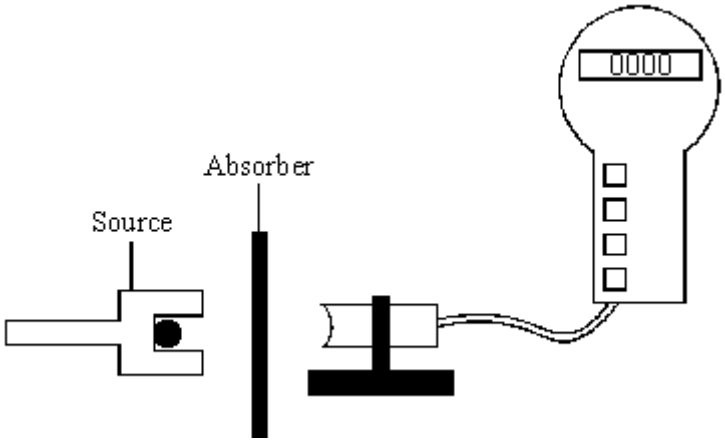
ATOMS AND NUCLEAR RADIATION PART II

Q1.

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)

Q2.

(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.

_____

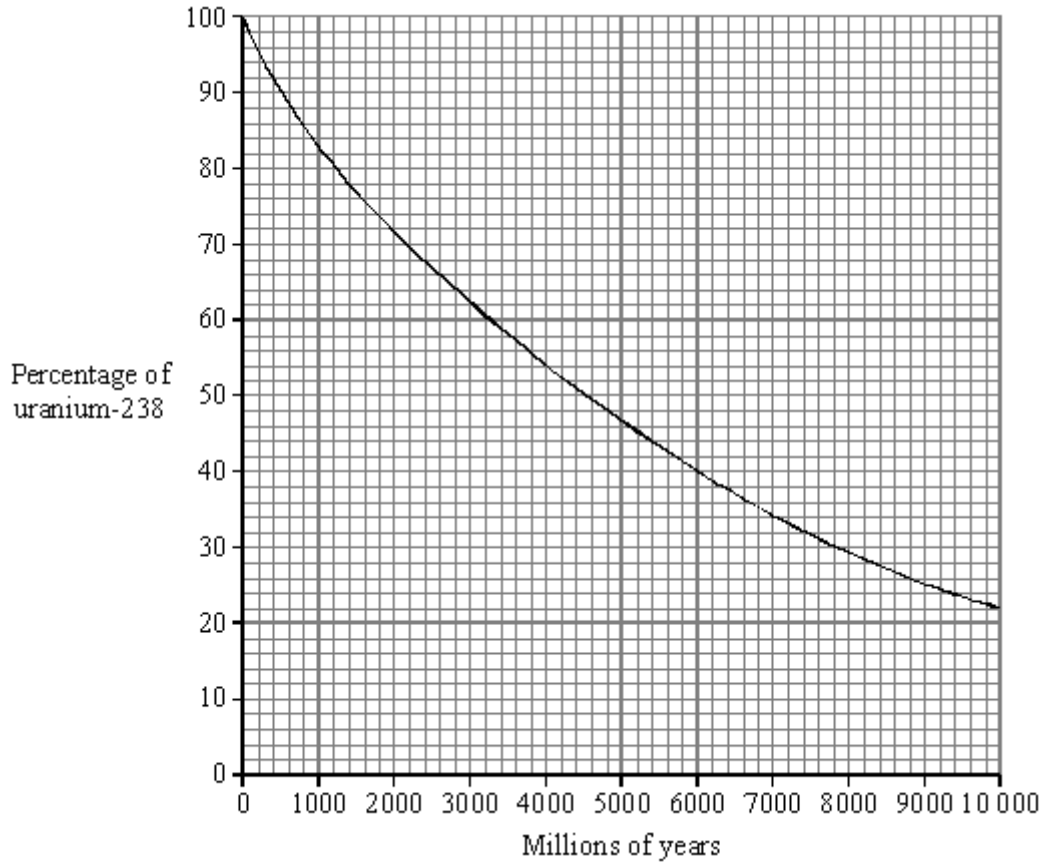
_____

_____

_____

(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)

Q3.

