cm of air

  accept gammas not stopped by air
  accept gammas travel further than alphas and betas

  strength of source is neutral

  references to penetrating power is neutral

2

(c) (i) increases

1

(ii) Group **A** think that (even a very small level of exposure) gives some risk

accept there is always a risk, no matter how small the level of exposure

1

Group **B** think that there is no risk (from a very low level of exposure)

accept below a certain level of exposure there is no risk

no marks for a simple graph description

1

[7]

19 (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 $_2{}^4He$

*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]

20 (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

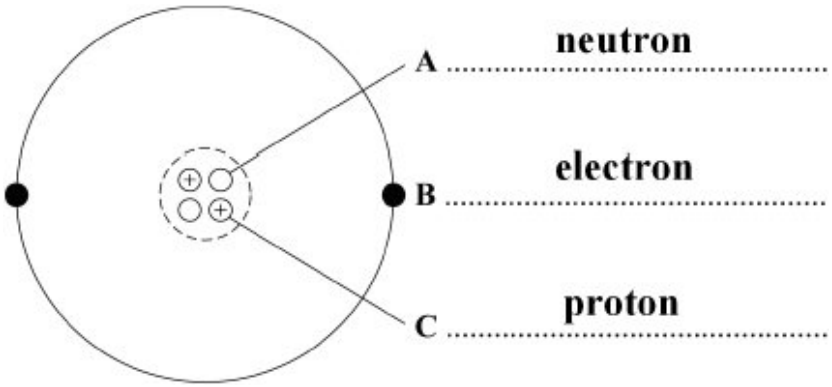
*do **not** accept protons with any other particle e.g. number of protons and neutrons changes incorrect*

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

1

[4]

21 (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]

22 (a) (i) gamma hardly ionises the air

accept does not ionise
accept gamma radiation is not charged
*do **not** accept answers in terms of danger of gamma or other properties*

1

(ii) half-life (too) short

accept need frequent replacement 'it' refers to curium-242

1

(iii) (two) fewer neutrons

accept different numbers of neutrons if a number is specified it must be correct
*do **not** accept more neutrons unless curium-244 is specified*

1

(b) (i) gamma

accept correct symbol

1

(ii) both absorbed by the metal / steel / weld

only scores if (b)(i) is correct
accept cannot pass through the metal / steel / weld

1

(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]

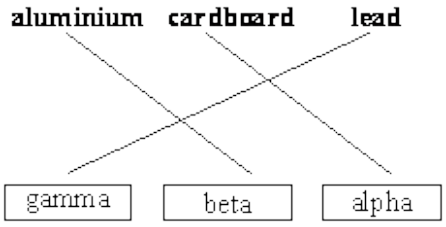
23 (a) (i) **P**

1

(ii) **Q**

1

(b) 3 lines correct



*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]

24 (a) (i) beta and gamma

both answers required

accept correct symbols

1

(ii) alpha and beta

both answers required

accept correct symbols

1

(iii) gamma

accept correct symbol

1

(b) nothing *(*you do to a radioactive substance / source*)* changes the count rate / activity / rate of decay / radiation (emitted)

accept it = radiation emitted

or *(*reducing*)* the temperature does not change the activity / count rate / rate of decay / radiation (emitted)

1

(c) (i) has <u>one</u> more neutron

correct answer only

1

(ii) 14 days

no tolerance

*allow **1** mark for showing a correct method on the graph*

2

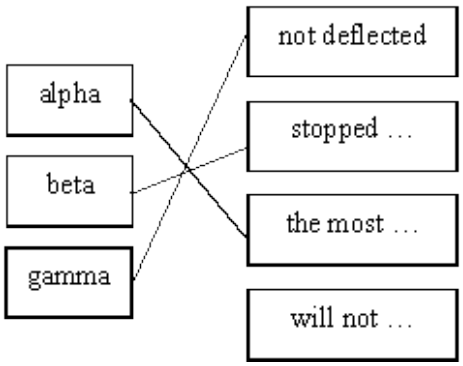
(iii) any **two** from:

- beta particles / radiation can be detected externally
- beta particles / radiation can pass out of / through the plant
- long half-life gives time for phosphorus to move through the plant / be detected / get results
- phosphorus-32 is chemically identical to phosphorus-31
- phosphorus-32 is used in the same way by a plant as phosphorus-31

2

[9]

25 (a) 3 lines correctly drawn



1 *mark for each correct line if more than one line is drawn from a box in List* ***A*** *all lines from that box are wrong*

3

(b) nucleus

accept nuclei
do ***not*** *accept nuclear*

1

(c) **Y**

do ***not*** *accept gamma*

any **two** from:

do ***not*** *accept other properties of gamma*

- least dangerous (inside the body)

  do ***not*** *accept not dangerous*
  accept not as harmful as alpha
  (inside the body)

- least ionising

- penetrates through the body

  do ***not*** *accept can be detected externally*

1

- is a gas / can be breathed in

  accept it is not a solid
  (cannot score if ***Z*** *chosen)*
  if ***X*** *chosen can score this gas mark*
  if ***Z*** *chosen can score* ***both*** *gamma marks*

2

(d) any **one** from:

*do **not** accept kills bacteria*

- longer shelf life

  accept stays fresh longer / stops it going bad / mouldy

- food can be supplied from around the world
- wider market for farmers
- cost to consumers (may be) lower
- less likely to / will not get food poisoning

  accept infection / disease / ill for food poisoning

1

[8]

26 (i) 50 ± 5

1

(ii) 50 ± 5

accept their (b)(i)

1

(iii) less

accept any way of indicating the correct answer

1

[3]

27 *answers must be comparative*
accept converse answers throughout

alpha: the count rate is (greatly) reduced
by the card **or** the card absorbs alphas <u>but not betas</u>

accept paper for the card

1

beta: the count rate is (greatly) reduced by the metal **or** the thin metal absorbs alphas and betas **or** the thin metal absorbs all of the radiation (from the source)

accept aluminium for the metal

1

gamma: would pass through the thin

accept aluminium for the metal

metal but count rate is background **or** no radiation passing through **or** a higher reading would be recorded **or** to reduce the count to 2 would require much more than 3 mm of metal

accept lead / aluminium for the metal

1

[3]

28 (a) (i) two protons and two neutrons **or** the nucleus of a helium atom

1

(ii) different numbers of neutrons **or** one has (3) more or less neutrons than the other

accept different mass (numbers)

if give a number as a difference it must be 3

1

(iii)

*if polonium or hydrogen chosen gets **0** marks*

technetium (99) or none

1

any **two** from:

*do **not** accept gamma rays are less dangerous*

gamma rays less dangerous inside the body

gamma radiation less likely to be absorbed by cells **or** gamma rays do not ionise cells

gamma rays can penetrate the body (to be detected externally)

first 3 points valid if either technetium or iridium or none is given

2

short half-life so safe levels inside body soon reached

half-life long enough to obtain measurements

half-life short enough not to cause long term damage

last 3 points valid if either technetium or uranium or none is given

(b) 2200 ± 200

*allow **1** mark for attempted use of 70% on the graph*

2

[7]

29 (a) 95

1

(b) alpha

1

accept correct symbol

(c) any **two** from:

- radiation is outside the body

  accept detector is on ceiling or high up the wall

- radiation will not reach (living) cells

  accept radiation cannot pass through the body / skin

- radiation absorbed by the air

  accept cannot pass through the plastic casing

  *do **not** accept because it is alpha radiation – unless qualified*
  *do **not** accept does not give off harmful substance*
  *do **not** accept cannot pass through building materials etc*

2

(d) less (than)

1

[5]

30 (i) nucleus / neutron

*do **not** accept shells or orbits*

1

(ii) neutron changes to a proton **or** number of neutrons goes down 1 and the number of protons goes up by 1

*do **not** accept becomes positive*

1

[2]

31 (a) bigger

accept any word which means bigger

1

(b) **Z**

if Z is not given, the reason does not score

1

alpha will not pass through aluminium or lead

accept alpha cannot go through metals / dense material
accept there is nothing to stop the radiation
accept alpha will not pass through aluminium
*do **not** accept alpha will not pass through lead*
*do **not** accept alpha stopped by air*

