Q1. When atoms of uranium 238 (U^{234}) decay they produce another radionuclide called thorium 234 (Th^{234})

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

(i) What does beta radiation consist of?

.....

(1)

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

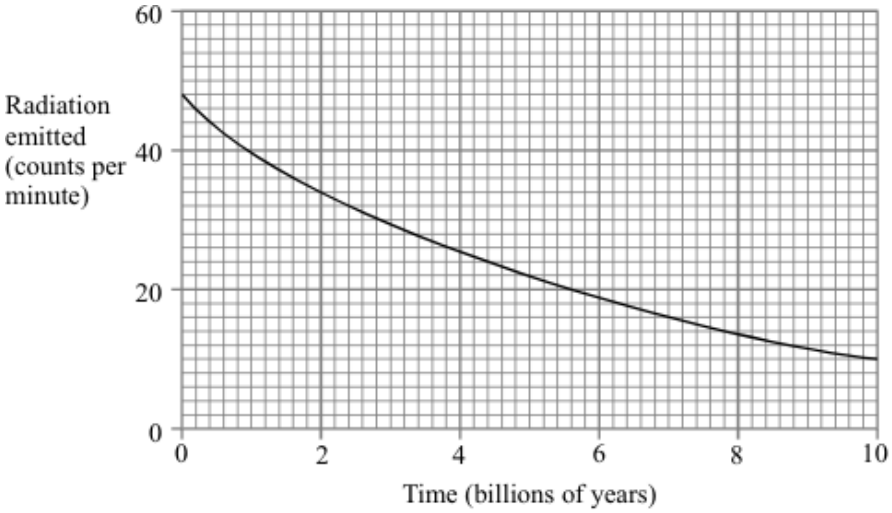
What differences are there between the nucleus of a protactinium 234 (Pa^{234}) atom and the nucleus of a thorium 234 (Th^{234}) atom?

.....

.....

(2)
(Total 3 marks)

Q2. 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.)

.....

.....

.....

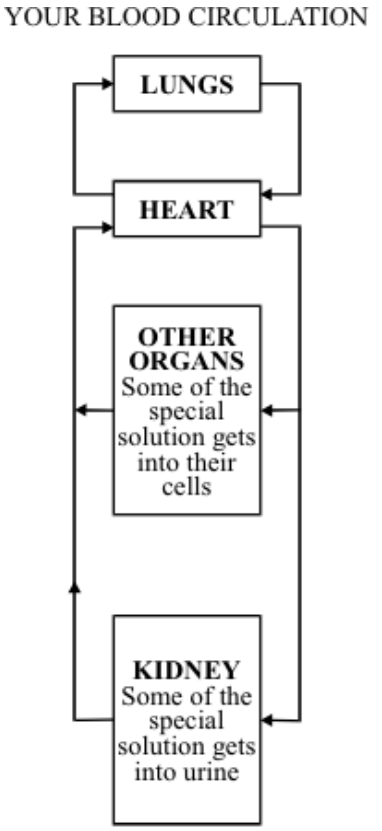
Answer ..... billion years

(3)
(Total 8 marks)

Q3. 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.)

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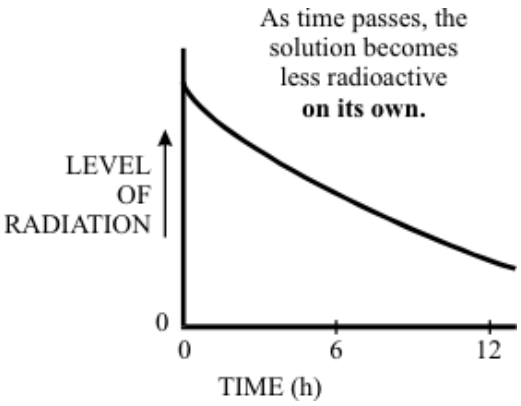
.....

(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)

Q4. (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.

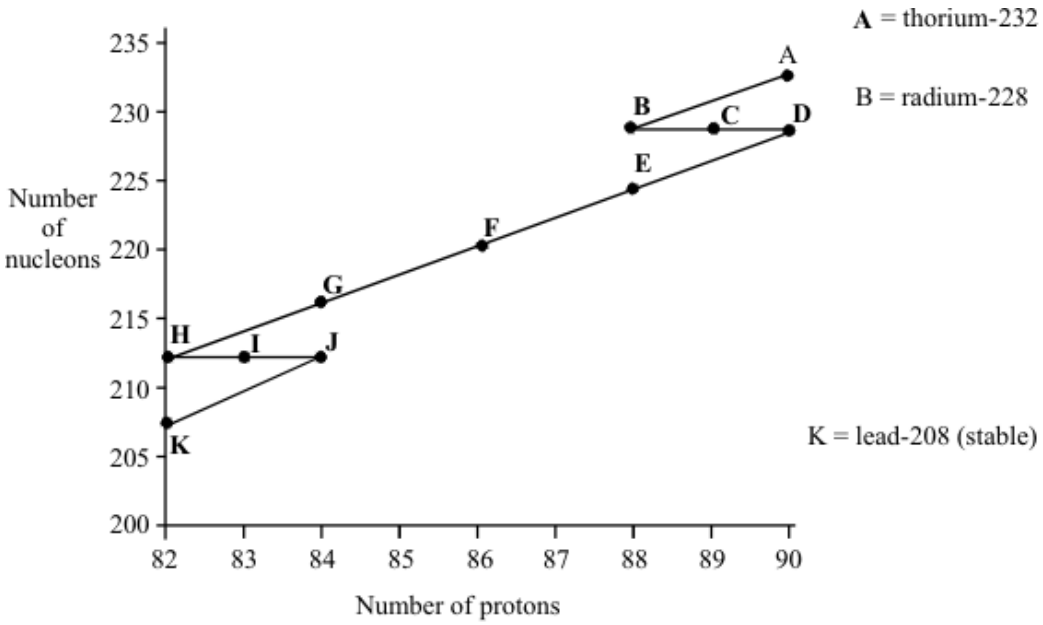
Complete the equation for this decay.

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

(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.

.....

.....

.....

.....

.....

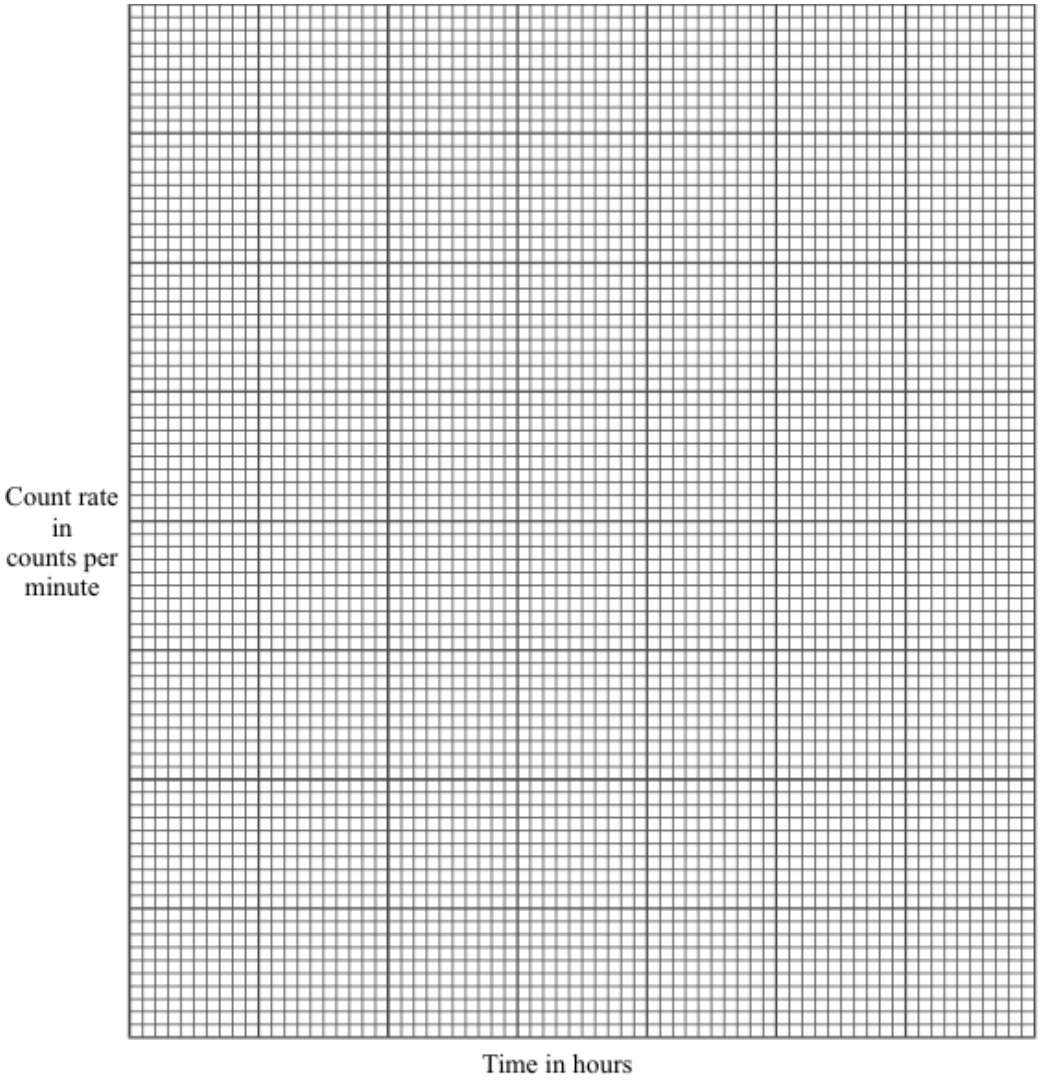
(3)
(Total 13 marks)

