

AQA GCSE PHYSICS (HIGHER) • 8463

PHYSICS



EXAM QUESTION PACK

4.4.2 ATOMS AND NUCLEAR RADIATION (PACK 2)

SCORE

/208

PERCENTAGE

%

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Q1.

A beta particle is a high-energy electron.

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

_____ (1)

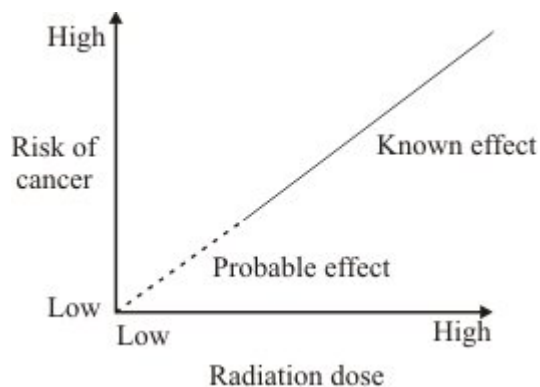
- (ii) How does the composition of an atom change when it emits a beta particle?

_____ (1)

(Total 2 marks)

Q2.

- (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.

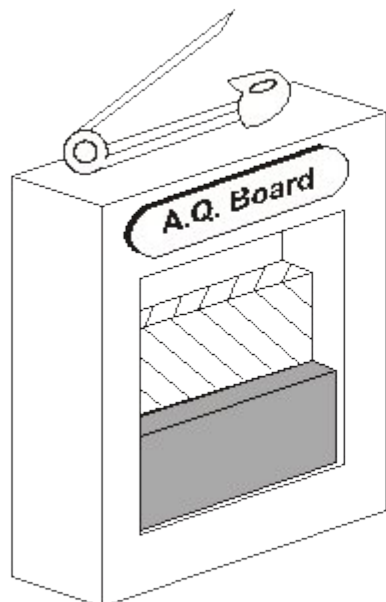


Diagram 1

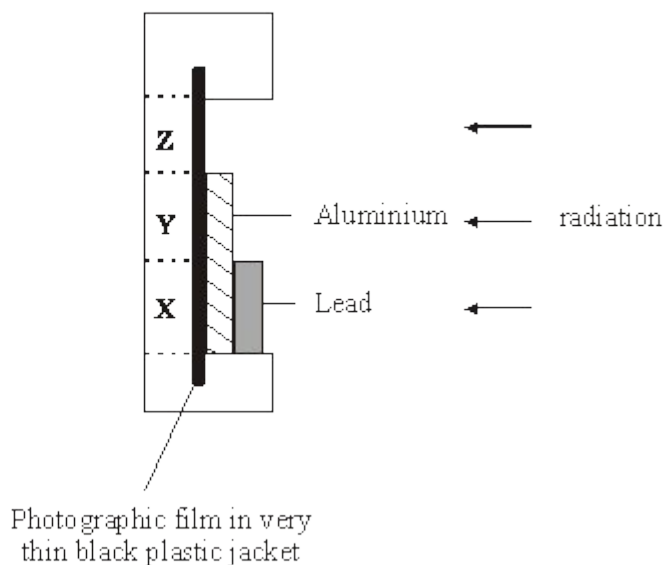


Diagram 2

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)

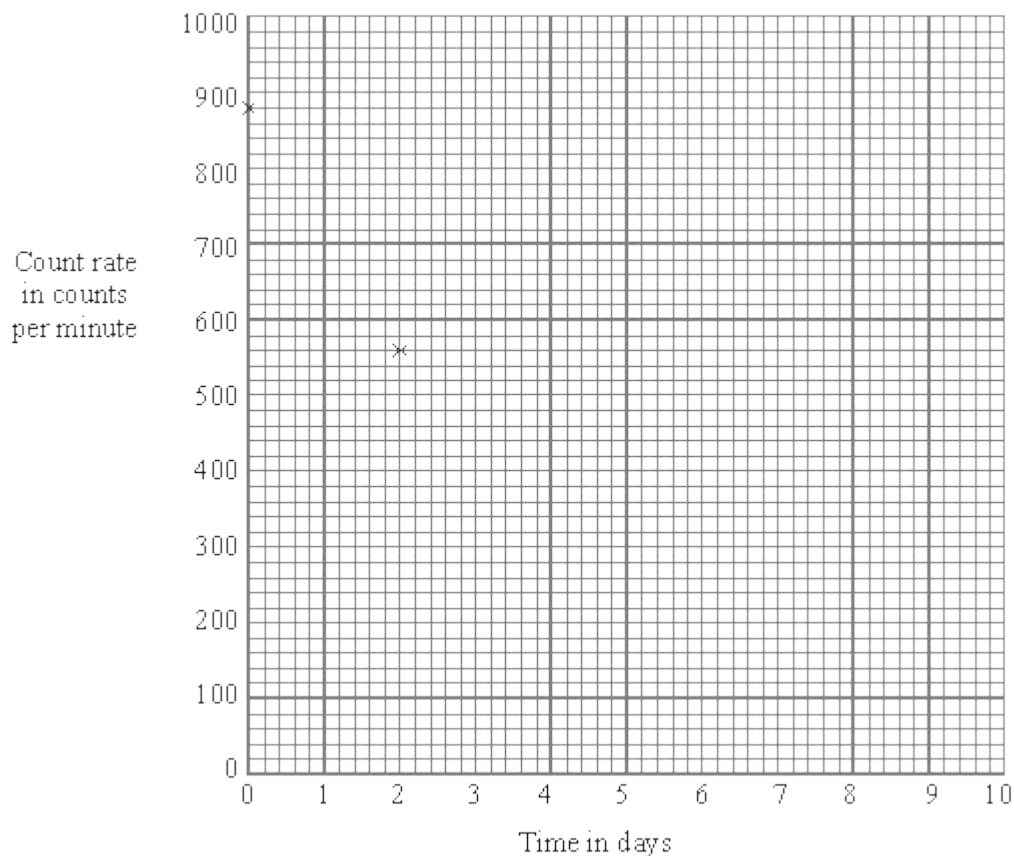
Q3.

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 counts per 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)

Q4.

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.