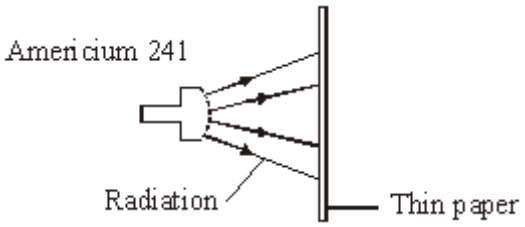
A smoke detector fitted inside a house contains a radioactive source, americium 241.

(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)

Q4.

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?

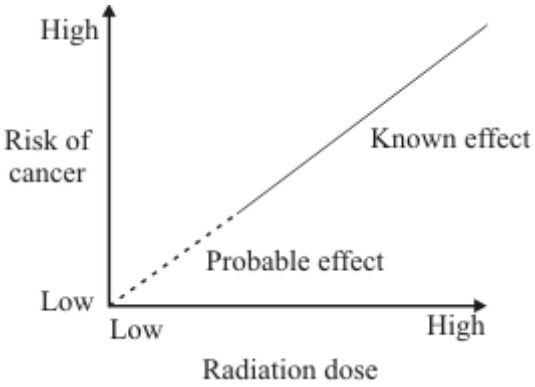
_____

(1)

(Total 2 marks)

Q5.

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

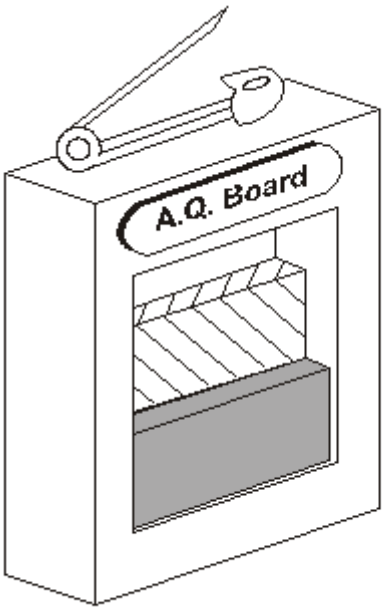


Complete the following sentence.

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.



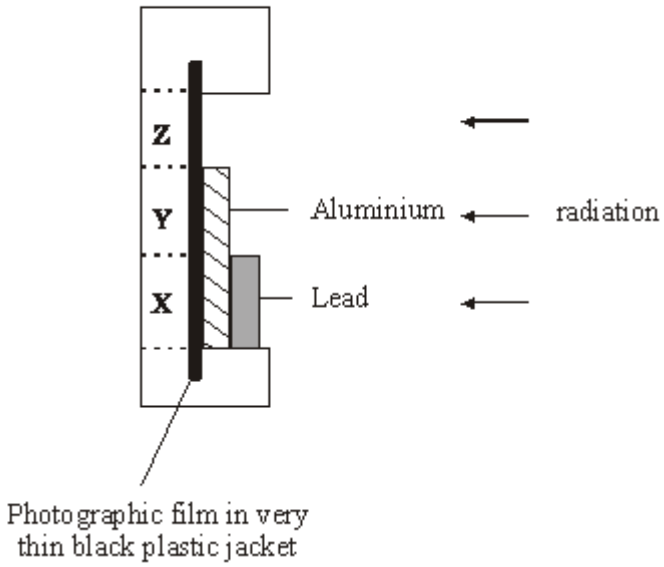


Diagram 1 **Diagram 2**

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)