##

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

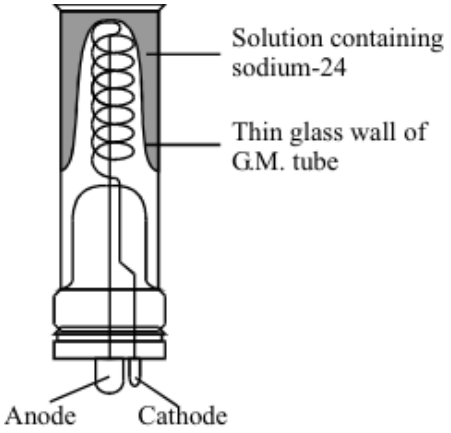
(a) Draw a graph of the results and find the half-life for the isotope. On the graph show how you obtain the half-life.



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)

Q6. $^{99}_{43}Tc$ (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)

Q7. The table gives the properties of some radionuclides (radioactive isotopes).

Radionuclide	Half life	Main type of radiation emitted
Radon-220	54.5 seconds	Alpha
Americium-241	433 years	Alpha
Phosphorus-32	14 days	Beta
Strontium-90	28 years	Beta
Technetium-99	6 hours	Gamma
Cobalt-60	5 years	Gamma

(i) Which radionuclide would be best for monitoring the thickness of aluminium foil?

.....

Explain the reason for your answer.

.....

.....

.....

(2)

(ii) Which radionuclide would be best for acting as a tracer inside the human body?

.....

Explain the reason for your answer.

.....

.....

.....

(2)
(Total 4 marks)

Q8. (a) (i) Describe the structure of alpha particles.

.....

.....

.....

.....

(2)

(ii) What are beta particles?

.....

.....

.....

(1)

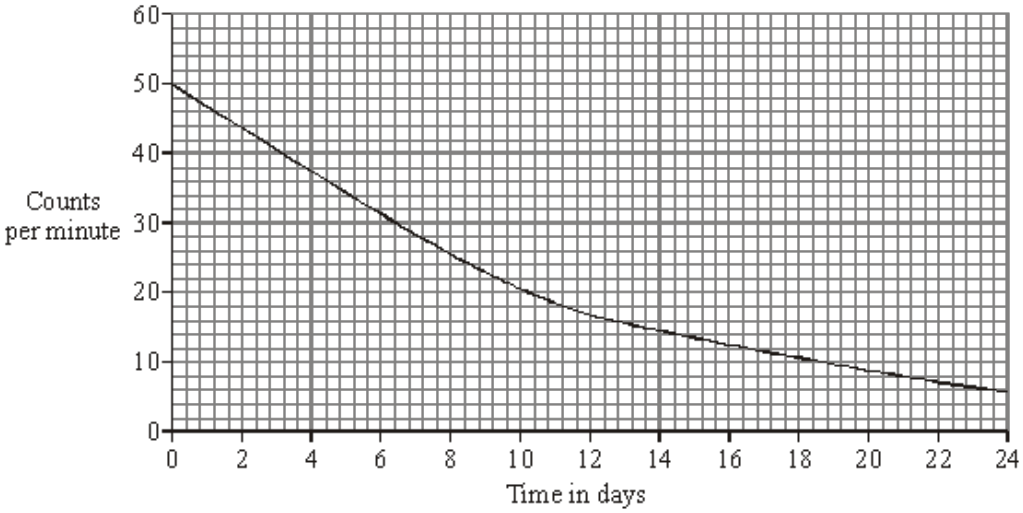
(b) Describe how beta radiation is produced by a radioactive isotope.

.....

(1)
(Total 4 marks)

Q9. 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)

Q10. (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.

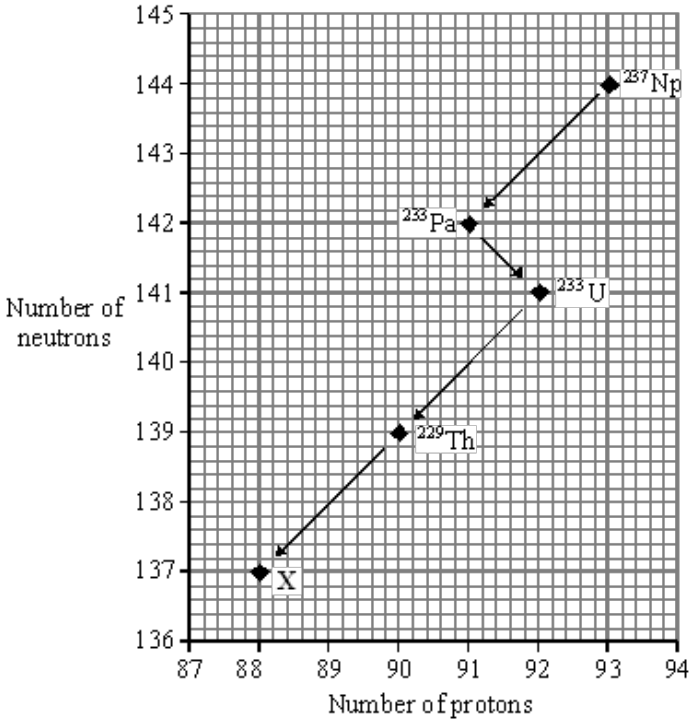
.....

.....

(1)

(Total 4 marks)

Q11. Neptunium-237 (^{237}Np) is a radioactive element. The graph shows the numbers of neutrons and protons in the nuclei of the elements formed when ^{237}Np decays.



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

.....

(1)

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

.....

.....

(1)

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

.....

(1)

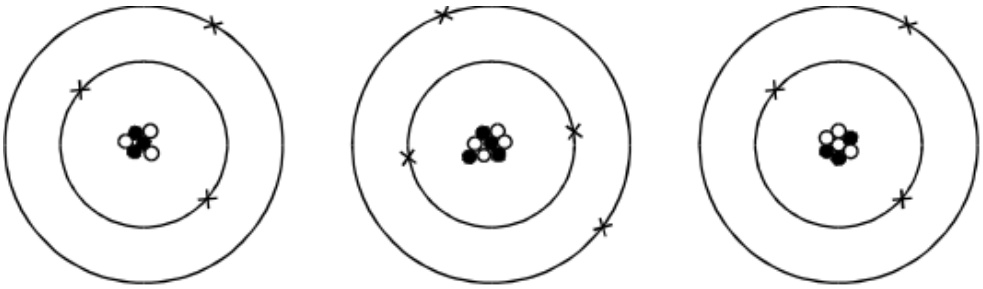
(d) What change takes place in the nucleus when ^{233}Pa changes into ^{233}U?

.....

(1)

(Total 4 marks)

Q12. The diagrams below represent three atoms, **A**, **B** and **C**.