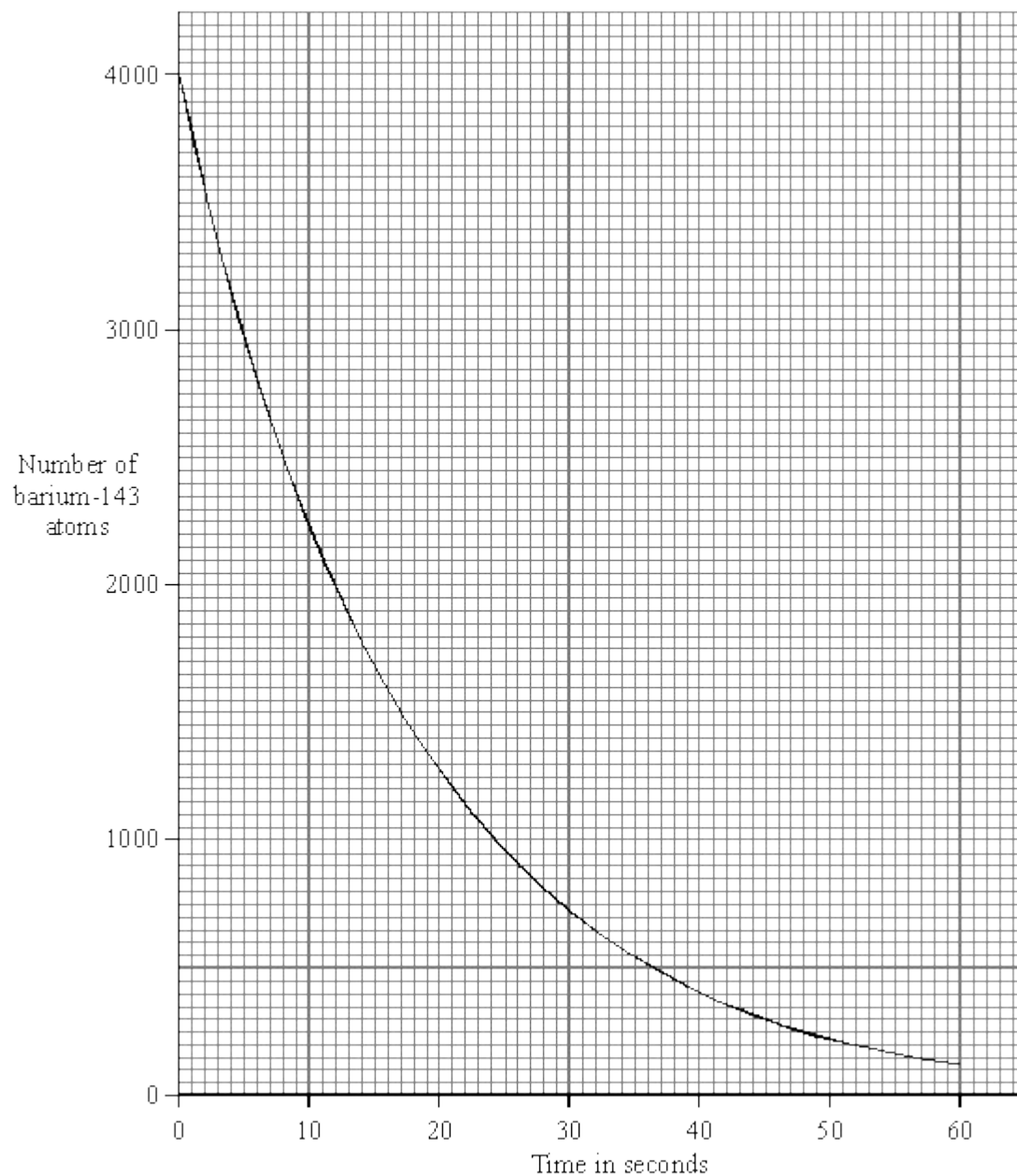
Age of rock = _____ million years

(1)

(Total 2 marks)

Q5.

- (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)

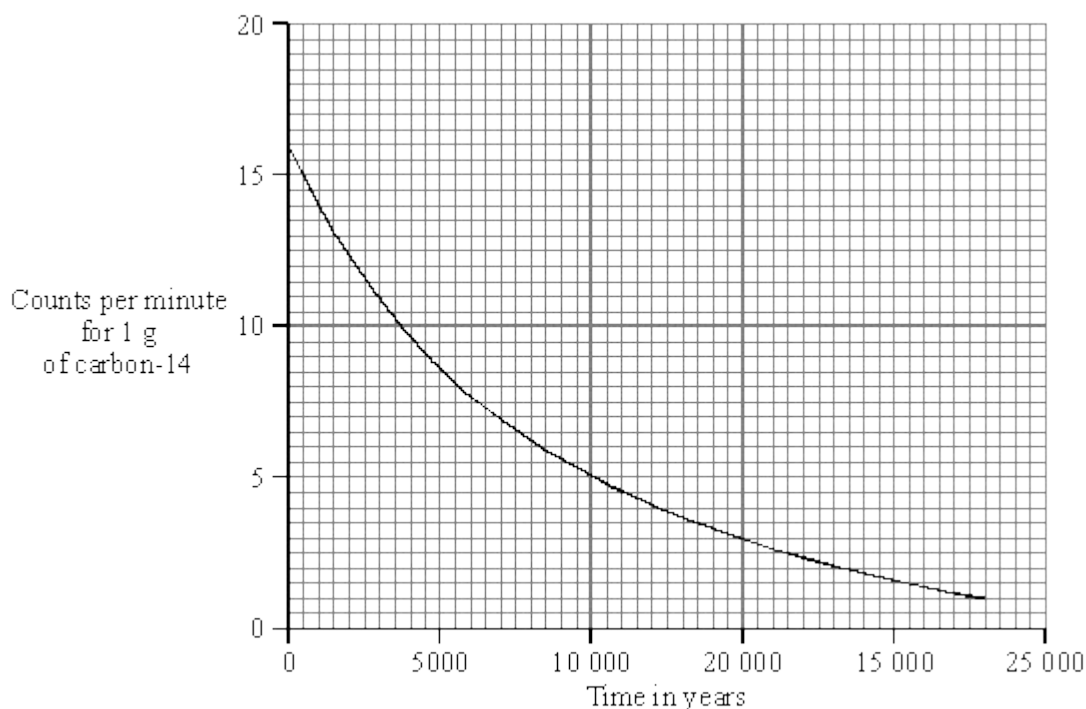
Q6.

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-14 taken from a flax plant.



Use the graph to find the half-life of carbon-14. 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)

Q7.

- (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)

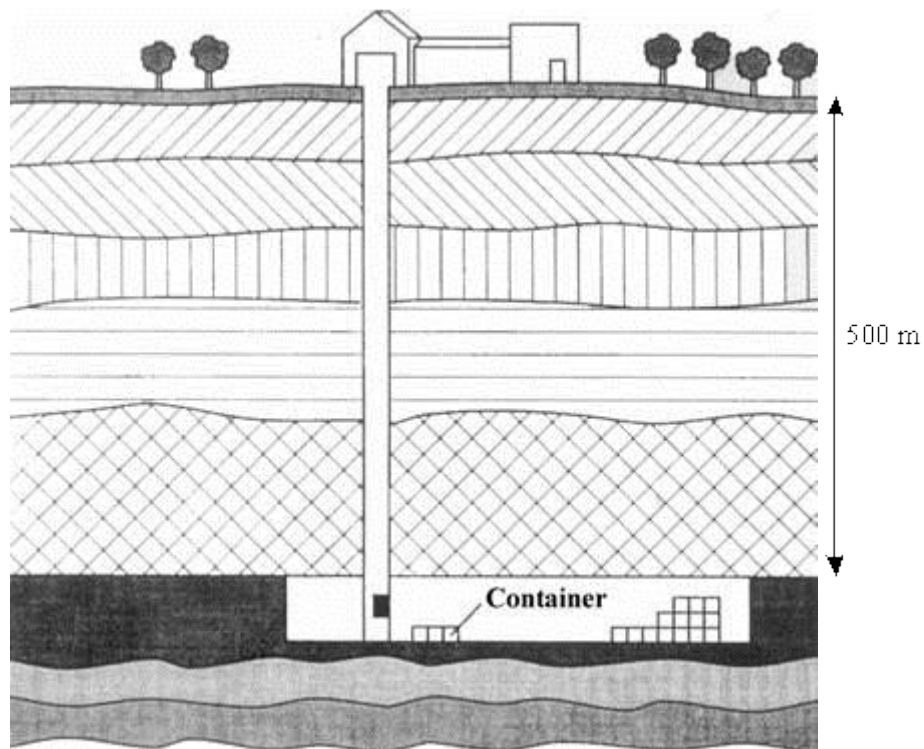
(ii) What is meant by the term half-life?

(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)

Q8.