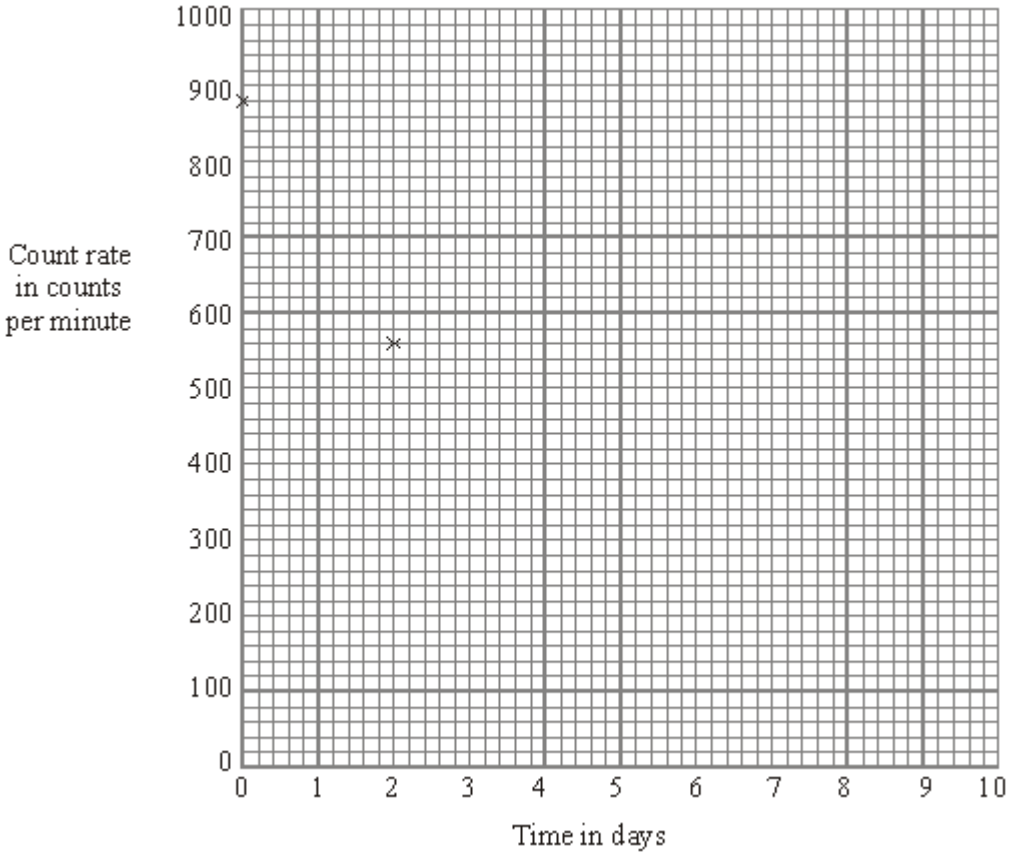
Q6.

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)

Q7.

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.