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

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

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

.....

.....

.....

(2)

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

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

(ii) Explain your answer.

.....

.....

.....

(3)

(c) Which of the particles ○, ● and **X**, shown in the diagrams:

(i) has a positive charge; .....

(ii) has no charge; .....

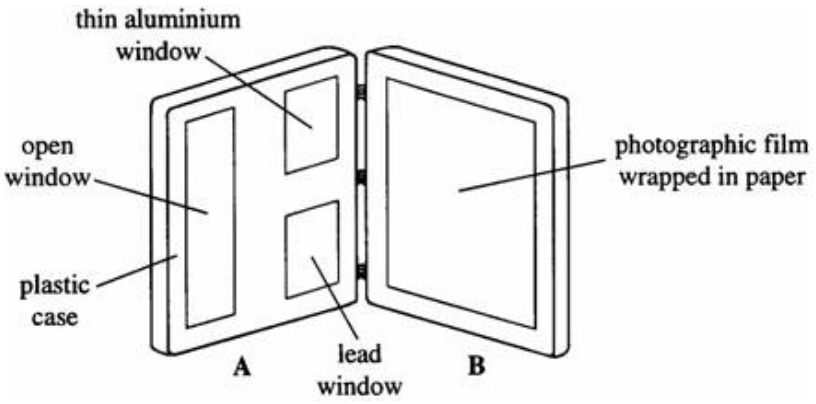
(iii) has the smallest mass? .....

(3)

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

(1)
(Total 9 marks)

Q13. 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.

.....

.....

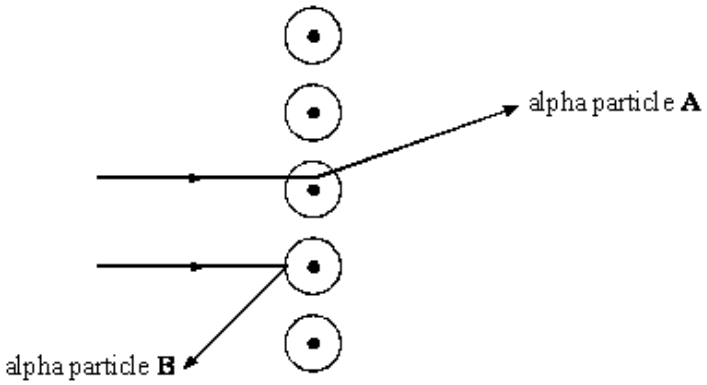
.....

Age ..... million years

(2)

(Total 10 marks)

Q14. The diagram below shows the paths of two alpha particles A and B into and out of a thin piece of metal foil.



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

.....

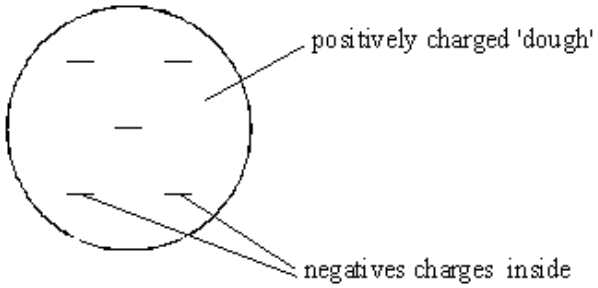
.....

.....

.....

(3)

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



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

.....

.....

.....

.....

.....

(2)

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

.....

.....

.....

.....

.....

.....

(3)

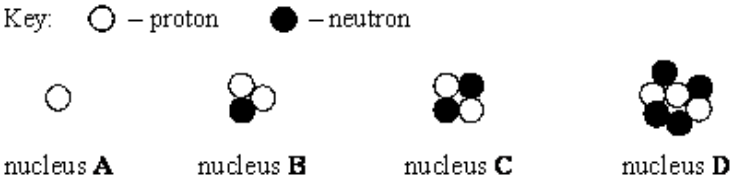
(c) We now believe that atoms are made up of three types of particles called protons, neutrons and electrons.

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

PARTICLE	RELATIVE MASS	RELATIVE CHARGE
proton	1	+1
neutron		
electron		

(2)

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



(i) State the mass number of C. .....

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

Explain your answer.

.....

.....

.....

.....

(4)

(Total 14 marks)

Q15. (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)

TYPE OF RADIATION	CHANGE IN	
	PROTON (ATOMIC) NUMBER	MASS NUMBER
alpha α	goes down by 2	goes down by 4
beta β	goes up by 1	no change
gamma γ	no change	no change

Use the table above, together with the Data Sheet, to help you to answer the following questions.

(i) Name the type of radiation given out in part (b) (iv).

.....

(1)

(ii) Give the name, or symbol, of the element formed when an atom of sodium-24 (proton number = 11) emits gamma radiation.

.....

(1)

(iii) State the Group number of the element formed when an atom of radon-220 (proton number = 86) emits an alpha particle.

.....

(1)

(d) (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.

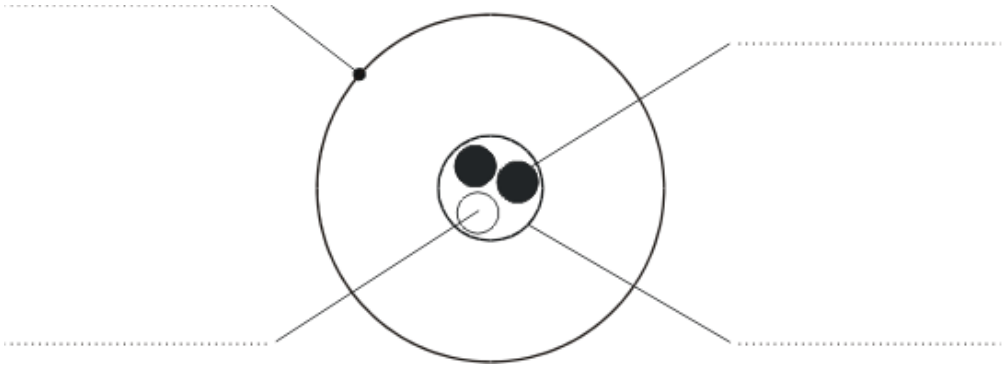
.....

(1)

(Total 13 marks)

Q16. (a) Tritium ($^{3}_{1}\mathrm{H}$) 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 ($^{1}_{1}\mathrm{H}$) have a mass number of 1.

.....

.....

.....

(2)

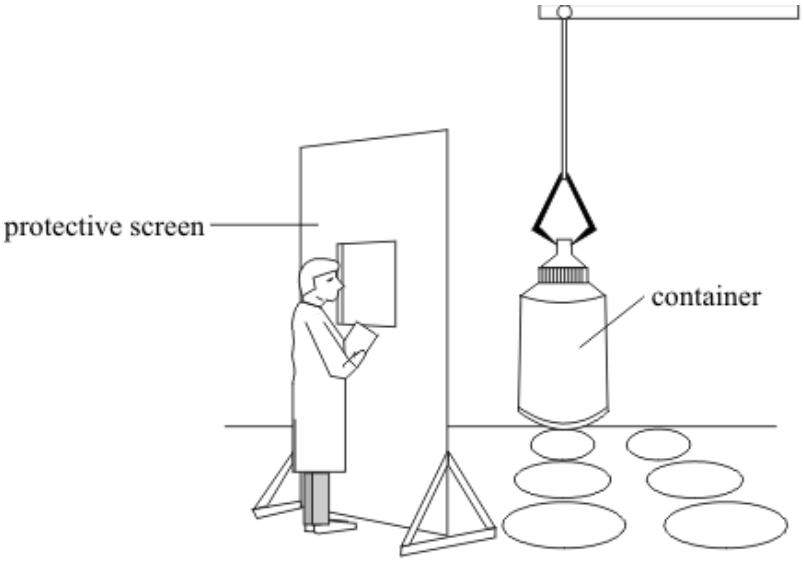
(iii) Tritium is a radioactive substance which emits beta (β) radiation.
Why do the atoms of some substances give out radiation?

.....

.....

(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.

.....