1

[3]

32 (a) all points correctly plotted

tolerance ± $\frac{1}{2}$ square on y axis only

*allow **1** mark for 3 correctly plotted points*

2

attempt made to draw a smooth curve

*do **not** accept dot-to-dot line*

1

(b) (i) 3 days ± 0.2
or any value correctly obtained using their graph line

if no line drawn in (a), answer must be exactly 3

1

(ii) 3 days or their (b)(i)

1

(c) radon-222

*accept radon **or** 222*
accept alpha or 3.8
correct isotope required for reason to score

1

has the shortest half-life

accept the others have longer half-lives

1

[7]

33

(i) $\frac{1}{4}$

accept 0.25 or 25%

1

(ii) 2600

if answer to (c)(i) is ½ then accept 1300

1

[2]

34

(a) (i) element with equal number of protons, different number neutrons
or
same atomic/proton number different mass/nuclear number

1

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

*accept parents atoms **or** radioactive isotope*

do not accept time taken for radioactivity/substance/ material to halve

1

(iii) 12 (s)

1

(b) (i) 22800 (years)

*allow 1 mark for iterative steps 80-40-20-10-5 **or** statement of 4 half-lives*

2

(ii) decay (of carbon 14) over 150 years is insignificant

accept very little decay

accept change is too small

1

(c) either argument gains full credit

accept any 3 valid points from for and/or against arguments

FOR

– massive dilution of waste
– reduces concentration (within a given volume) to insignificant levels
– distant from habitation

AGAINST

– pollution (of the sea/beach)
– mutation **or** harm caused to living things (animals/plants)
– effect on food chain
– long period of time necessary

3

[9]

35 (a) electron

accept e

1

(b) 5400 – 7000

horizontal line drawn corresponding to their halving

1

or

a cross in the correct position on the line

1

(c) count rate converted to 14.5/min for 1g mass

accept 14.5 clearly marked on graph

1

decay time taken as 750 years ± 100 years

accept 750 years clearly marked on graph

1

refer their answer to 837 years (or approximately 800 **or** a value 837 - 937 years)

no the shirt was made after he died (if numbers justify)

or

yes it could have been his shirt (if numbers justify)

allow an alternative answer working backwards from 837 years

1

[6]

36 (a) (i) helium nuclei

1

or

two protons and two neutrons or $^{4}_{2}He$

*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 <u>detected</u> 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]

37 (a) presence of a radioactive source

*accept radioactivity **or** radioactive or radiation*

accept a named source

accept a named type of radiation ignore reference to relative levels

*do **not** accept thermal **or** heat radiation*

*do **not** accept nuclear waste*

1

(b) (i) gamma

accept correct symbol

1

(ii) alpha

accept correct symbol

1

[3]

38 (a) (i) it is random

*do **not** accept unpredictable*

*do **not** accept irregular*

1

(ii) source adds nothing **or** little to the count

1

continues to record background level

accept a clear explanation of background

1

(b) (i) an electron

accept $\frac{0}{-1}e$

1

(ii) <u>electromagnetic</u> wave with **high frequency** or short wavelength

*must have high frequency **or** short wavelength*

1

(iii) 15

*allow **1** mark for **3** iterative steps 584/2 292/2 146/2*

allow I mark for 45/3

3

(iv) [A] a safe level of radiation reached much quicker

could answer in terms of isotope but answer must be clear whether it refers to isotope or sodium-24

1

[B] long enough to obtain measurements

1

[10]

39 (a) suitable arrangement of source and GM tube ie <u>fixed distance apart</u>

accept 'detector' for GM tube and counter

1

suitable test

*eg introduce absorbing material **or** increase distance between source and GM tube*