_____

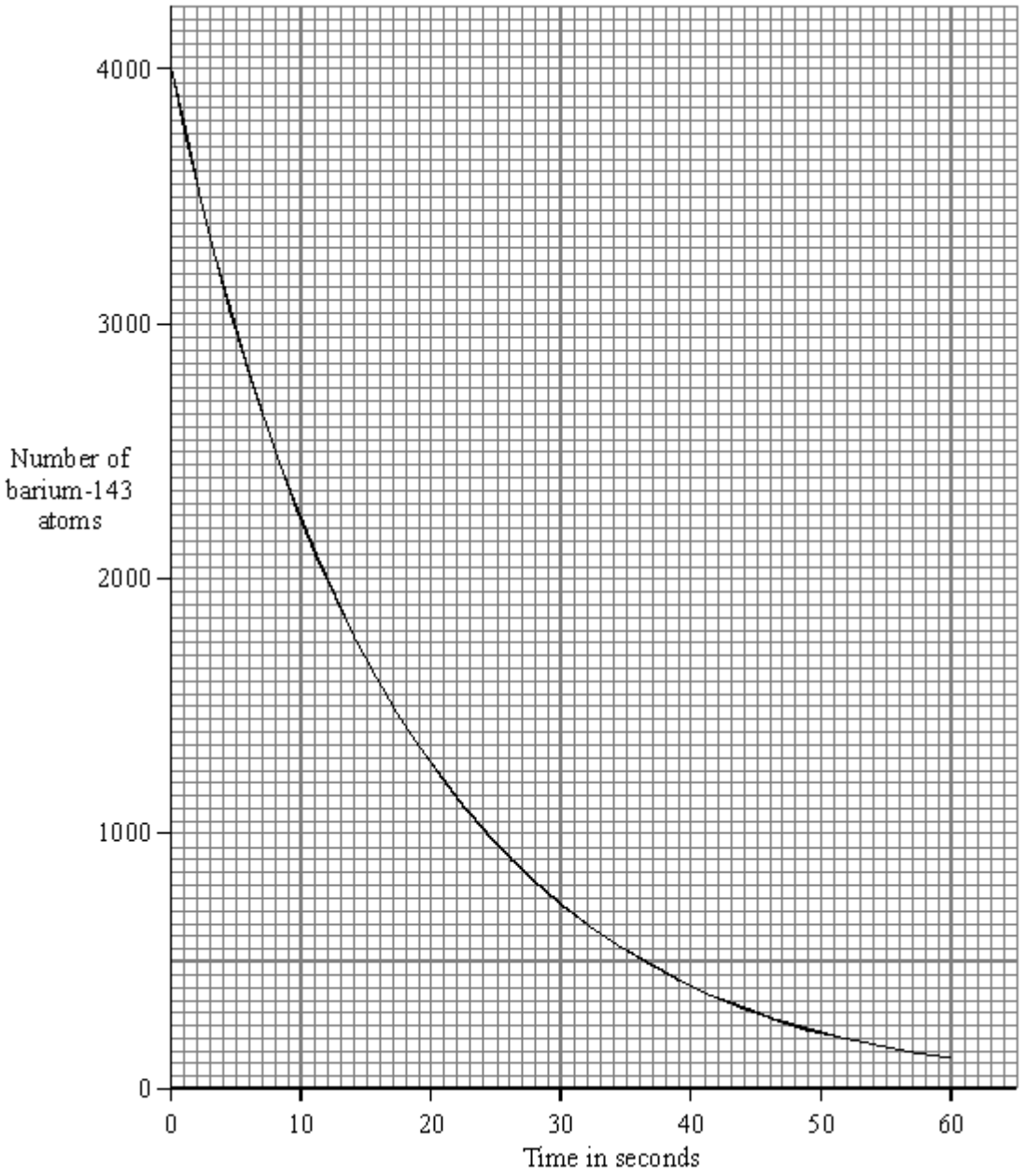
Age of rock = _____ million years

(1)

(Total 2 marks)

Q8.

(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)

Q9.

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

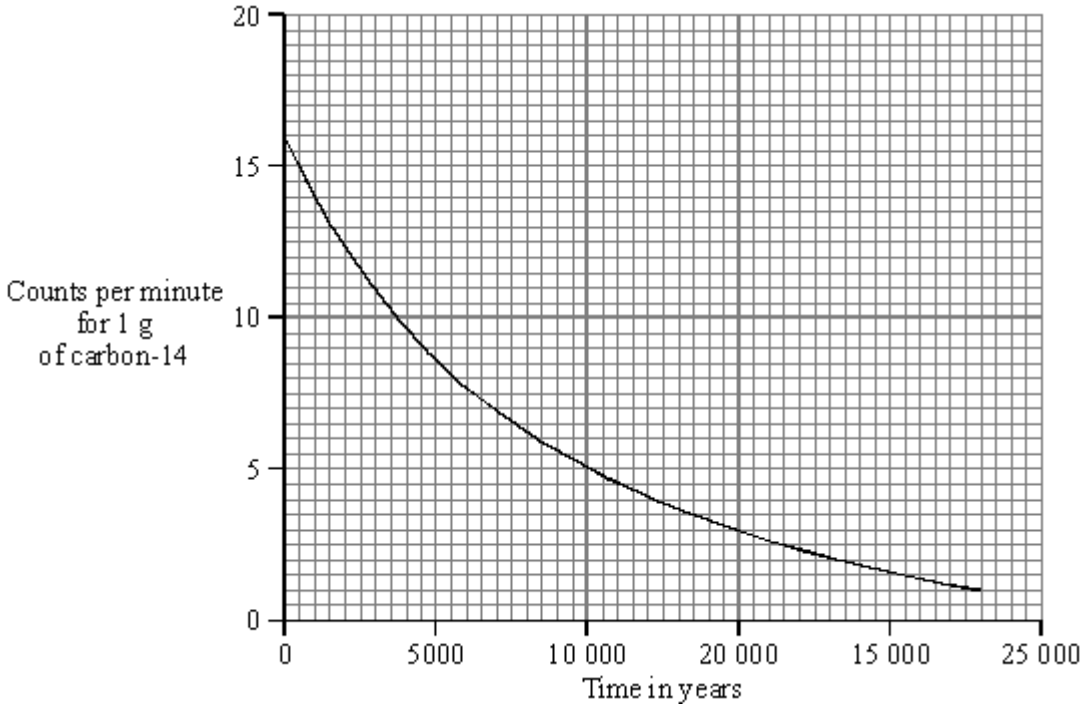
(a) What is a beta (β) particle?