(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)

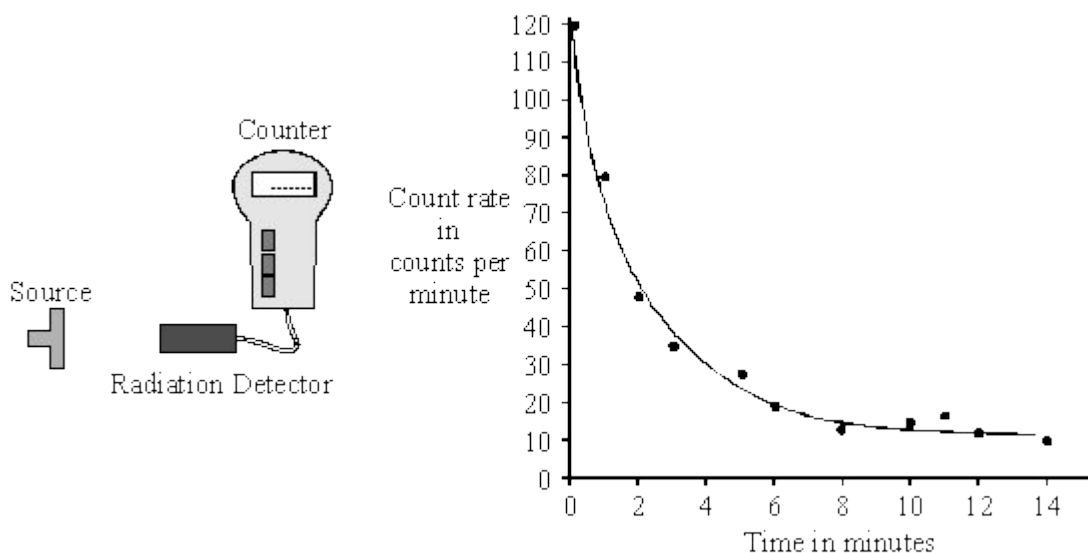
- (ii) The type of radiation that is stopped by thick paper is _____

(1)

(Total 3 marks)

Q9.

- (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-24. 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)

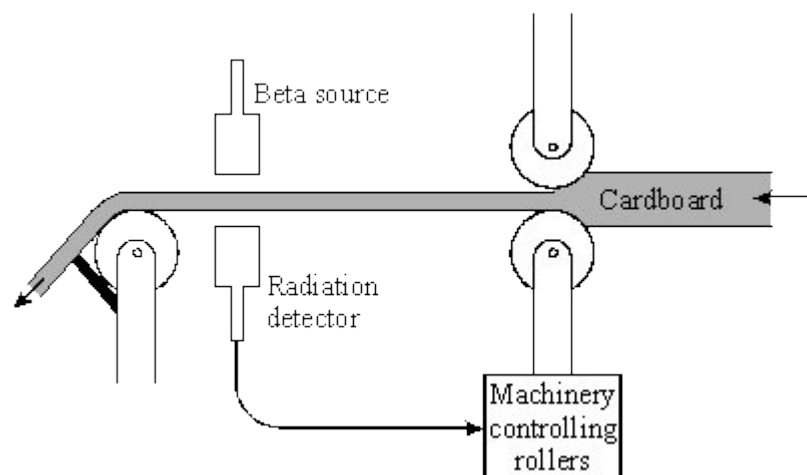
(Total 10 marks)

Q10.

- (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)

Q11.

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

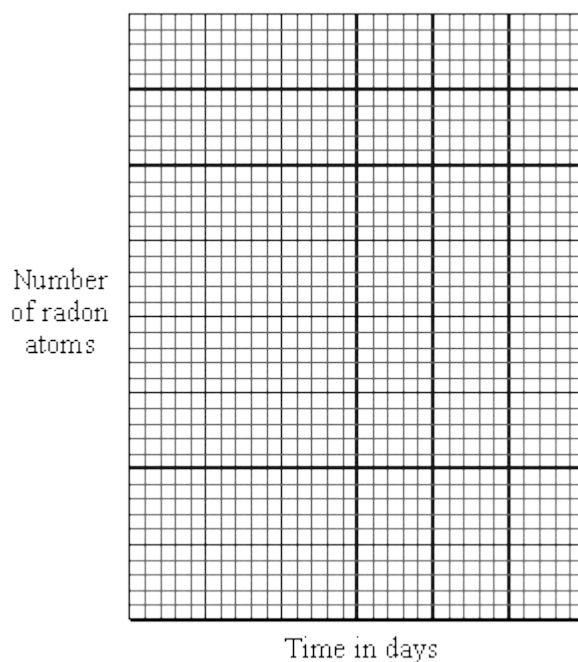
- (a) (i) What is an *alpha particle*?

(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)

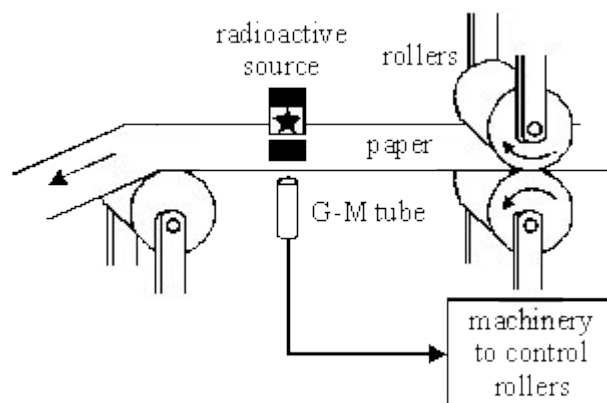
- (ii) Explain why the long term exposure to large concentrations of radon gas could be a danger to health.

(2)

(Total 11 marks)

Q12.

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 = _____

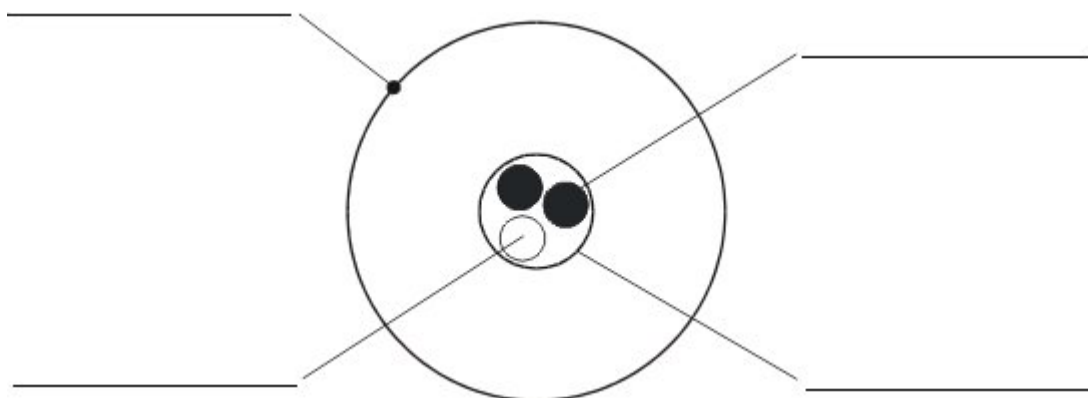
(3)

(Total 8 marks)

Q13.