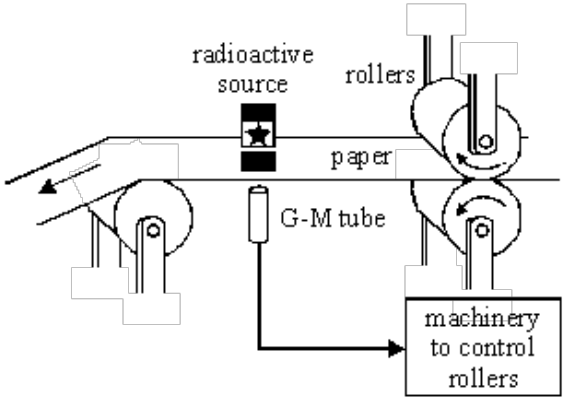
.....

.....

(2)

(Total 10 marks)

Q17. 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)

Q18. The first commercial nuclear power station in the world was built at Calder Hall in Cumbria.

The atoms produced by the fission of uranium are also radioactive. The used fuel is sent to a reprocessing plant where it can be safely treated.

(i) Calder Hall power station is next to the Sellafield reprocessing plant. Suggest an advantage of having the two plants close together.

.....

.....

(1)

(ii) One of the radioactive products is iodine-138. This has a half-life of 6 seconds.
A sample of radioactive material contains 2000 atoms of iodine-138.
How long will it take for the number of iodine-131 atoms to decrease to 125?

.....

.....

.....

.....

Answer = ... seconds

(3)

(Total 4 marks)

Q19. The first commercial nuclear power station in the world was built at Calder Hall in Cumbria.

(a) The fuel used at the Calder Hall power station is uranium. Natural uranium consists mainly of two isotopes: uranium-235 ($^{235}_{92}U$) and uranium-238 ($^{238}_{92}U$). The nucleus of a uranium-235 atom is different to that of a uranium-238 atom.

(i) Where is the nucleus in an atom?

.....

(1)

(ii) Name the **two** types of particle found in the nucleus.

..... and .....

(2)

(iii) How is the nucleus of a uranium-238 atom different to the nucleus of a uranium-235 atom?

.....

.....

.....

(2)

(b) In the nuclear reactor fission of uranium atoms takes place in reactions such as the one shown below.

$$^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{138}_{53}I + {}^{95}_{39}Y + 3({}^{1}_{0}n)$$

The nuclear reactions are carefully controlled in the power station so that a chain reaction takes place.

Explain, as fully as you can:

(i) how fission of uranium atoms takes place in a nuclear reactor;

.....

.....

.....

.....

(ii) how this leads to a chain reaction;

.....

.....

.....

.....

(iii) why it can be used to generate electricity.

.....

.....

(4)

(Total 9 marks)

Q20. 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*?

.....

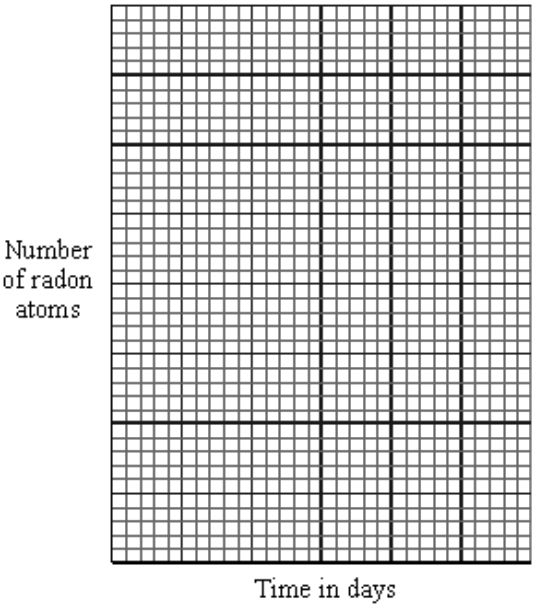
(1)

(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.

.....

.....

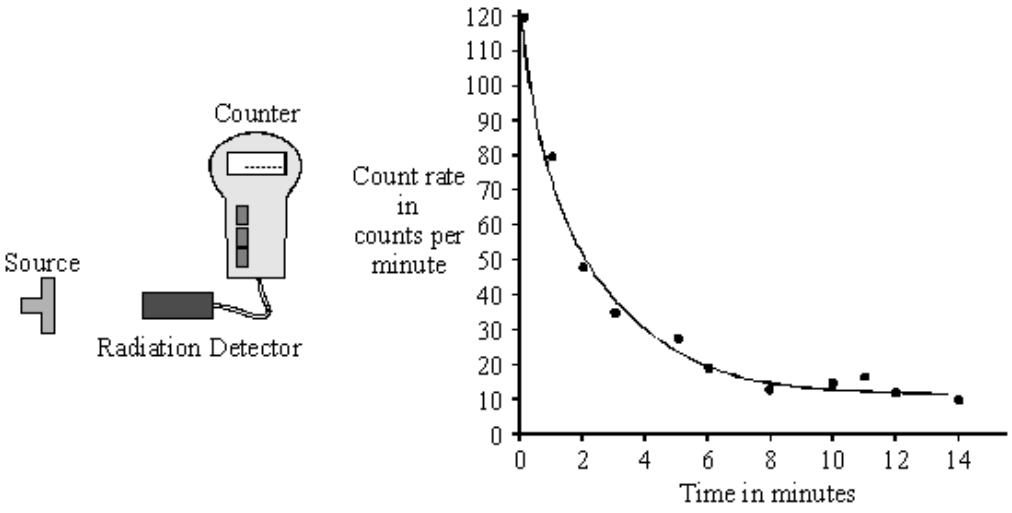
.....

.....

(2)

(Total 11 marks)

Q21. (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.

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(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)

##

(a) The table shows the half-life of some *radioactive* isotopes.

Radioactive isotope	**Half-life**
magnesium-27	10 minutes
sodium-24	15 hours
sulphur-35	87 days
cobalt-60	5 years

(i) What is meant by the term *radioactive?*

.....

.....

(1)

(ii) Which **one** of the isotopes in the table could form part of a compound to be used as a tracer in medicine? Explain the reason for your choice.

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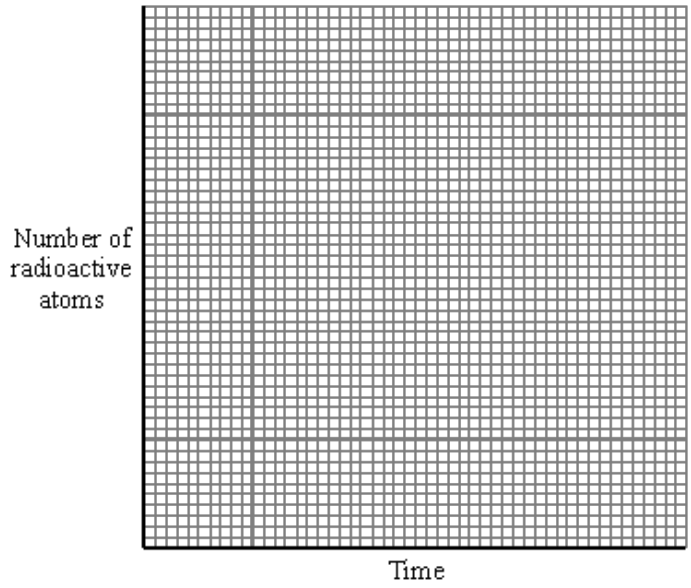
(3)

(iii) Draw a graph to show how the number of radioactive atoms present in the isotope cobalt-60 will change with time.



(3)

(b) Nuclear power stations provide about 17% of the world's electricity. They add less than 1% to the total background levels of radiation. Some people are opposed to the use of nuclear fuels for the generation of electricity. Explain why.

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(3)

(Total 10 marks)

##

(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?

.....