1

suitable conclusion

*alpha that which gives a greatly reduced count with a paper absorber **or** alpha if count decreases rapidly when distance between source and GM tube exceeds 5 cm (approx)*

the first two marks could be scored from a <u>labelled</u> diagram

1

(b) (i) (changes to) background radiation

*do **not** accept the source is decaying if it is their only answer*

or

(beta) decay is random

accept decay is not constant

1

(ii) thickness decreasing

accept it is thin

1

increased count rate

1

(means) less (beta) radiation absorbed

accept more (beta) radiation passes through

1

(iii) changing thickness will not change count rate (significantly)

accept insufficient absorption of gamma radiation irrespective of thickness

*do **not** accept gamma rays too penetrating*

*do **not** accept answers in terms of speed*

1

[8]

40 (a) (i) a helium nucleus

accept $^{4}_{2}He$

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 ± 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]

41 (a) decrease

for 1 mark

1

(b) (i) none would go through paper

for 1 mark

1

(ii) all would go through paper

for 1 mark

1

(iii) only some absorbed/amount absorbed
depends on thickness of paper

for 1 mark each

2

(c) 1 → 1/2 → 1/4 → 1/8

for 1 mark

3 half lives/3 × 433

for 1 mark

1299 years

gains 3 marks

3

[8]

42 (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]

43 (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]

44 (a) two half lives

gains 1 mark

but
20 minutes

gains 2 marks

2

(b) alphas will be stopped by skin / air **or** do not penetrate betas and gammas can reach / damage organs / cells

for 1 mark each

2

[4]

45 (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^- 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]

46 beta

1

alpha absorbed by paper
allow beta <u>and</u> alpha
second mark is linked to first

1

or beta absorbed by aluminium allow beta can penetrate paper
or gamma would affect all of film
i.e. cannot obtain second mark unless first mark is correct

[2]

47 (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 <u>all</u> / <u>most</u> (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]

48 (a) (i) two protons

1

2 neutrons

if neither point gained allow 1 mark for helium nucleus

1

(ii) electron

1

(b) neutron splits (to form proton and electron)

1

[4]

49 (i) 7 **or** 8

1

correct data extracted from graph e.g. takes 8 days to drop from 50 to 25

allow appropriate annotation of graph

1

(ii) long enough to destroy cancer cells

do not accept dangerous unqualified

1

but short enough to minimise damage to surrounding tissues

1

[4]

50 (a) (i) two protons

1

2 neutrons

if neither point gained allow 1 mark for helium nucleus

1

(ii) electron

1

(b) neutron splits (to form proton and electron)

1

[4]

51 2 weeks

if answer is incorrect 2 gains two marks weeks gains one mark
half of 68 or 34 gains one mark / allow working shown on graph

[3]

52 neutron becomes proton / neutron emits electron / neutron emits beta particle

gains proton neutral

[1]

53 (a) sensible scales

full use of y axis

1

completely accurate plotting

1

a smooth curve going through all bar one of the points

do not accept a dot-to-dot graph if two parts shown for curves
accept the more correct

1

at least one line or a clear mark showing how to obtain the half life
from the graph and obtaining between 13 and 15

at the bottom of the page cross or ticks in the order of the mark scheme

1

(b) (i) to let the beta particles get through

*accept must be there to let the radiation through **or** if thick they may be stopped*

1

(ii) alpha particles would be stopped by the glass **or** cannot penetrate glass

do not accept alphas are weak

1

(c) (i) it will give more counts per minute for a small quantity **or** it does not last so long so may not be as dangerous

accept answers in terms of 5 years assume it refers appropriately

1

(ii) it will not be there long enough to act as a tracer **or** it could cause radiation damage as all its activity will be in the first place it enters the system

accept answer in terms of 5 seconds

accept not there long enough to work assume it refers appropriately

1

[8]

54 (a) (i) alpha particles cannot penetrate covering

do not credit any answer not relating to film badge or its case

1

(ii) film gets fogged **or** blackened

accept film gets exposed
*do not credit film changes colour **or** goes white **or** blotchy*

1

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

may cause cancer may damage cells **or** cell nucleii causes mutations changes DNA

*accept (causes) burns **or** kills cells*

1

(ii) any **two** from

treating cancers
tracers in body
sterilising instruments **or** bandages

accept two descriptions of named treatments, eg thyroid check and circulation monitoring