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

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



(4)

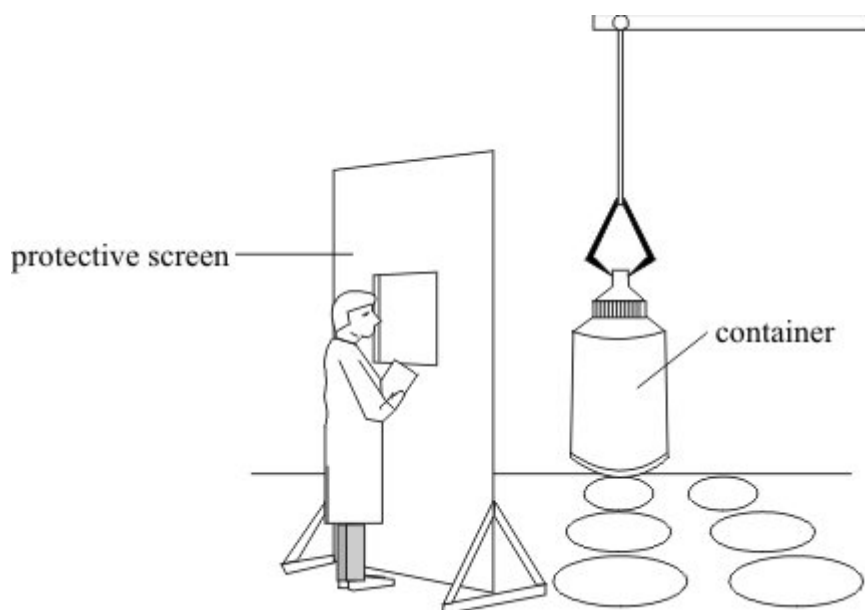
- (ii) Explain how the nucleus of an ordinary hydrogen atom is different from the nucleus of a tritium atom. Ordinary hydrogen atoms (${}^1_1\text{H}$) have a mass number of 1.

(2)

- (iii) Tritium is a radioactive substance which emits beta (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)

Q14.

- (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, ($^{39}_{19}\text{K}$).

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

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

Number of protons _____

Number of neutrons _____

Number of electrons _____

(2)

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

(1)

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

(1)

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

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

(1)

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

(1)

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

(1)

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

(1)

(Total 10 marks)

Q15.

- (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.

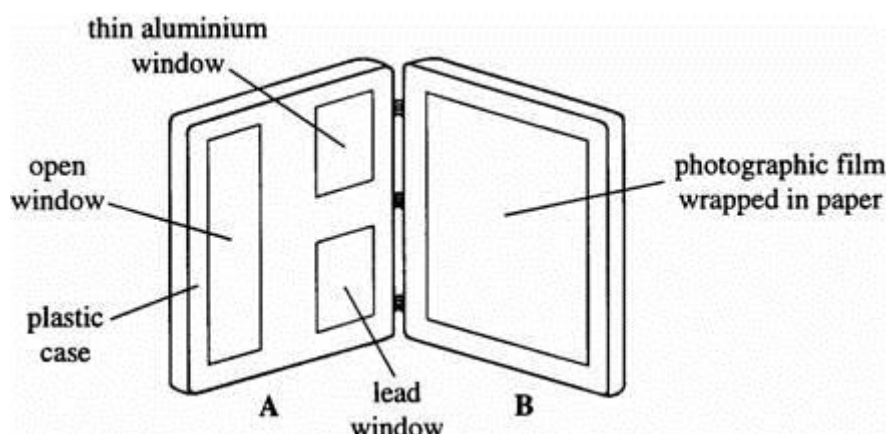
Explain why the alpha particles are less dangerous than the beta particles and gamma rays.

(2)

(Total 4 marks)

Q16.

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

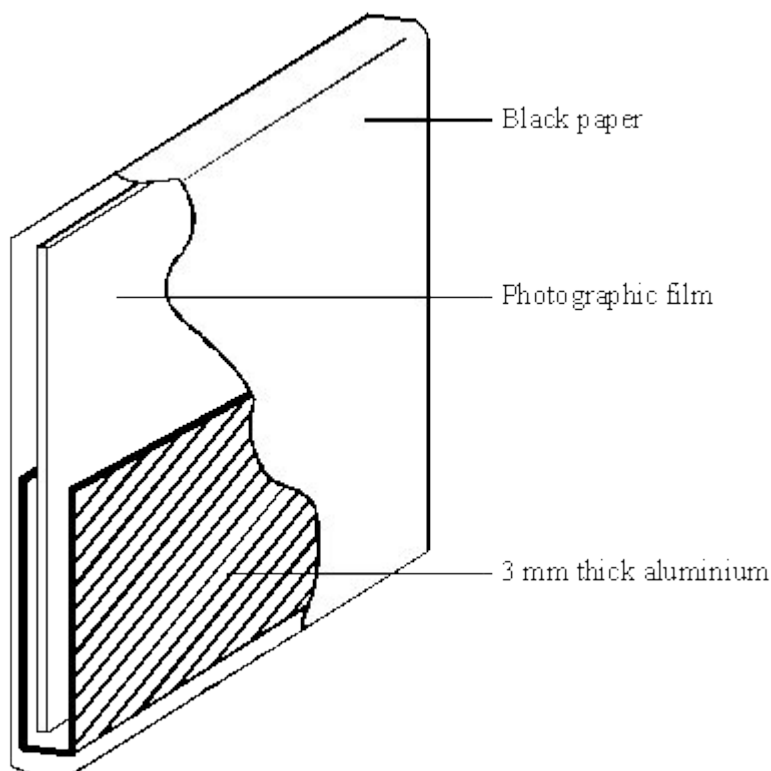
(2)

(Total 10 marks)

Q17.

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.

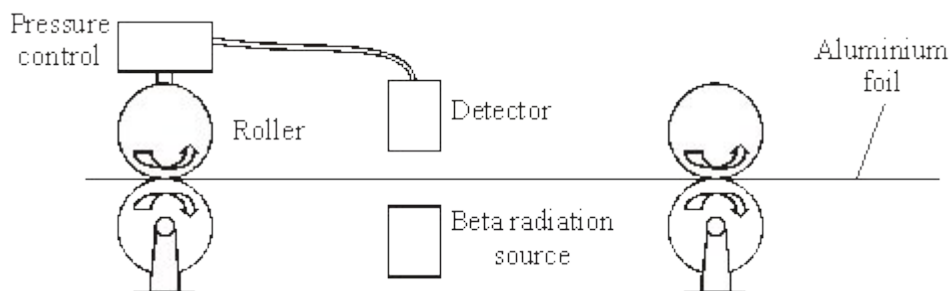
They found that the top part of the badge had been affected by radiation, but the bottom half had not.

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

(Total 2 marks)

Q18.

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)

Q19.

- (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.

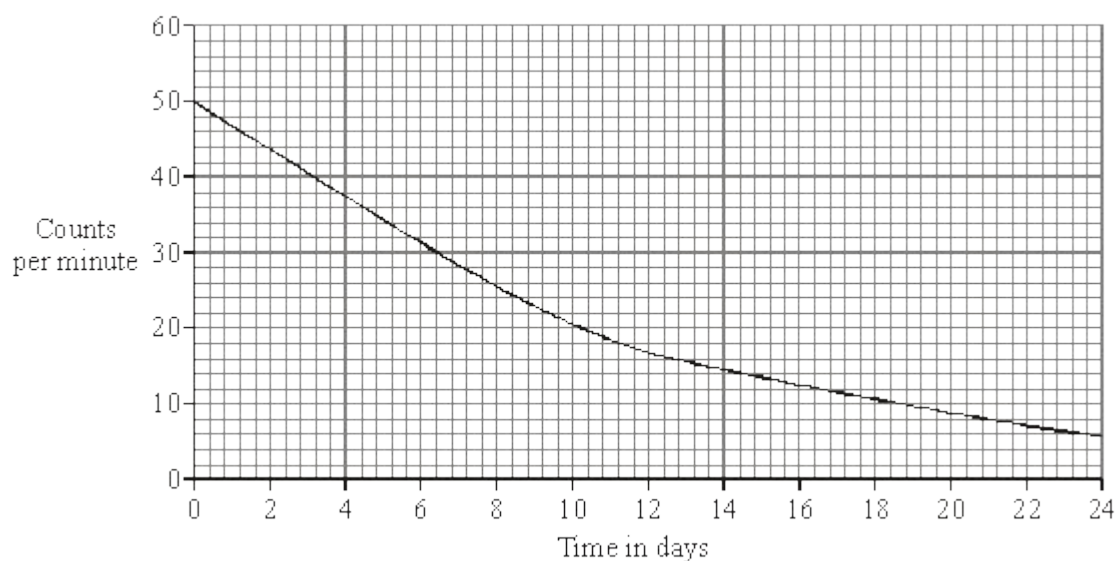
(1)

(Total 4 marks)

Q20.