_____

_____

(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)

Q10.

(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.

_____

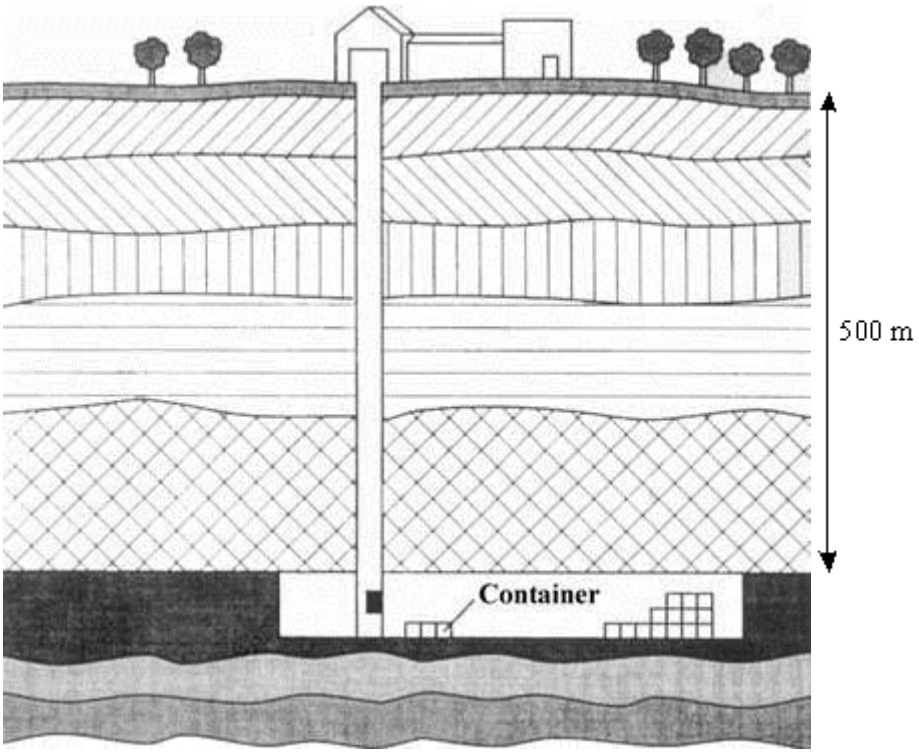
_____

_____

_____

(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)

Q11.

(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)

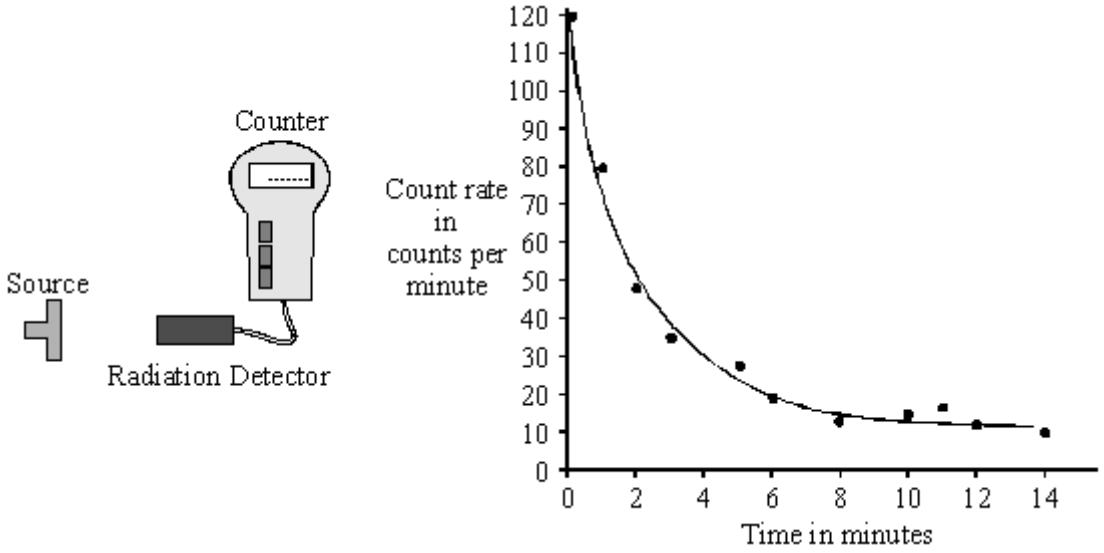
(ii) The type of radiation that is stopped by thick paper is _____

