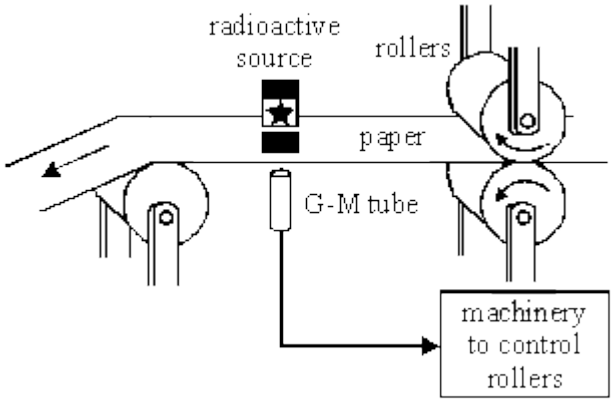
1 The diagram below shows a method of controlling the thickness of paper produced at a paper mill. A radioactive source which emits beta radiation is placed on one side of the paper and a radiation detector is placed on the other.



(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.

.....

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(1)

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

.....

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(1)

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

.....

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.....

(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?

.....

.....

.....

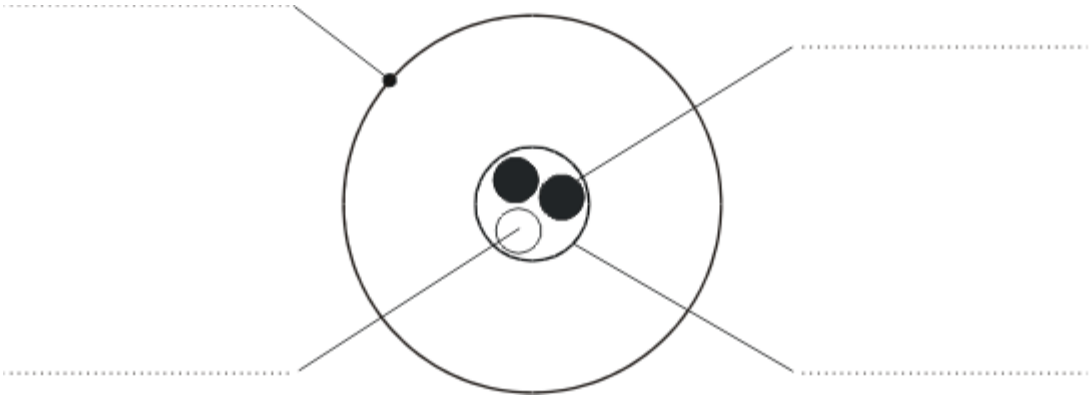
Answer = ...

(3)

(Total 8 marks)

2 (a) Tritium ($^{3}_{1}H$) is an isotope of hydrogen. Tritium has a proton number of 1 and a mass number of 3.

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



(4)

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

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(2)

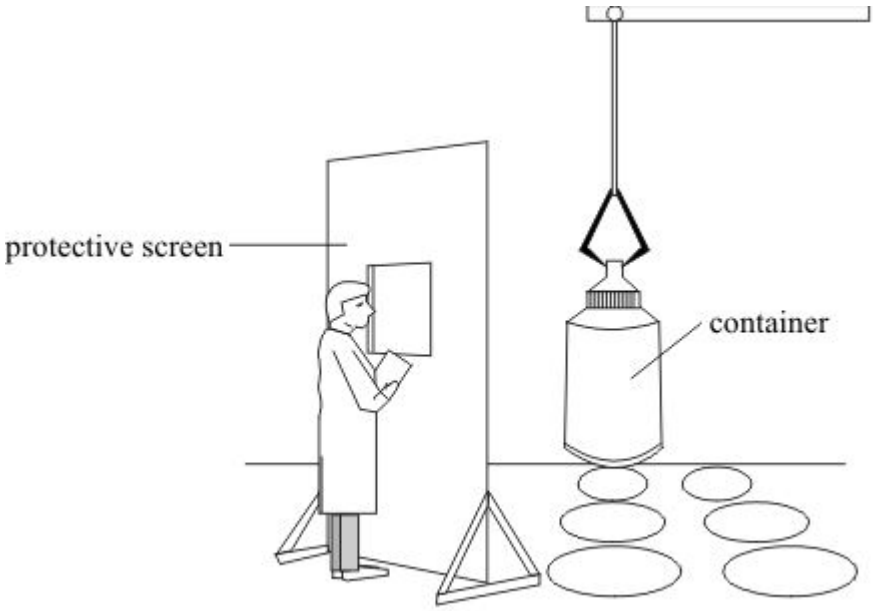
(iii) Tritium is a radioactive substance which emits beta (β) radiation.
Why do the atoms of some substances give out radiation?