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)

Q21.

- (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.

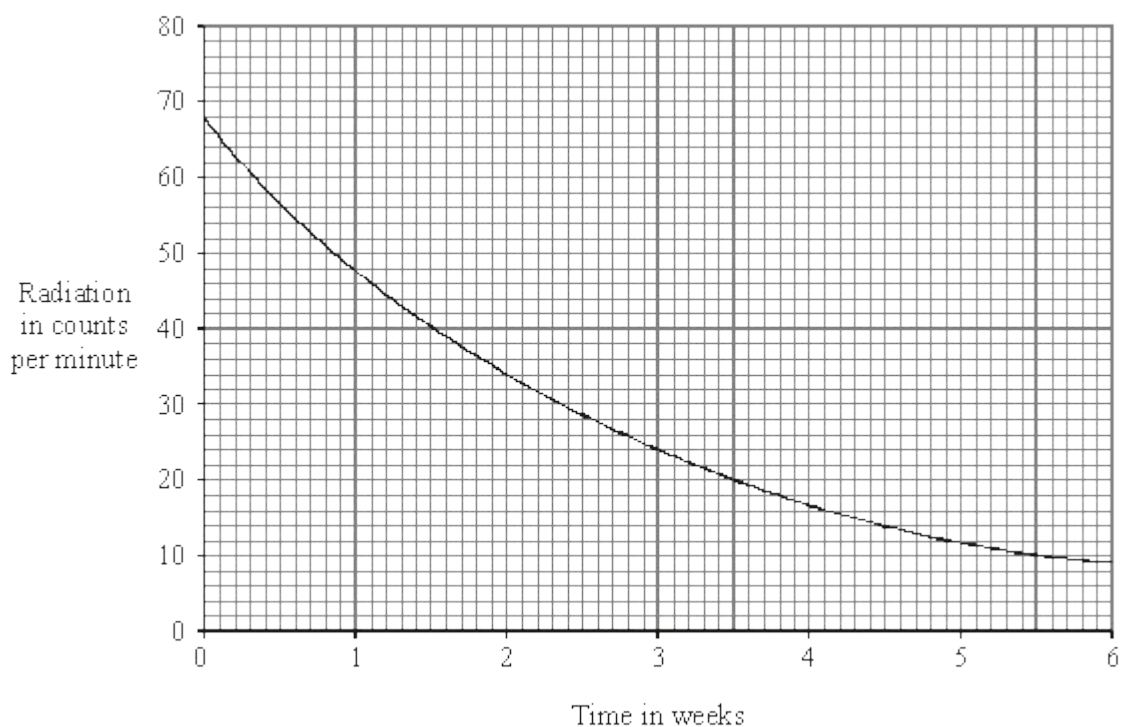
(1)

(Total 4 marks)

Q22.

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)

Q23.

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

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

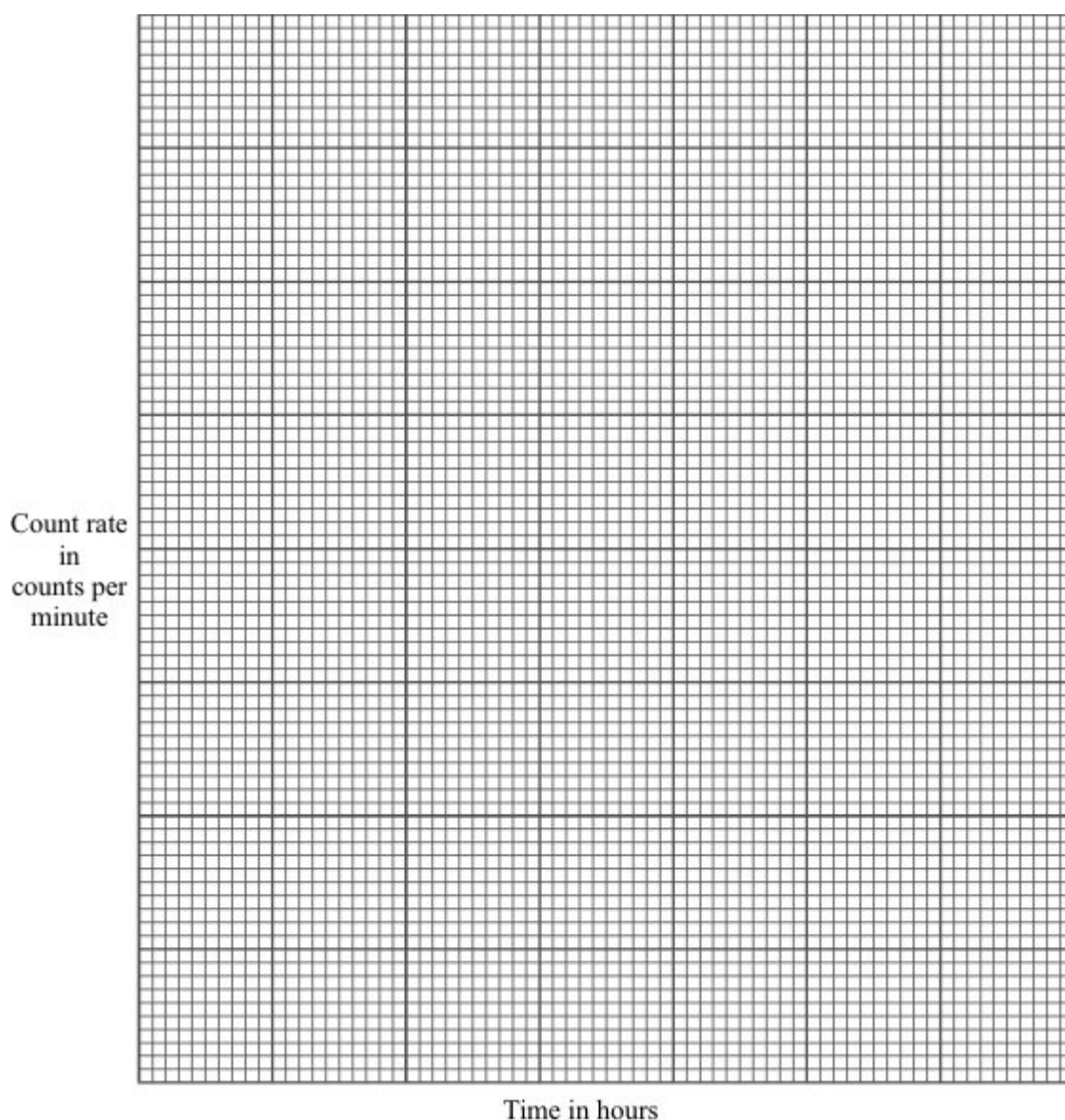
(Total 1 mark)

Q24.

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

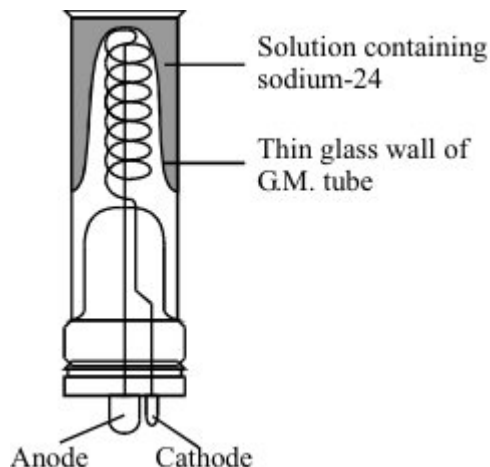
- (a) Draw a graph of the results and find the half-life for the isotope. On the graph show how you obtain the half-life.