(1)

(Total 3 marks)

Q12.

(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)

Q13.

(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.

_____

_____

_____

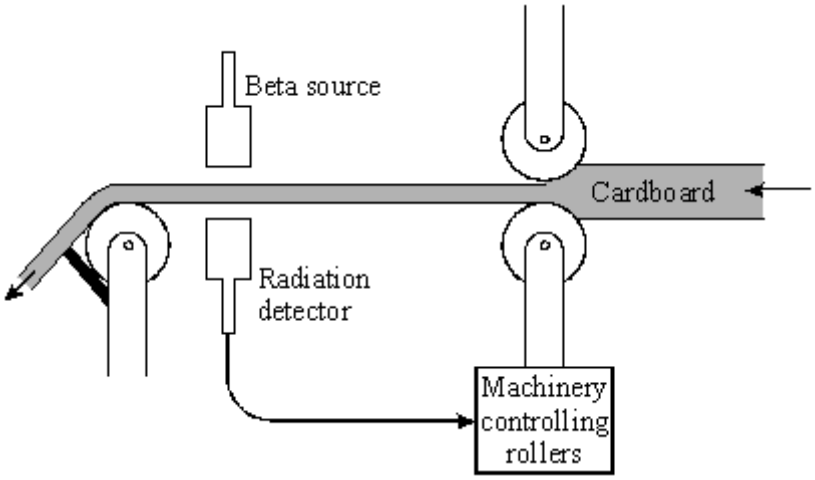
_____

_____

_____

(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)

Q14.

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*?

_____

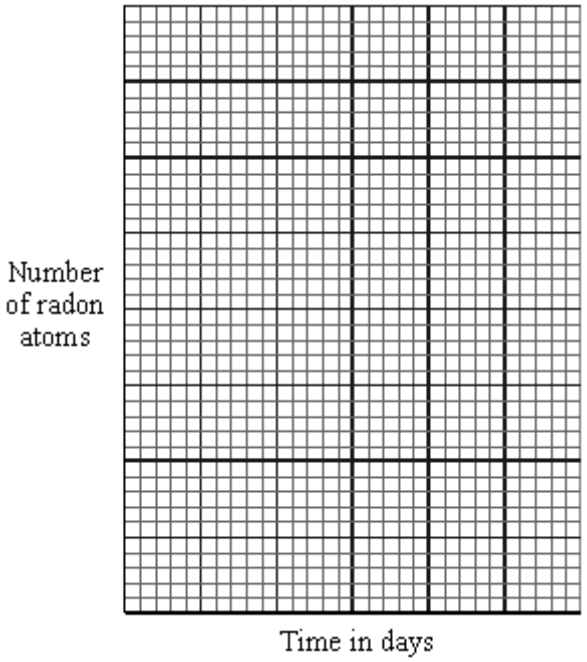
(1)

(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.

_____

_____

_____

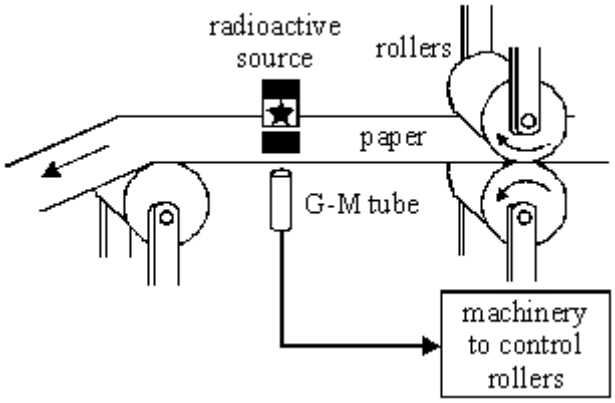
_____

(2)

(Total 11 marks)

Q15.