.....

.....

(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.

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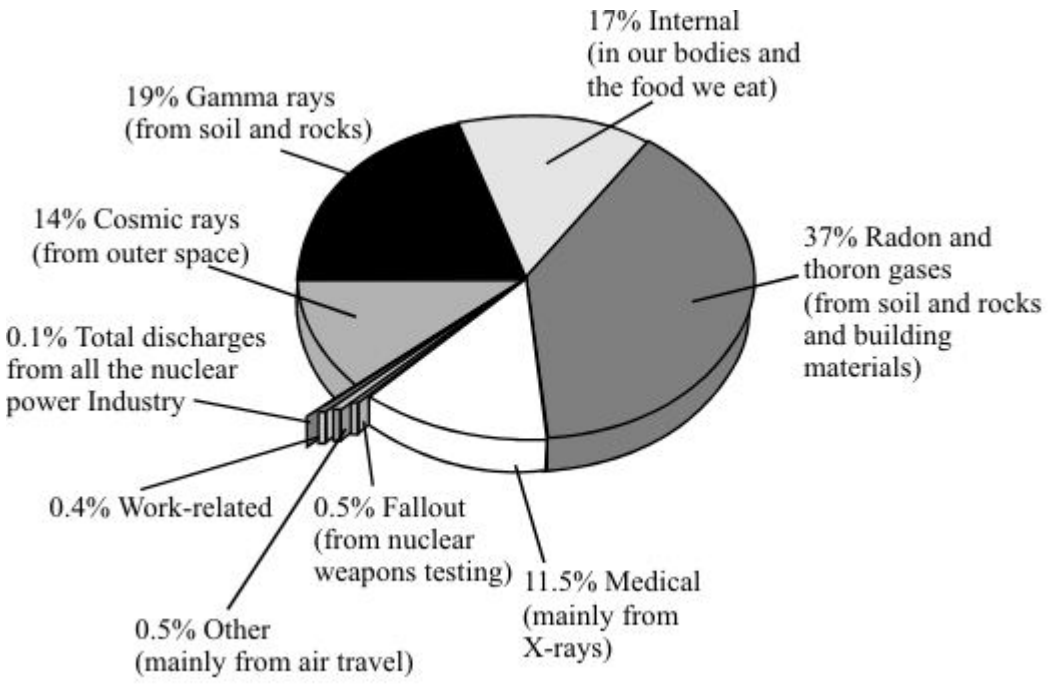
(2)
(Total 10 marks)

3 The chart below shows the sources of radiation in Britain.



(a) Give **two** sources of natural radioactivity from the chart.

.....

(2)

(b) How might the chart be used to reassure people that nuclear power is safe?

.....

.....

.....

(1)

(c) Some material is spilled on a bench. How could you find out if this material is radioactive?

.....

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.....

.....

(2)

(d) The table shows the proton number and mass number of two isotopes of iodine.

Iodine is found naturally in the world as the isotope I-127. Iodine-127 is not radioactive and is essential to life.
Other isotopes of iodine are formed in nuclear reactors. In the Chernobyl nuclear power station disaster in Ukraine an explosion caused a large quantity of the isotope iodine-131 to be released into the atmosphere. Iodine-131 is radioactive.

	proton number	mass number
iodine–127	53	127
iodine–131	53	131

Explain, in terms of particles found in the nucleus, how an iodine-131 nucleus is different from an iodine-127 nucleus.