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)

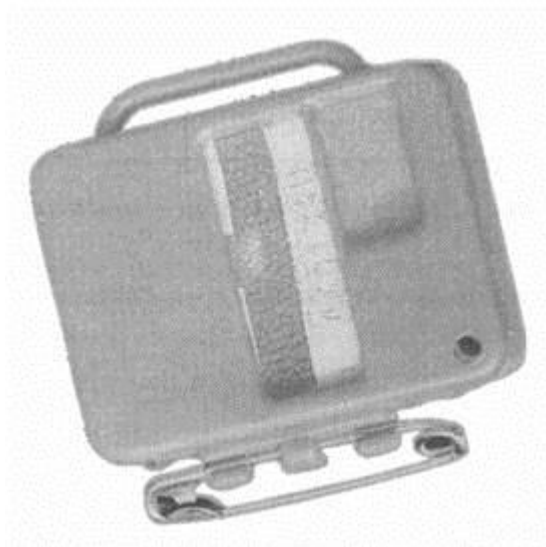
- (ii) five seconds. _____
-

(1)

(Total 8 marks)

Q25.

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)

Q26.

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 _____

(ii) Name _____ Symbol _____

(4)

- (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)

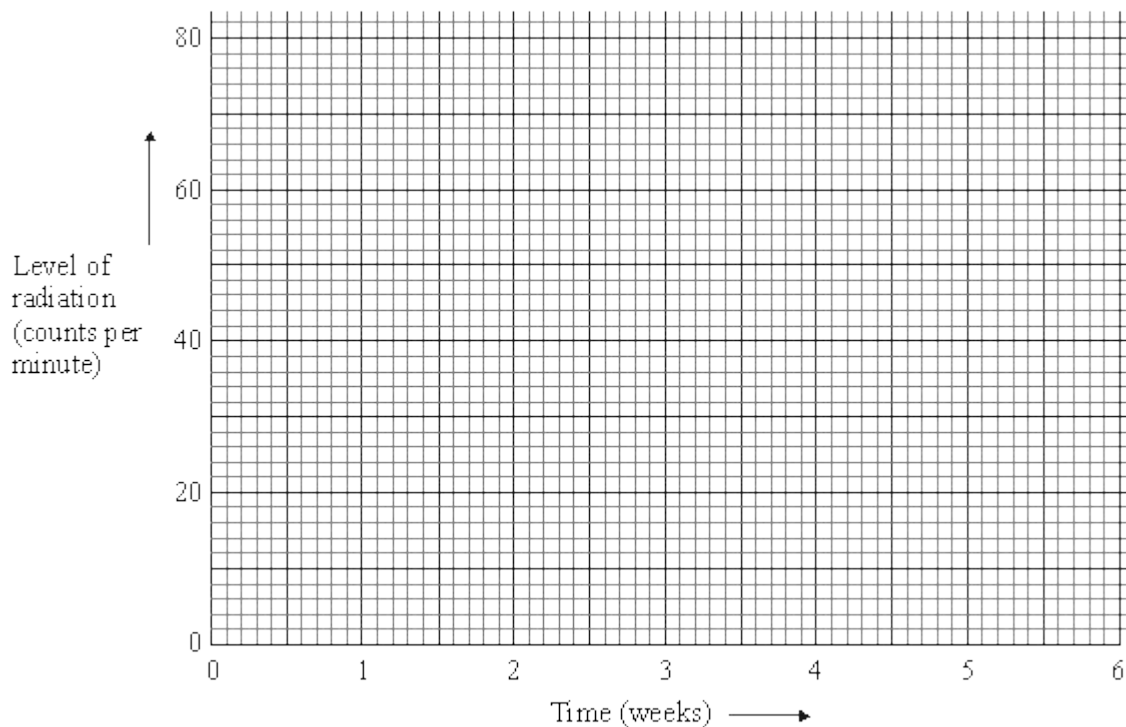
Q27.

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)

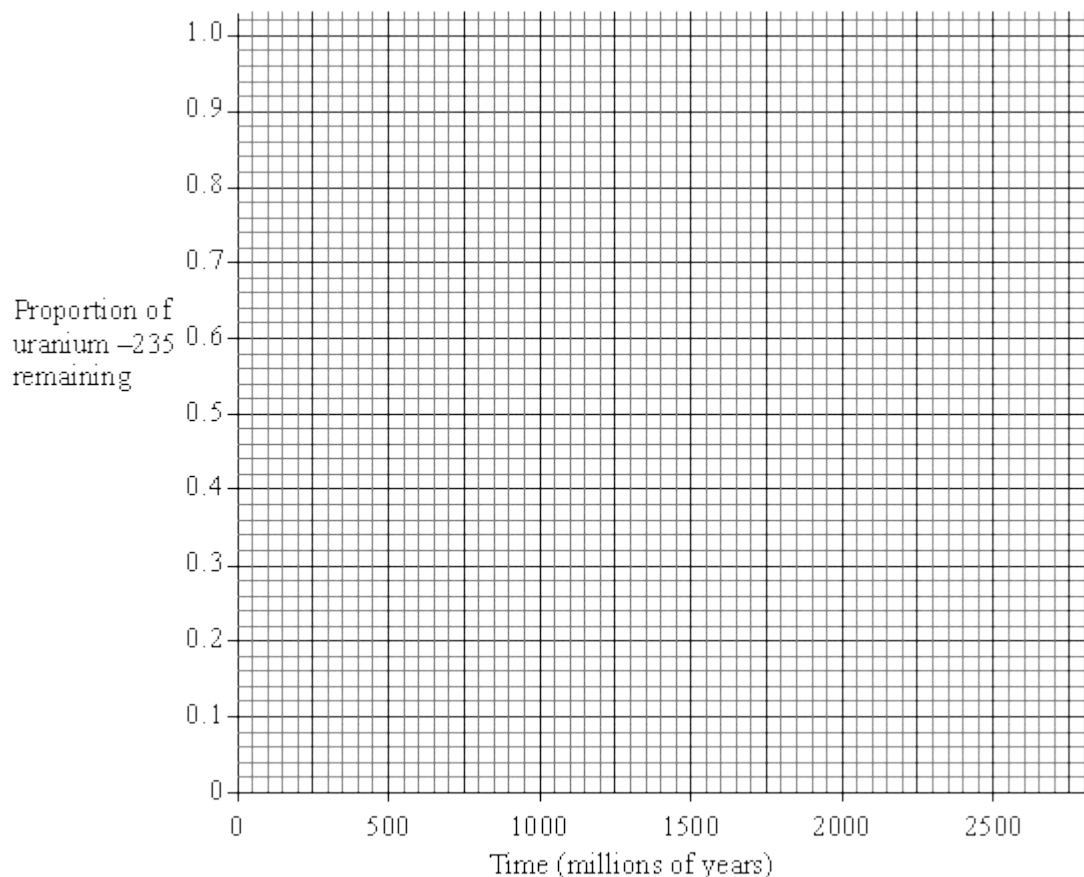
(Total 8 marks)

Q28.

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)

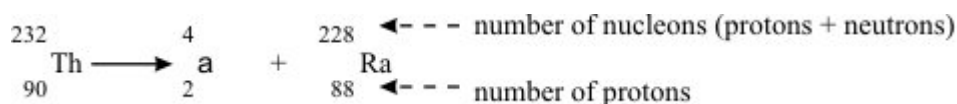
(Total 7 marks)

Q29.

- (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.

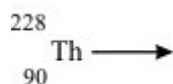
We can represent this radioactive decay in a special kind of equation:



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.