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 = _____

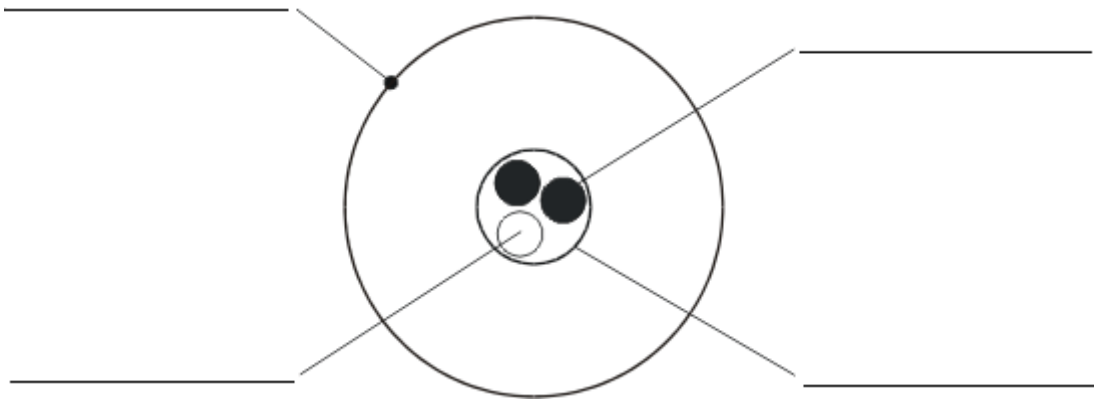
(3)

(Total 8 marks)

Q16.

(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)

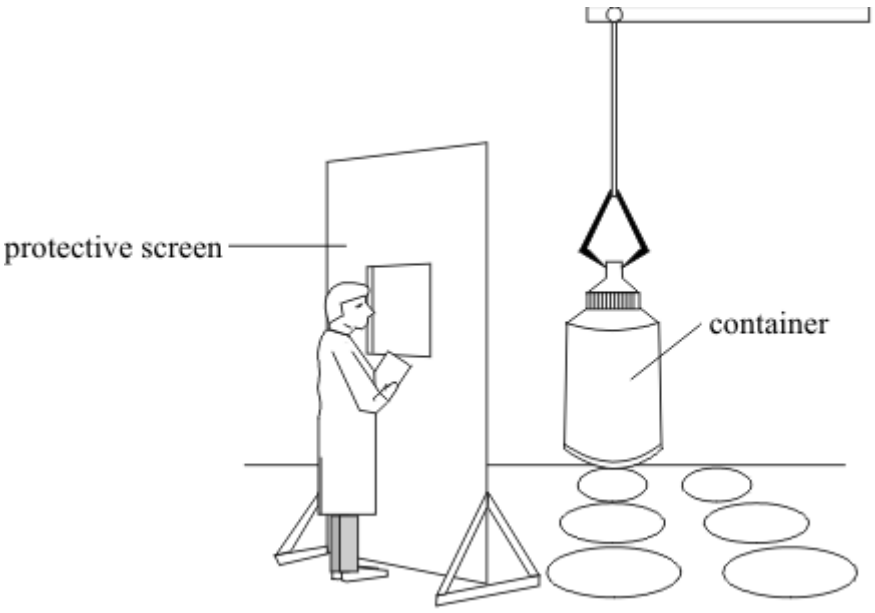
(iii) Tritium is a radioactive substance which emits beta (β) radiation.
Why do the atoms of some substances give out radiation?

_____

_____

(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)

Q17.

(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)

Q18.

(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.