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.....

(2)

(e) (i) Explain, as fully as you can, why iodine-131 could be harmful to our bodies.

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(4)

(ii) Iodine-131 and iodine-127 have the same chemical properties. Explain why this would be a problem if iodine-131 was taken into our bodies.

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(1)

(iii) The Chernobyl disaster took place in 1986. Do you think that iodine-131 from the disaster is still a threat to us today? Explain your answer.

.....

.....

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(3)
(Total 15 marks)

4 (a) Complete the table about atomic particles.

ATOMIC PARTICLE	RELATIVE MASS	RELATIVE CHARGE
proton		+1
neutron	1	0
electron	negligible	

(2)

(b) Use the Data Sheet to help you to answer some parts of this question.

Read the following passage about potassium.

Potassium is a metallic element in Group 1 of the Periodic Table.
It has a proton (atomic) number of 19.

Its most common isotope is potassium-39, ($^{40}_{19}K$).

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

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

Number of protons .....

Number of neutrons .....

Number of electrons .....

(2)

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

.....

(1)

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

.....

.....

(1)

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

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

.....

(1)

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

.....

(1)

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

.....

(1)

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

.....

(1)
(Total 10 marks)

5 Nuclear fusion in the Sun releases large amounts of energy.

(i) Explain what is meant by nuclear fusion.

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(3)

(ii) Why is energy released by such nuclear fusion reactions?

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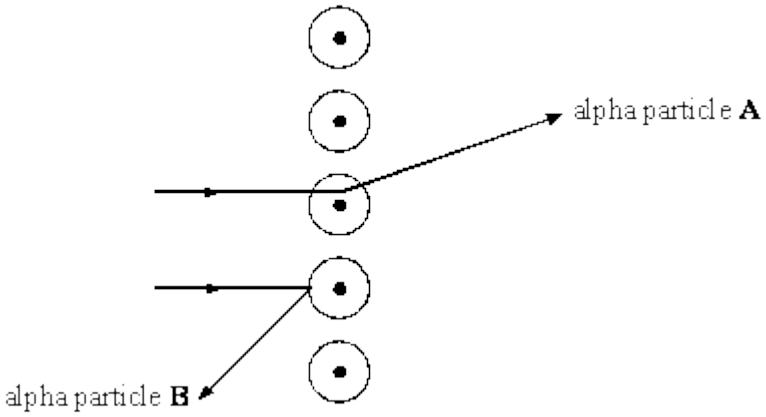
(2)
(Total 5 marks)

6 (a) Atoms are made up of three types of particle 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 has already been done for you.

PARTICLE	RELATIVE MASS	RELATIVE CHARGE
proton	1	+1
neutron		
electron		

(2)

(b) The diagram below shows the paths of two alpha particles **A** and **B**, into and out of a thin piece of metal foil.



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.

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(3)
(Total 5 marks)

7 (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.

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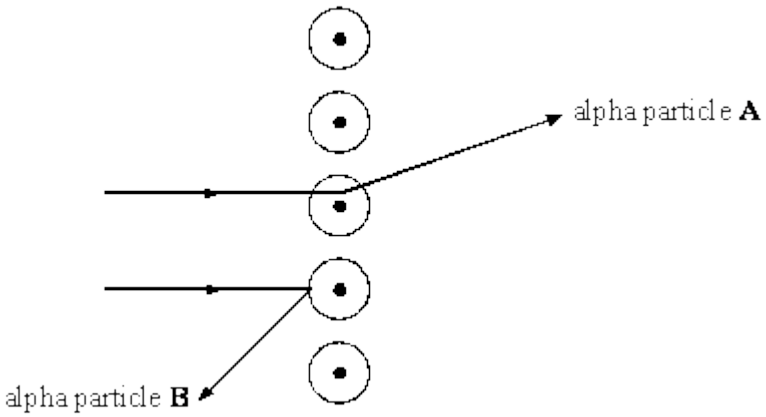
(2)
(Total 4 marks)

8 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.