(4)

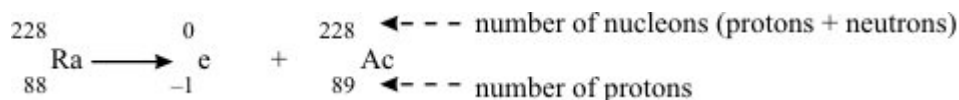
- (b) An atom of radium-228 decays by emitting a beta (β) particle from the nucleus.

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:

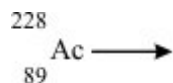


This isotope of actinium is radioactive.

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

An isotope of thorium is left behind.

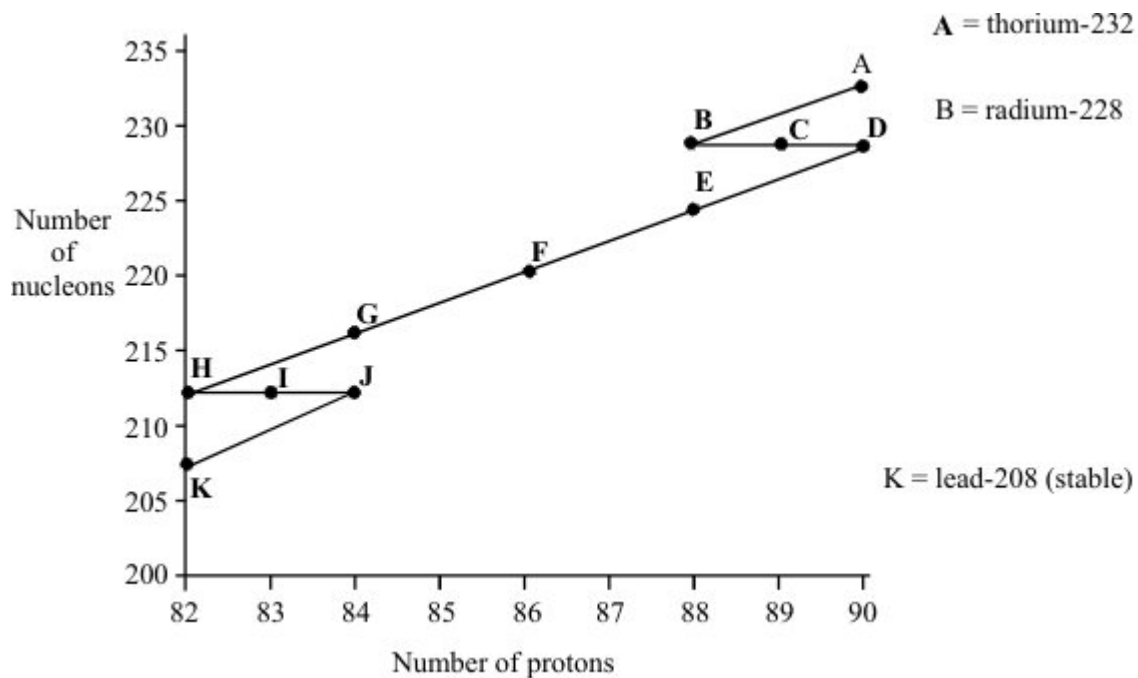
Complete the equation for this decay.



(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)

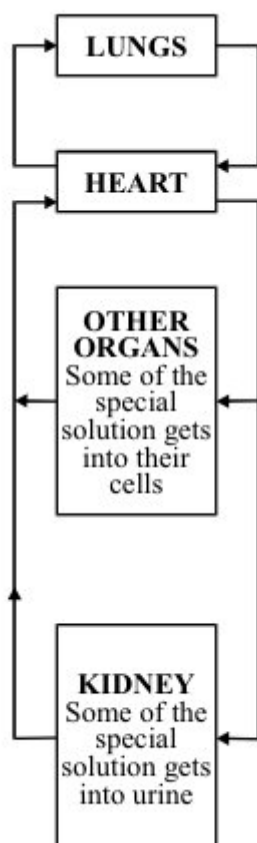
Q30.

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

They can find out by using a radioactive solution.

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

YOUR BLOOD CIRCULATION



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

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

Example:

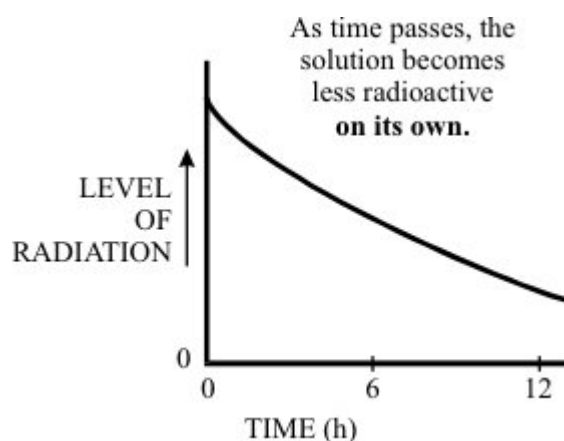
If the doctor injects 10 cm^3 of the radioactive solution and this is diluted 500 times by the blood there must be $10 \times 500 = 5000 \text{ cm}^3$ of blood.

(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.

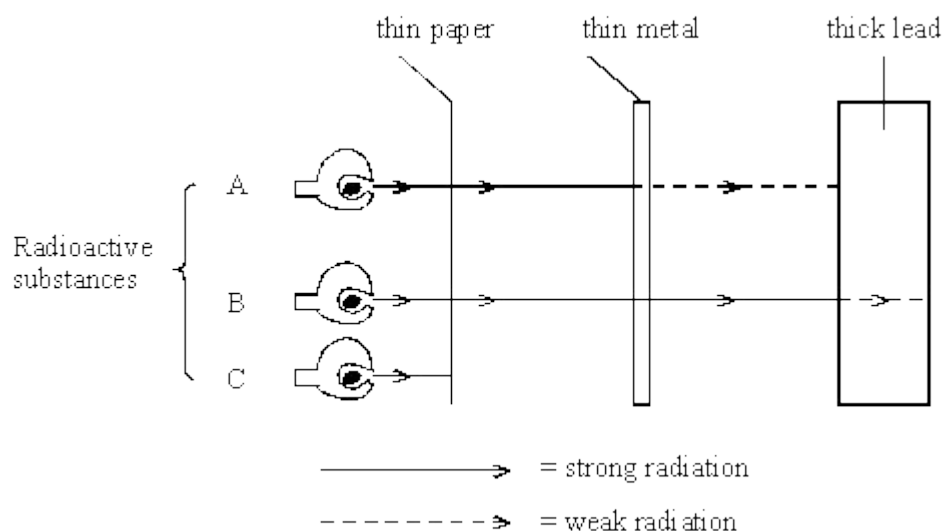
1. _____
2. _____
3. _____

(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.

Q31.

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.