_____

_____

_____

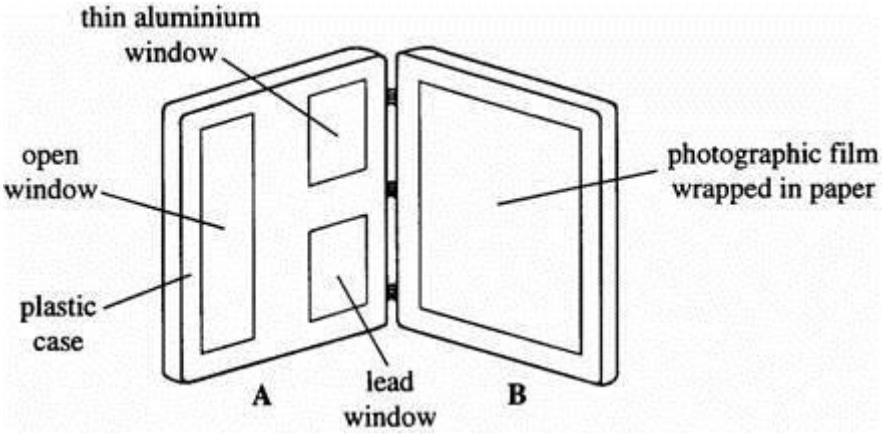
_____

(2)

(Total 4 marks)

Q19.

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

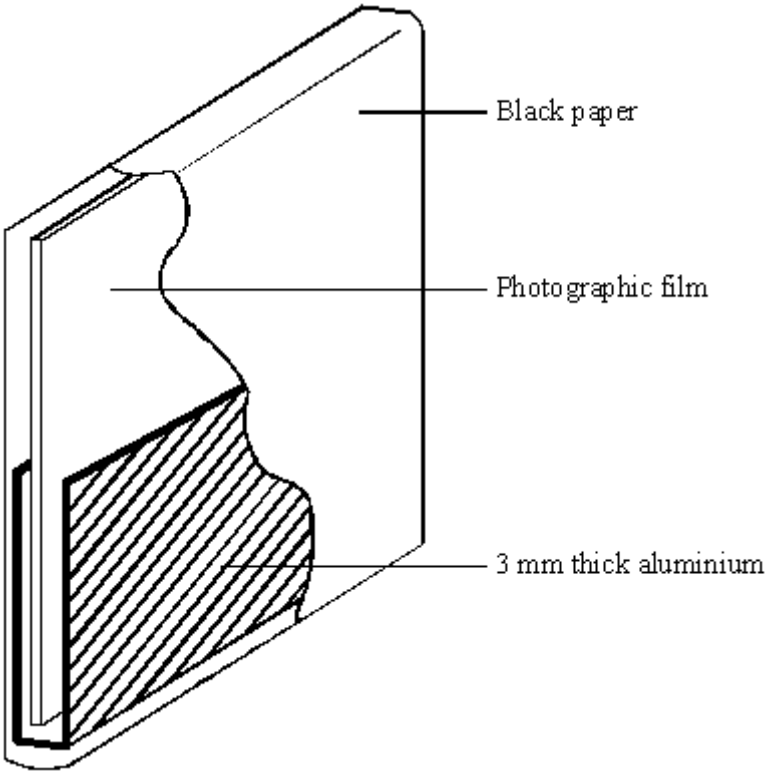
(2)

(Total 10 marks)

Q20.

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.

_____

_____

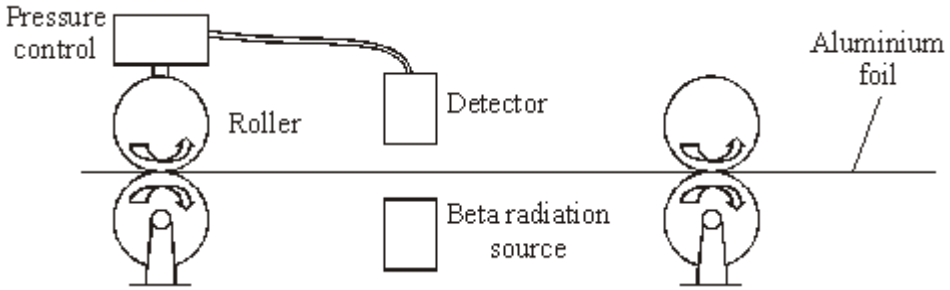
_____

_____

(Total 2 marks)

Q21.

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)