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(1)

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

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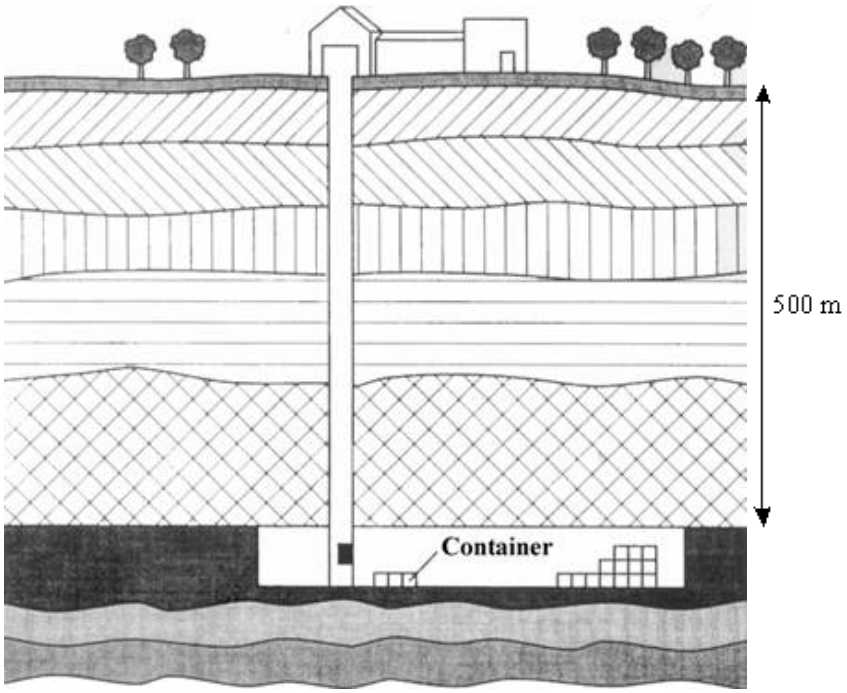
(3)

(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.

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(3)

(Total 8 marks)

Q24. The radioactive isotope, carbon-14, decays by beta (β) particle emission.

(a) What is a beta (β) particle?

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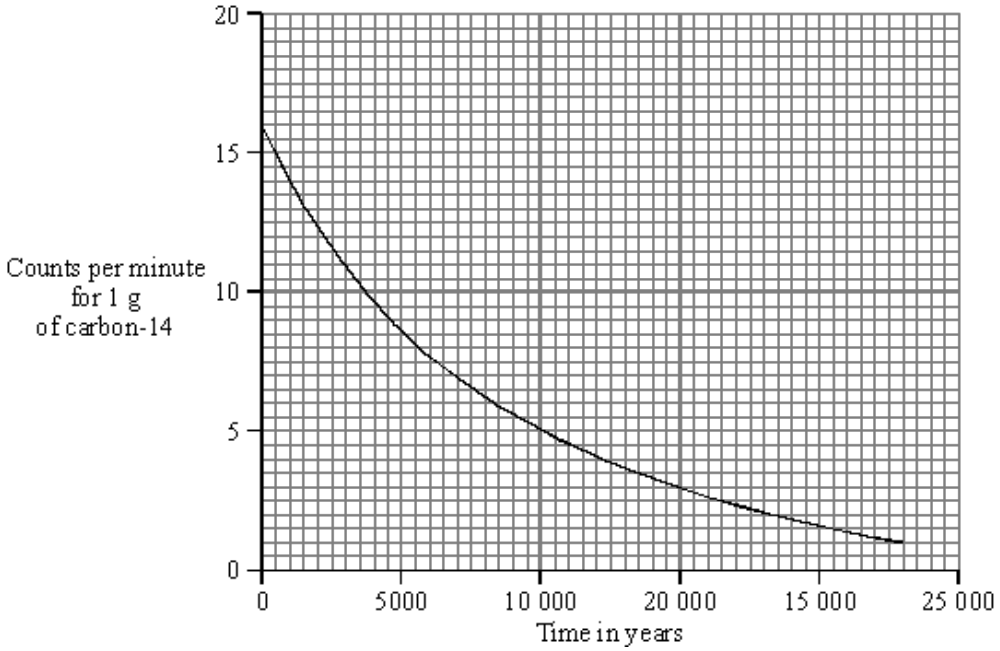
(1)

(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.

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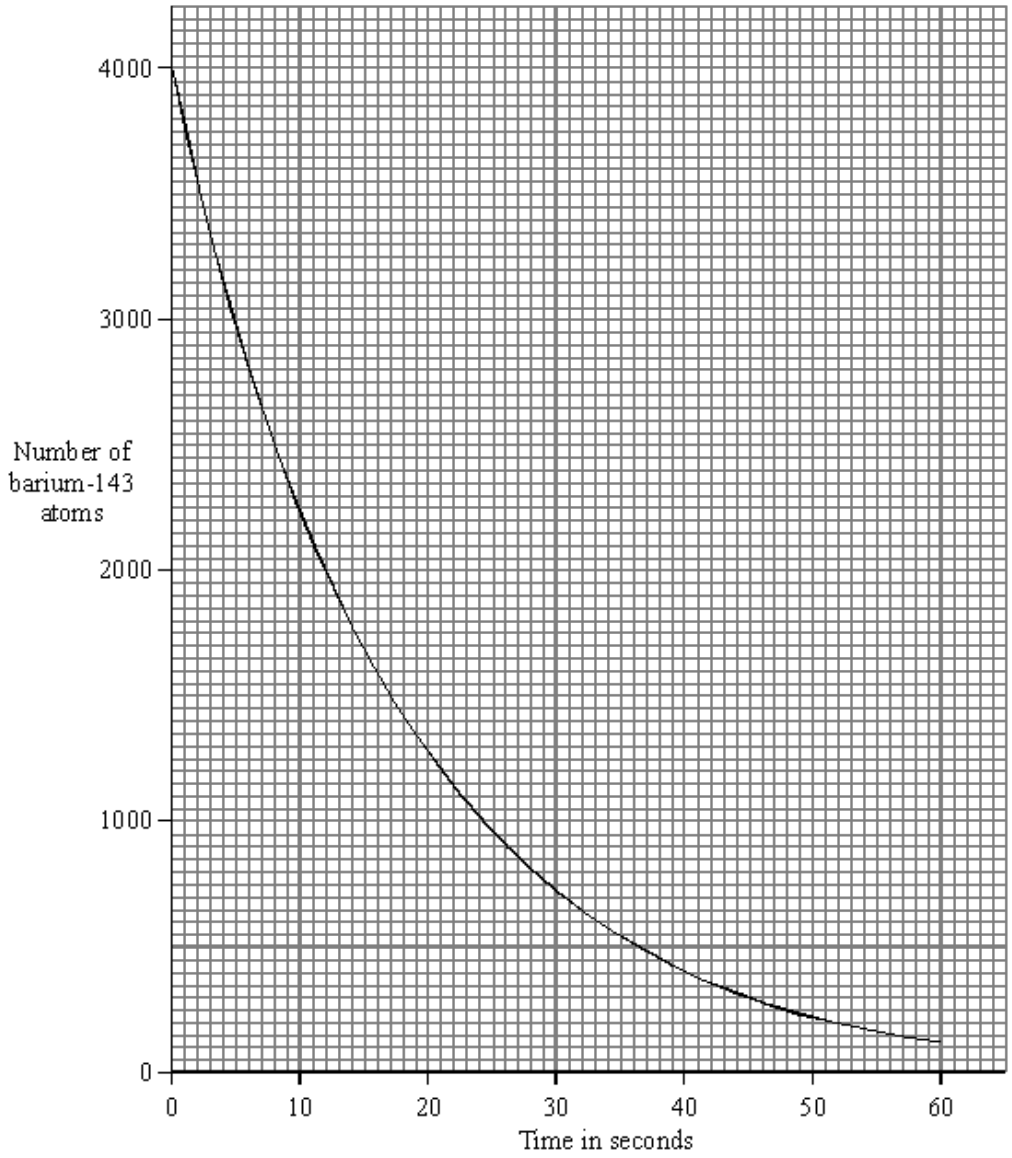
(3)

(Total 6 marks)

Q25. (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.

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(3)

(Total 9 marks)

Q26. 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.

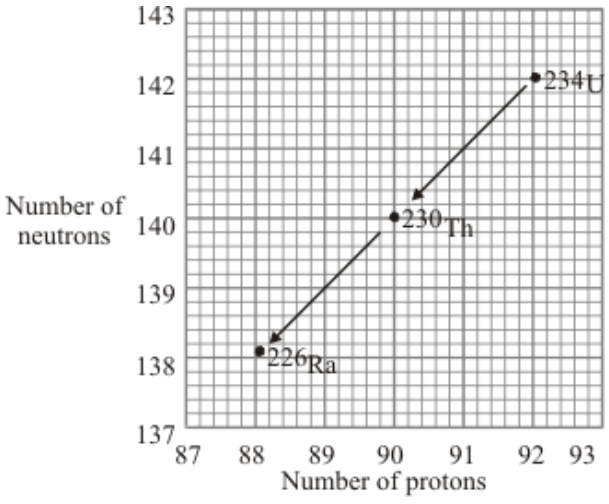
.....