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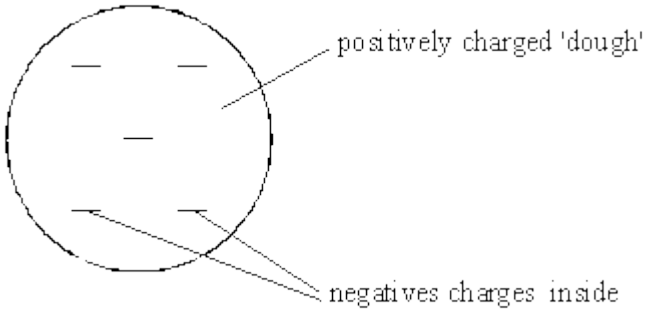
.....

(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.

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(2)

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

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(3)

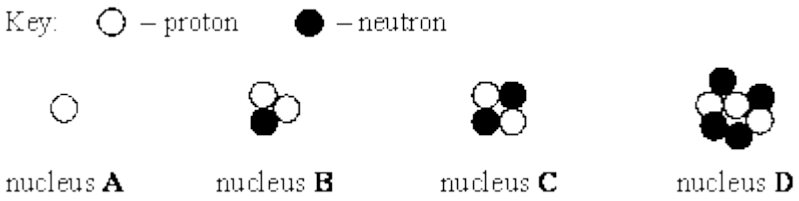
(c) We now believe that atoms are made up of three types of particles called protons, neutrons and electrons.

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.

.....

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.....

.....

(4)
(Total 14 marks)

9 Use the Data Sheet to help you answer this question.
This question is about elements and atoms.

(a) About how many different elements are found on Earth?
Draw a **ring** around the correct number.

40 **50** **60** **70** **80** **90**

(1)

(b) The following are parts of an atom:

electron **neutron** **nucleus** **proton**

Choose from the list the one which:

(i) has no electrical charge; .....

(ii) contains two of the other particles; .....

(iii) has very little (negligible) mass. .....

(3)

(c) Scientists have been able to make new elements in nuclear reactors. One of these new elements is fermium. An atom of fermium is represented by the symbol below.

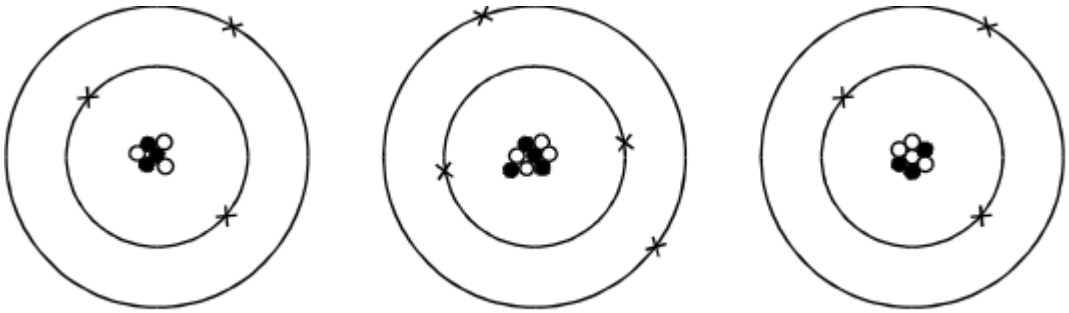
$$^{257}_{100}\mathrm{Fm}$$

(i) How many protons does this atom contain? .....

(ii) How many neutrons does this atom contain? .....

(2)
(Total 6 marks)

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



(a) Two of the 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.