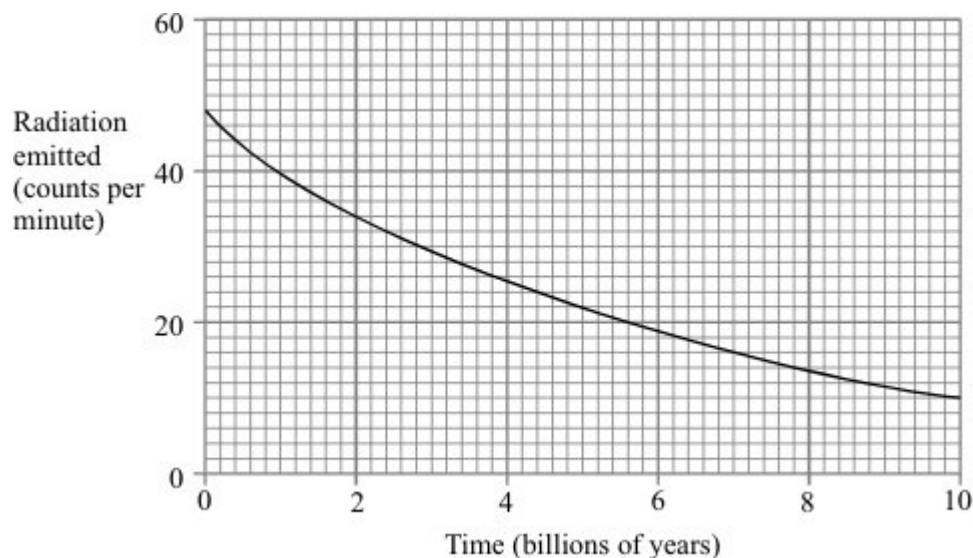
α (alpha) β (beta) γ (gamma) UV (ultraviolet)

RADIOACTIVE SUBSTANCE	TYPE OF RADIATION IT EMITS
A	
B	
C	

(Total 3 marks)

Q32.

The graph shows how the amount of radiation emitted by a sample of the radionuclide uranium 238 (U^{238}) changes as time passes.



- (a) What is the half-life of uranium 238 (U^{238})?
(You should show how you obtained your answer. You may do this on the graph if you wish.)

Answer _____

(3)

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

(1)

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

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

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

(1)

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

Answer _____ billion years

(3)

(Total 8 marks)

Q33.

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

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

- (i) What does beta radiation consist of?

(1)

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

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

(2)

(Total 3 marks)

Mark schemes

Q1.

- (i) nucleus / neutron
do not accept shells or orbits
- (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

1

[2]

Q2.

- (a) bigger
accept any word which means bigger
- (b) **Z**
if Z is not given, the reason does not score
- 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

1

1

[3]

Q3.

- (a) all points correctly plotted
tolerance $\pm \frac{1}{2}$ square on y axis only
allow 1 mark for 3 correctly plotted points
- attempt made to draw a smooth curve
do not accept dot-to-dot line
- (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
- (ii) 3 days or their (b)(i)
- (c) radon-222

2

1

1

1

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]

Q4.

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

accept 0.25 or 25%

1

(ii) 2600

if answer to (c)(i) is $\frac{1}{2}$ then accept 1300

1

[2]

Q5.

(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]

Q6.

- (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 $\pm$ 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]

Q7.

- (a) (i) helium nuclei

1

or

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

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

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

1

- (iii) Technetium-99

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

1

any **two** of the following:

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

2

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

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

3

[8]

Q8.

- (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

Q9.

- (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
 $\frac{0}{-1}e$
accept $\frac{0}{-1}e$ 1
- (ii) electromagnetic 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 1 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]

Q10.

- (a) suitable arrangement of source and GM tube ie fixed distance apart
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 labelled 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]

Q11.

- (a) (i) a helium nucleus
*accept ${}^4_2\text{He}$
 accept 2 protons + 2 neutrons
 do **not** accept He
 do **not** accept helium atom*

1

- (ii) nucleus
only answer, no alternative

1

- (b) (i) each axis given a linear scale
*time axis must go up to 12 days
 y-axis must go up to 40 000*

1

curve concave to axis drawn

1

curve shows correct half-life of four days

*do **not** accept a straight line must show one half-life*

check first two plotted points correct to $\pm$ half square

a curve drawn dot-to-dot scores a maximum of 1 mark

1

(ii) 38 750

no tolerance

allow 1 mark for 5 half-lives

allow 1 mark for showing that 1 250 are undecayed

3

(c) (i) more radon enters shaft (through cracks in the rock face)

accept radon emitted from surroundings

1

(ii) (alpha) radiation will damage cell structure or ionise cells

accept kill cells

1

causing cancerous growth

an answer in terms of the daughter product polonium being a

*solid **or** lodging in the throat and also emitting alpha gains*

full credit

1

[11]

Q12.

(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) $1 \rightarrow 1/2 \rightarrow 1/4 \rightarrow 1/8$

for 1 mark

3 half lives/ 3×433

for 1 mark

1299 years

gains 3 marks

3

[8]

Q13.

- (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]

Q14.

- (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]

Q15.

- (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]

Q16.

- (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) $2 \times$ 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]

Q17.

beta

1

alpha absorbed by paper

allow beta and 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]

Q18.

- (a) (i) cannot penetrate aluminium

allow can only pass through air / paper too weak is neutral

1

- (ii) gamma rays not affected (by aluminium)

allow all / most (gamma rays) to pass through
too strong is neutral
danger is neutral

1

- (b) (i) (nuclei) unstable

1

- (ii) causes harm / damage to body / cells

allow radiation sickness

1

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

allow two effects for 2 marks

1

[5]

Q19.

- (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]**Q20.**

- (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]**Q21.**

- (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]**Q22.**

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]

Q23.

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

[1]**Q24.**

(a) sensible scales

full use of y axis

1

completely accurate plotting

1

a smooth curve going through all but 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]**Q25.**

(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 nuclei 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 $3 \times \text{half life} = 31.8 \text{ hr}$

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

1

[7]

Q26.

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

1

- (i) alpha

accept Greek symbol (α)

1

He^{2+} **or** ${}^4_2\text{He}$

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]

Q27.

(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]

Q28.

(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

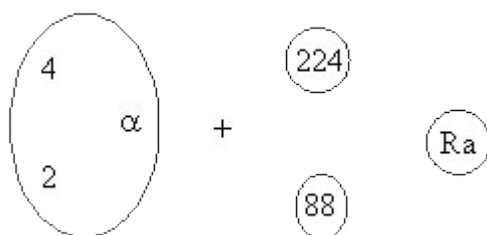
(allow ^{207}Pb may not have come from this ^{235}U)

2

[7]

Q29.

(a)

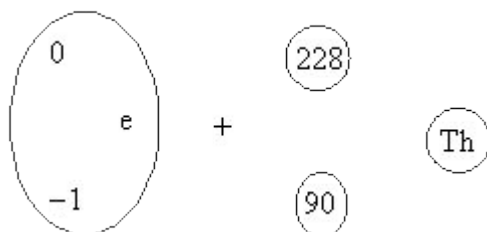


[Accept He^{2+} for α]

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]

Q30.

- (a) evidence of $\frac{7350}{15}$
gains 1 mark

but

490
gains 2 marks

but

4900
gains 3 marks

units cm³
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]

Q31.

- A β / beta
 B γ / gamma
 C α / alpha

for 1 mark each

[3]

Q32.

- (a) indication (in writing or on graph) of finding point where radiation is halved (e.g. to 24 [from an initial 48]) and relating to the time difference between the two points

gains 1 mark

but

4.2-4.8*

(*i.e. in this range, including extremes)

gains 2 marks

units billions of years

for 1 mark

3

- (b) $\frac{3}{4}$ **or** 75%
[allow ecf from (a)]

for 1 mark

1

- (c) (i) *idea that* the intermediate nuclides are relatively short-lived
for 1 mark

1

- (ii) *idea that* $\frac{1}{4}$ has decayed **or** $\frac{3}{4}$ remains
gains 1 mark

but

read graph for radiation level of 36 (stated or shown on graph itself)

gains 2 marks

but

1.6-1.8* (billion years)

(* i.e. in this range, including extremes)

gains 3 marks

3

[8]

Q33.

- (i) (fast moving) electrons (from the nucleus)
(allow negatively charged particles)

for 1 mark

1

- (ii) protactinium has one neutron fewer
protactinium has one proton more
(credit has different numbers of neutrons / protons *with one mark*)

for 1 mark each

2

[3]