Age of rock = ... million years

(1)

(Total 2 marks)

Q27. (a) Uranium-234 (^{234}U) is a radioactive element. The graph shows the number of protons and neutrons in the nuclei of the elements formed when uranium-234 decays.



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

.....

(1)

(ii) What makes uranium and thorium different elements?

.....

(1)

(iii) Radioactive decay may also produce gamma radiation.

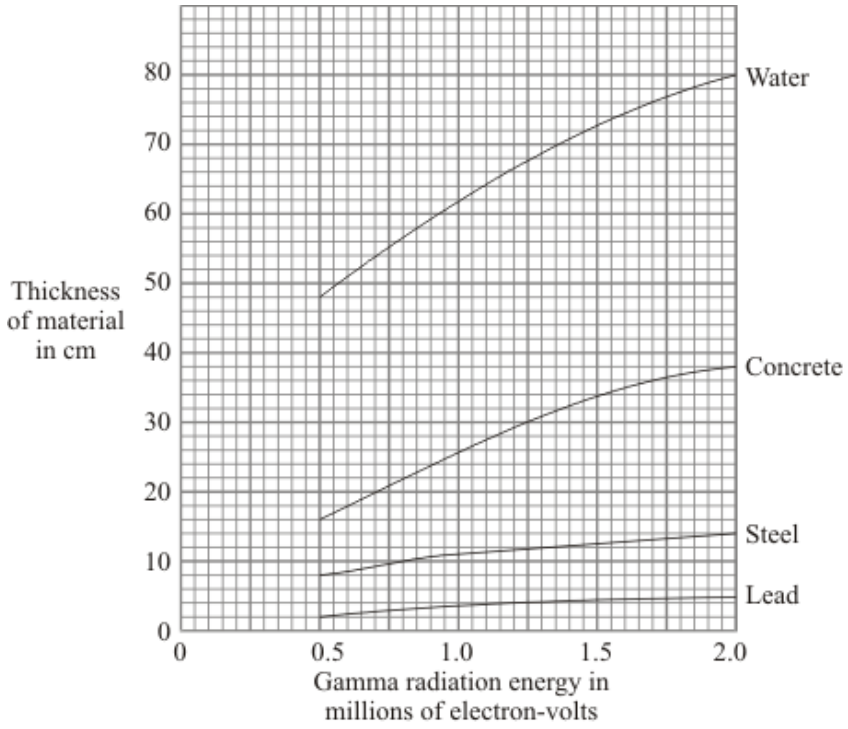
Why does the emission of gamma radiation **not** cause a new element to be formed?

.....

.....

(1)

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



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

.....

.....

(1)

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

.....

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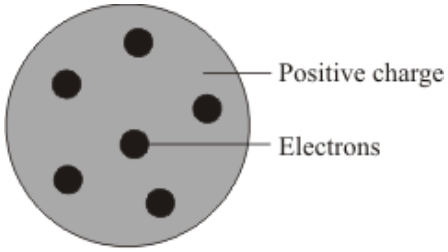
(2)

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



Plum pudding model

Rutherford and Marsden did an experiment, in which a beam of alpha particles was aimed at a thin sheet of gold.
Explain how the results of this experiment led to a new model of the atom.
You may include one or more diagrams in your answer.

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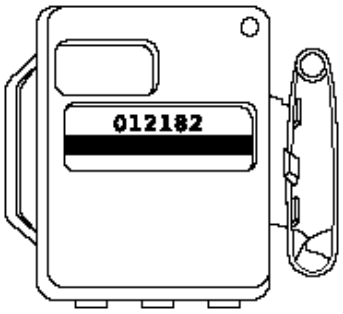
(3)
(Total 9 marks)

Q28. The diagram shows a badge used to monitor radiation. It measures the amount of radiation a worker has been exposed to in one month.



(i) What is used inside the badge to detect radiation?

.....

(1)

(ii) What would indicate that the worker has been exposed to a high level of radiation as opposed to a low level of radiation?

.....

.....

(1)

(iii) Why is it important to monitor the amount of radiation the worker has been exposed to?

.....

.....

(1)

(Total 3 marks)

Q29. 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)

Q30. (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.

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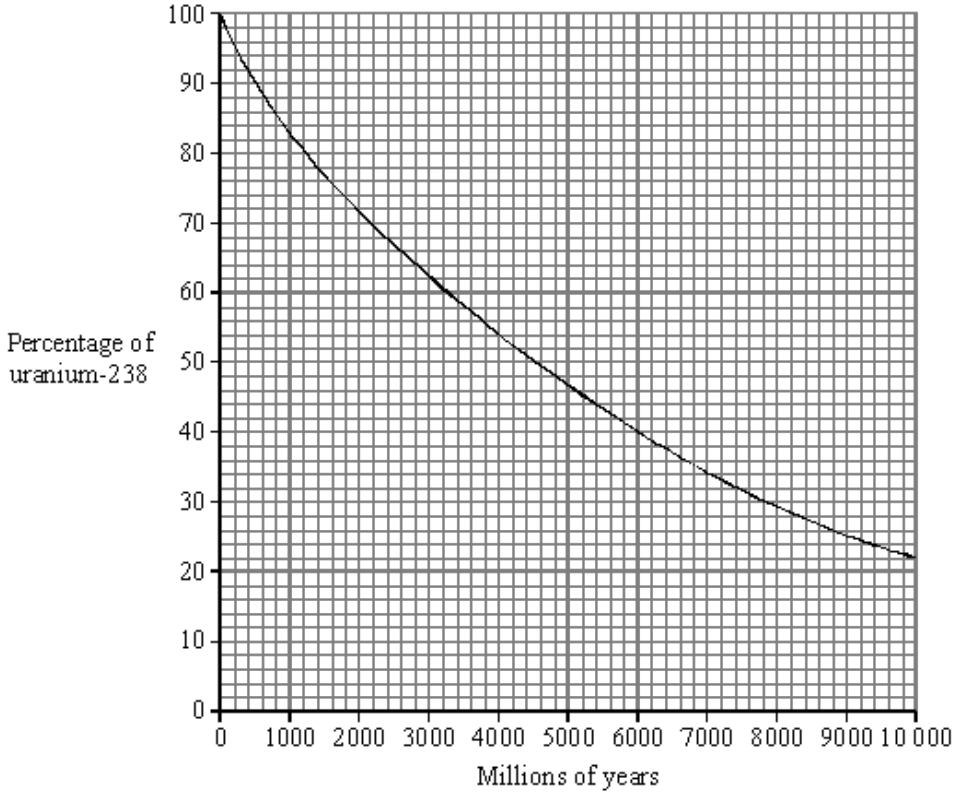
.....

(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)

Q31. (a) Alpha particles (α), beta particles (β) and gamma rays (γ) are types of nuclear radiation.

(i) Which of the three types of radiation is the most strongly ionising?

.....

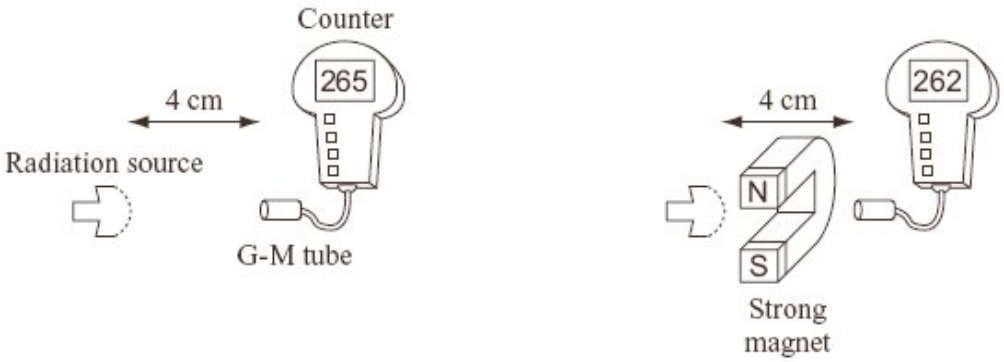
(1)

(ii) What effect does nuclear radiation have on living cells?