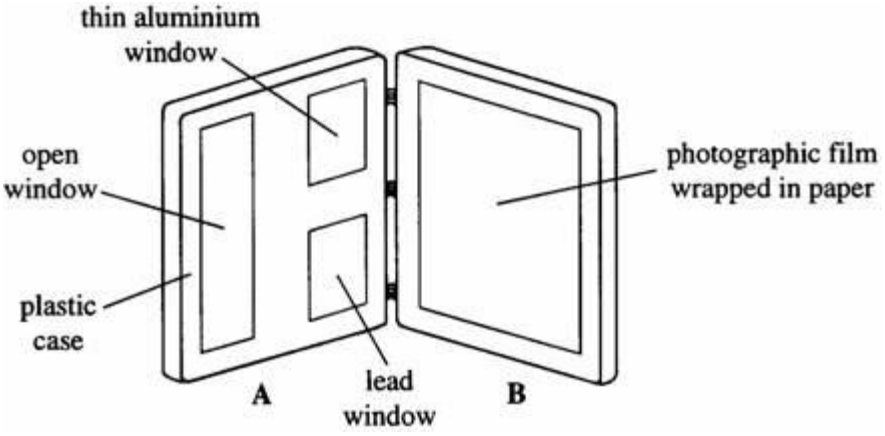
.....

.....

.....

(3)
(Total 5 marks)

11 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*.

.....

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.....

(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.)

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.....

(1)

(ii) The half-life of uranium-238 is 4500 million years.

Calculate the age of the rock.

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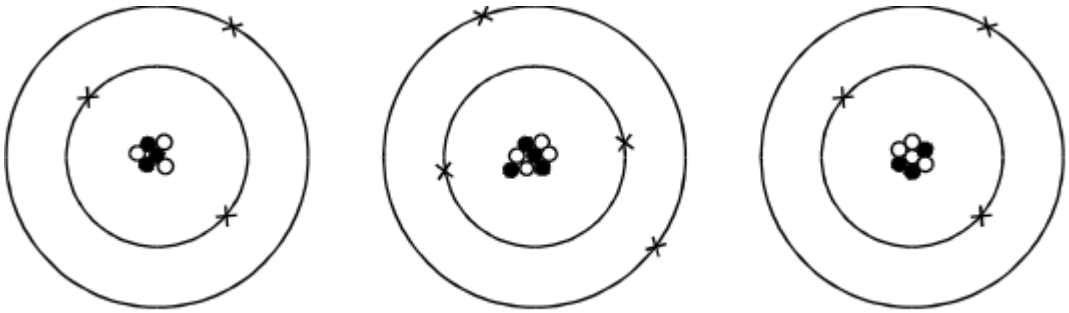
.....

Age ..... million years

(2)
(Total 10 marks)

12 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)

13 (a) The Sun is at the stable stage of its life.

Explain, in terms of the forces acting on the Sun, what this means.

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(3)

(b) At the end of the stable stage of its life a star will change.

Describe and explain the changes that could take place.

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(6)
(Total 9 marks)

14 In some areas of the U.K. people are worried because their houses are built on rocks that release radon.

Read the information about radon.

- It is a gas.
- It is formed by the breakdown of radium.
- It emits alpha radiation.
- Each radon atom has 86 protons.
- Each radon atom has 136 neutrons.

(i) How many electrons has each atom of radon? .....

(ii) What is the mass (nucleon) number of radon? .....

(Total 2 marks)

15 In some areas of the U.K. people are worried because their houses are built on rocks that release radon.

Read the information about radon.

- It is a gas.
- It is formed by the breakdown of radium.
- It emits alpha radiation.
- Each radon atom has 86 protons.
- Each radon atom has 136 neutrons.

Explain why it may be dangerous to live near rocks that release radon.

To gain full marks in this question you should write your ideas in good English. Put them into a sensible order and use the correct scientific words.