*accept is a source of X-rays, eg for dentistry **or** taking X-rays of bones*

2

(c) calculation that 1000 is 3 half lives on

8000 → 4000 → 2000 → 1000

1

time elapsed is 3 × half life = 31.8 hr

award both marks for 31.8 hr or 1 day 7.8 hr with no working shown

1

[7]

55 (a) (i) and (ii) in any order

1

(i) alpha

accept Greek symbol (α)

1

He^{2+} **or** $^{4}_{2}He$

1

(ii) beta

accept Greek symbol (β) ***or*** *electron*

1

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

mass and automatic numbers are not required

accept e

1

(b) (i) alpha

accept symbol

1

(ii) decreases

then stops (entirely) **or** after a few cm

accept stops because α can only travel a few cm in air

1

(c) it's gamma

accept its not ionising ***or*** *it is not charged* ***or*** *it's not* α *or β because a spark counter only measures α or β*

1

[8]

56 (a) at least **6** points correctly plotted

gains 1 mark

(to better than half a square) **but all** points correctly plotted

gains 2 marks

2

any **line** graph related to plotted points;
point (3,29) discounted;
best fit smooth curve

each for 1 mark

3

(b) radiation decreases with time

gains 1 mark

but decreases quickly at first then more slowly

gains 2 marks

but *idea that* it (about) halves every 2 weeks **or** half-life is (about) 2 weeks

gains 3 marks

3

[8]

57 (a) one relevant point correctly plotted

gains 1 mark

but two relevant points correctly plotted

gains 2 marks

but three relevant points correctly plotted

gains 3 marks

curved line drawn accurately through the points

for 1 further mark

4

(b) age of igneous rock = 400 ± 100 million years

1

(c) sandstone is a sedimentary rock

for 1 mark

there is likely to be some lead–207 present
or from the rocks from which the sandstone was formed

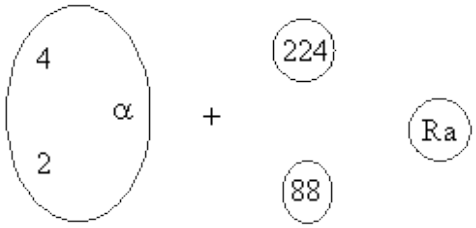
for 1 mark

(*allow* ^{207}Pb may not have come from this ^{235}U)

2

[7]

58 (a)

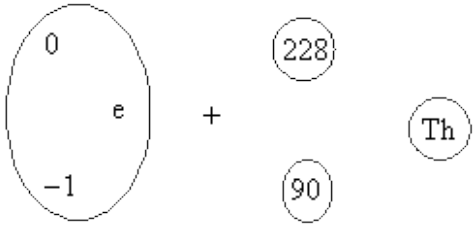


[Accept He^{2+} for α]

each ◯ *for 1 mark*

4

(b)



[Accept β for e]

each ◯ *for 1 mark*

4

(c) (i)

beta/ β		alpha/ α
alpha/ α		beta/ β
beta/ β	but	alpha/ α
alpha/ α		beta/ β

[i.e. consistent for 1; consistent and correct for 2]

gains 2 marks

2

(ii) *ideas that*

- many thorium atoms because they take so long to decay*
- (many lead atoms because) the thorium has been decaying for so long/for billions of years

or (because) the rock is so/very/billions of years of years old

- many lead atoms because this is the stable end product [of the decay series]
- few atoms of other isotopes because they decay so quickly*

[*N.B. credit answers in terms of half-life]

any three for 1 mark each

3

[13]

59

(a) evidence of $\frac{7350}{15}$

gains 1 mark

but

490

gains 2 marks

but

4900

gains 3 marks

units cm^3

for 1 further mark

4

(b) some of radioactive solution gets into cells/body organs
some of radioactive solution gets into urine (in the kidney)
the radioactive solution becomes less radioactive during the test
variability in readings

in any order for 1 mark each

3

(c) *ideas that*

- won't lose (too) much radioactivity during the test
- won't stay radioactive/harm cells for too long after test is over

for 1 mark each

2

[9]

60

A β / beta
B γ / gamma
C α / alpha

for 1 mark each

[3]