.....

(1)

(b) The diagrams show a G-M tube and counter used to measure the radiation emitted from a source. Both diagrams show the reading on the counter one minute after it was switched on.



Explain why the counter readings show that the source is giving out only gamma radiation.

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.....

.....

(2)

(c) The box gives information about the radioactive isotope technetium-99.

Type of radiation emitted: gamma
Half-life: 6 hours
Used as a medical tracer

What is meant by the term *half-life*?

.....

.....

(1)

(d) To study the blood flow in a patient's lungs, a doctor injects a small quantity of a technetium-99 compound into the patient. The radiation emitted by the technetium-99 atoms is detected outside the patient's body.

Explain why a doctor would not use a radioactive isotope with a very short half-life, such as 2 seconds, as a medical tracer.

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(2)

(Total 7 marks)

Q32. In 1986, a nuclear reactor exploded in a power station at Chernobyl in the Ukraine.

(a) The table gives information about some of the radioactive substances released into the air by the explosion.

Radioactive substance	Half-life	Type of radiation emitted
Iodine-131	8 days	beta and gamma
Caesium-134	2 years	beta
Caesium-137	30 years	beta

(i) How is the structure of a caesium-134 atom different from the structure of a caesium-137 atom?

.....

(1)

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

.....

.....

(1)

(iii) Once a radioactive substance is dissolved in rainwater, it can enter the food chain.

Following the Chernobyl explosion, some milk supplies were found to be radioactive.

If one litre of milk contaminated with iodine-131 gives a count rate of 400 counts/second, how long will it take for the count rate to fall to 25 counts/second?

Show clearly how you work out your answer.

.....

.....

.....

Time taken = ... days

(2)

(iv) After 20 years, the caesium-137 emitted into the atmosphere is a more serious problem than the iodine-131.

Explain why.

.....

.....

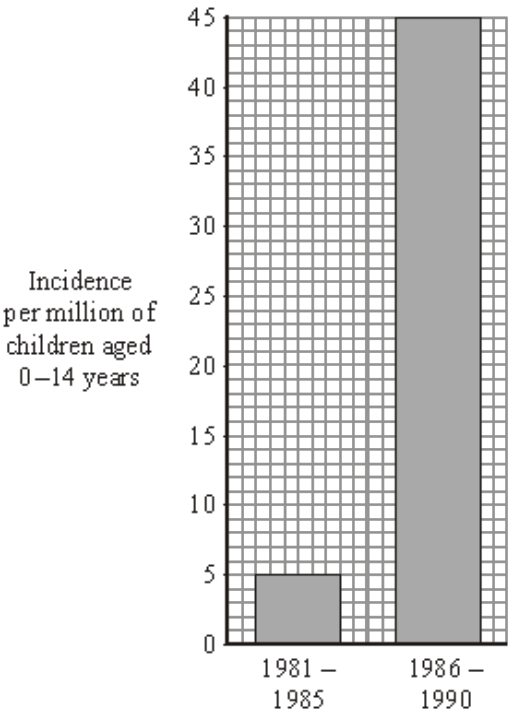
.....

.....

.....

(2)

(b) The bar chart compares the incidence of thyroid cancer in Ukrainian children, aged 0–14 years, before and after the Chernobyl explosion.



Of the children that developed thyroid cancer, 64% lived in the areas most contaminated by the radiation.

Considering this data, can you be certain that a child who developed thyroid cancer between 1986 and 1990 did so because of the Chernobyl explosion?

Explain the reason for your answer.

.....

.....

.....

.....

(2)

(c) In 1991, some scientists compared the health of two groups of people: a *control* group and a group that had been exposed to the radiation from Chernobyl.

What people would have been in the *control* group?

.....

(1)

(d) Although there are some risks associated with nuclear power stations, it is likely that new ones will be built.

Give **two** reasons to justify the use of nuclear power.

1 .....

.....

2 .....

.....

(2)

(Total 11 marks)

Q33. (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.

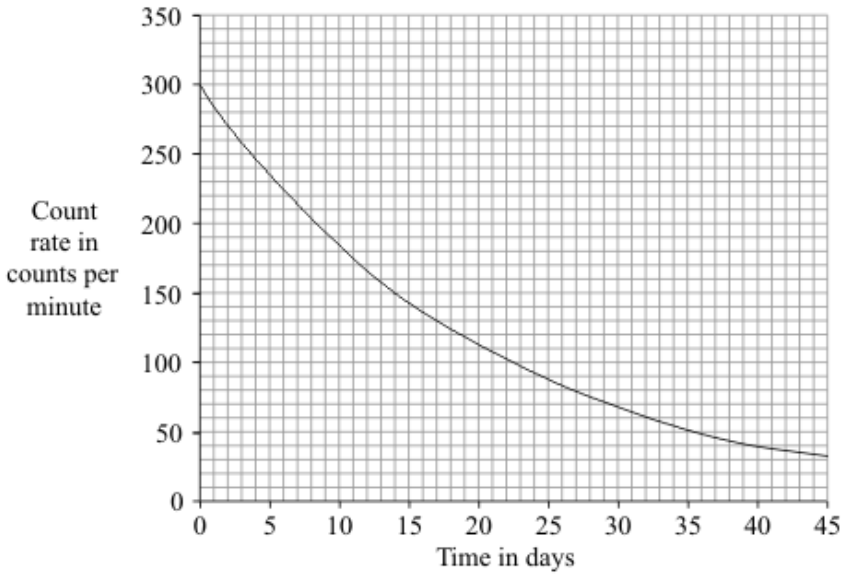
(i) How is an atom of phosphorus-32 different from an atom of the stable isotope phosphorus-31?

.....

.....

(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.

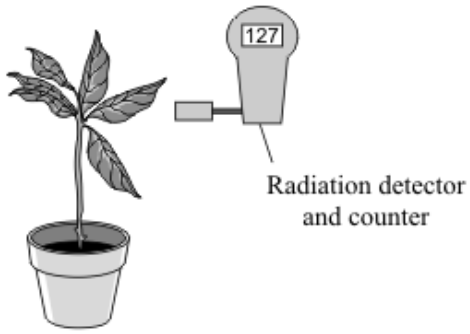
.....

.....

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.

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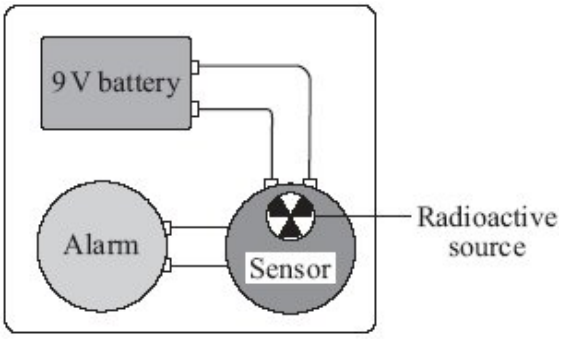
.....

(2)

(Total 9 marks)

Q34. (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.

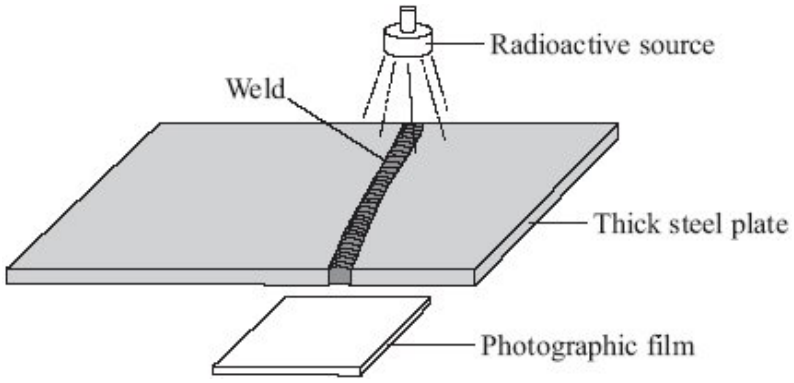
How is an atom of curium-242 different from an atom of curium-244?

.....

.....