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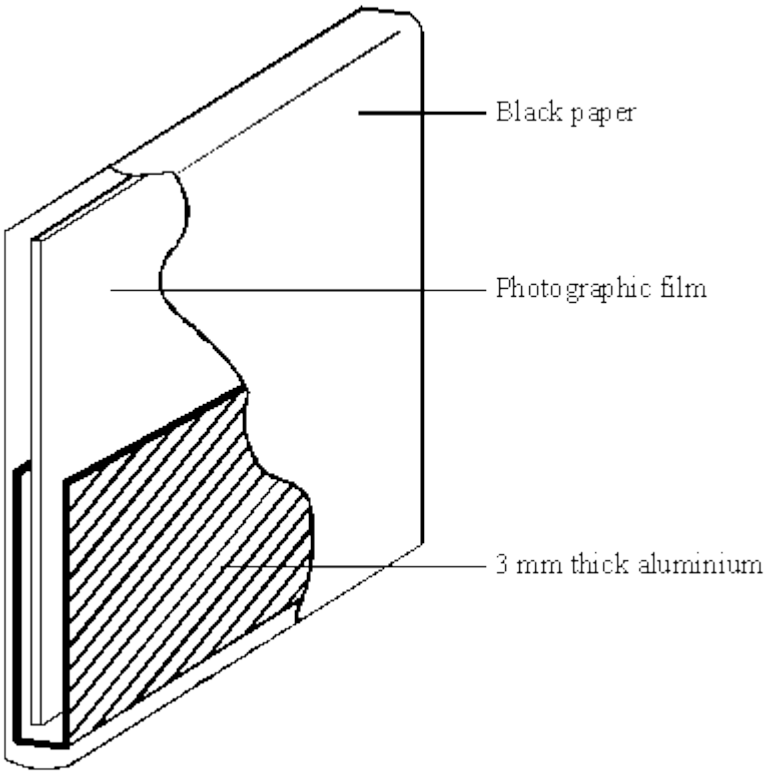
(Total 3 marks)

16 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.

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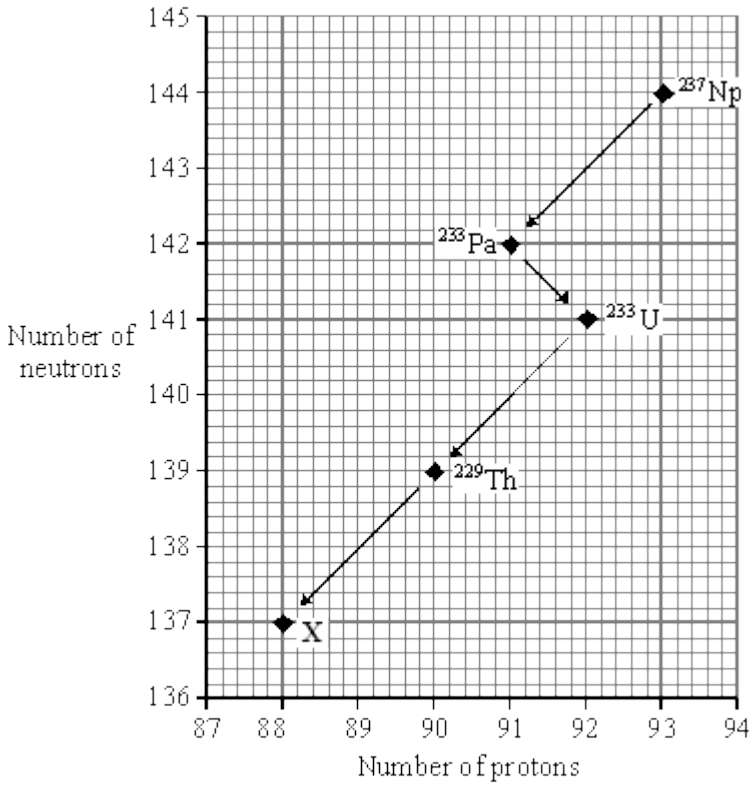
(Total 2 marks)

17 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)

18 Our Sun is just one of many millions of stars in a galaxy called the Milky Way.

Our Sun is in the main stable period of a star's lifetime. The massive force of gravity draws its matter together. This force is balanced by the very high temperatures, from the fusion of hydrogen atoms, which tend to make the Sun expand. Describe and explain what will happen to the Sun as the hydrogen is eventually used up.

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(Total 3 marks)

19 Studying stars gives scientists evidence about the evolution of the Universe.

(a) (i) In astronomy, what is meant by a black hole?

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(2)

(ii) How is it possible to detect a black hole?

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(2)

(b) The changes which happen in stars result in new elements being formed.

Nuclei of the heaviest elements are found in the Sun.

Describe how these nuclei are formed.