(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.

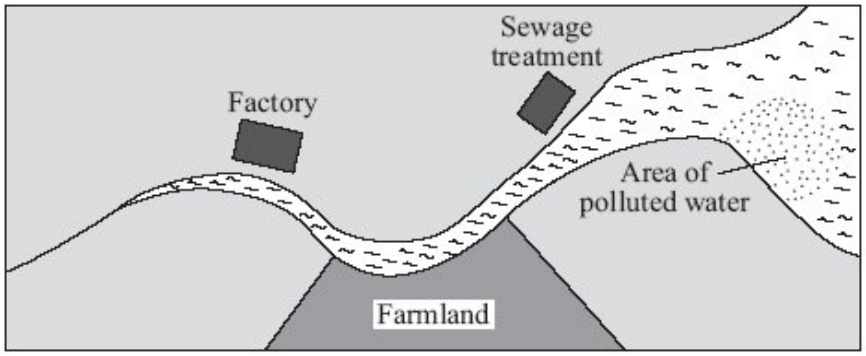
.....

.....

(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.

.....

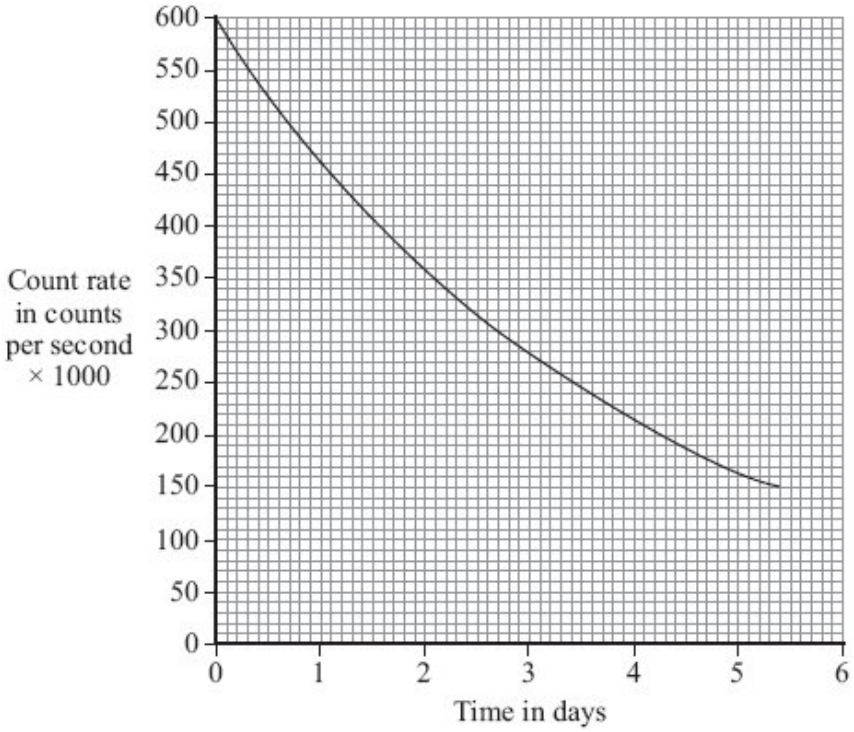
.....

.....

.....

(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.

.....

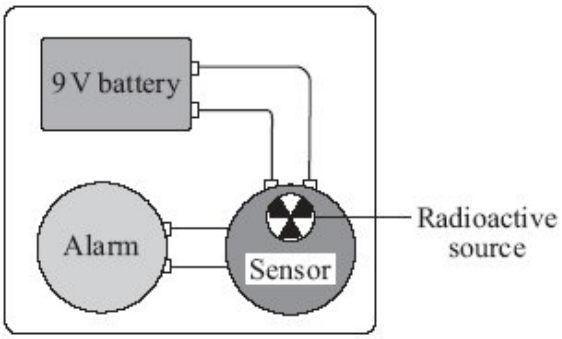
.....

Half-life = ... days

(2)

(Total 9 marks)

Q35. (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.

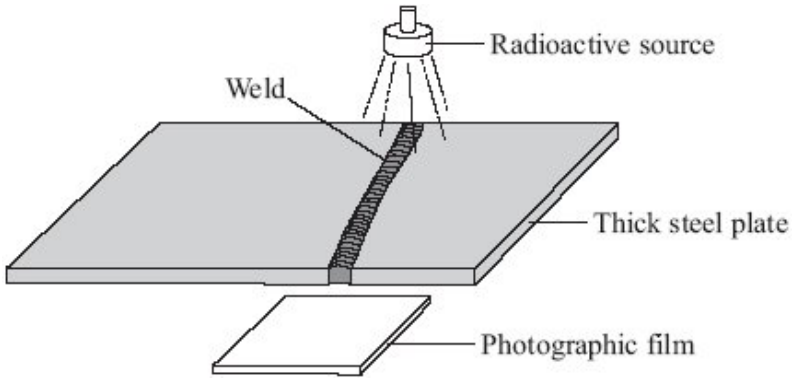
How is an atom of curium-242 different from an atom of curium-244?

.....

.....

(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.

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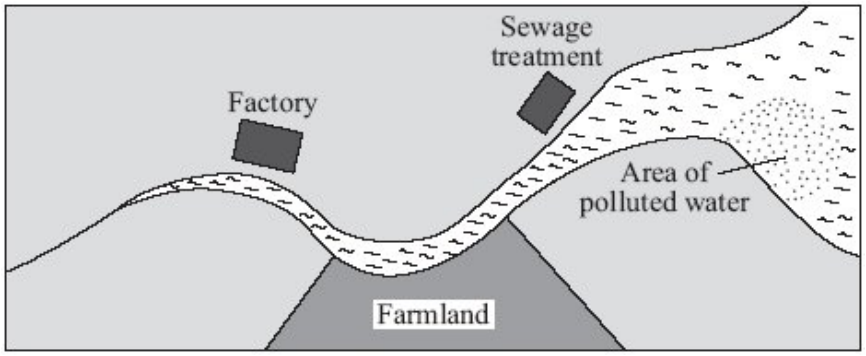

(i) Explain how the gold-198 is used to find where the pollution is coming from.

.....

.....

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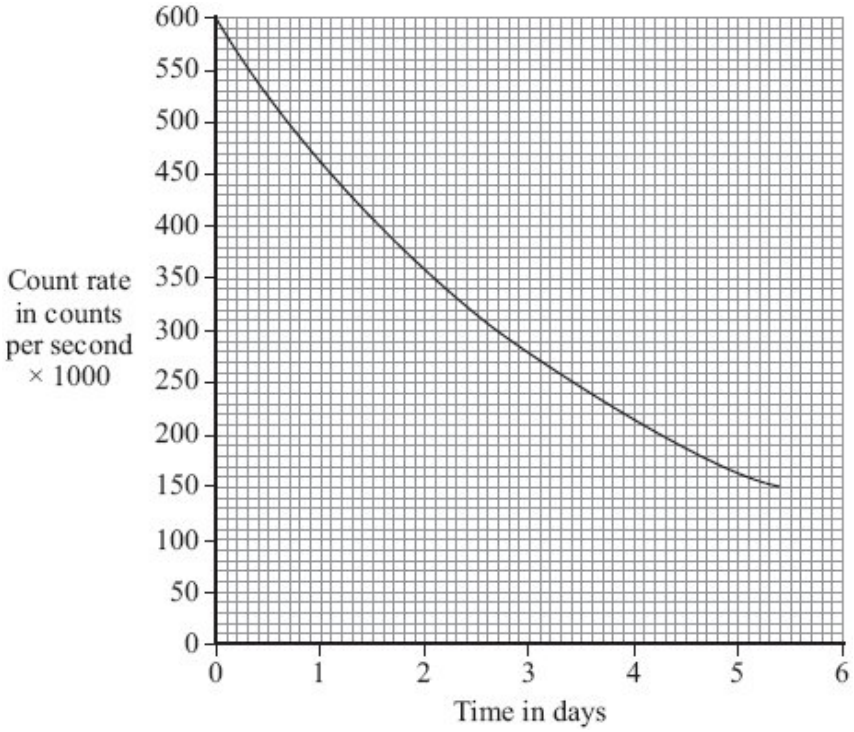
.....

(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)