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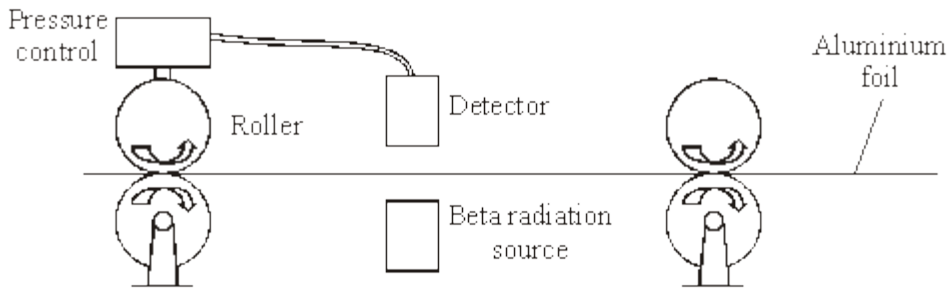
(2)
(Total 6 marks)

20 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?

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.....

(1)

(ii) Explain why radiation is dangerous to humans.

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(2)
(Total 5 marks)

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

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(2)

(ii) What are beta particles?

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.....

(1)

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

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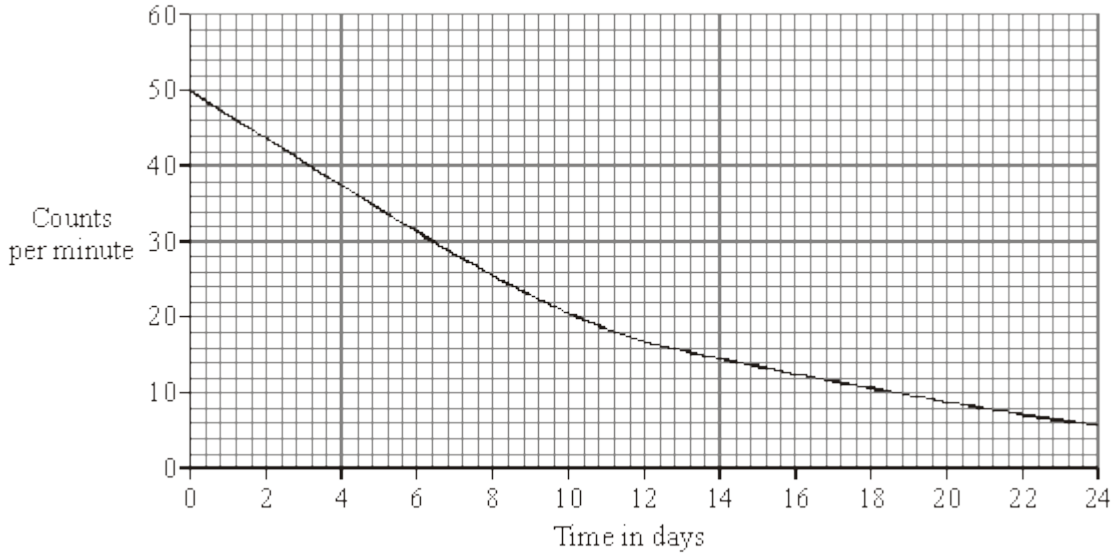
(1)
(Total 4 marks)

22 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.

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(2)

(Total 4 marks)

23 One theory of the origin of the Universe was that billions of years ago all matter was in one place, then it exploded ('big bang').
Describe, in as much detail as you can, how our star (the Sun) formed from the time when there was just dust and gas (mostly hydrogen) up to now when it is in its main stable period.

To gain full marks in this question you should write your ideas in good English. Put them into a sensible order and use the correct scientific words.

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(Total 5 marks)

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

.....

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.....

(2)

(ii) What are beta particles?

.....

.....

.....

(1)

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

.....

(1)

(Total 4 marks)

25 The picture shows a man at work in a factory that uses radioactive materials.

The radioactive material is kept behind glass shields. The man wears gloves so that he cannot touch the radioactive material directly.

Explain, as fully as you can, why these precautions are taken.

To gain full marks in this question you should write your ideas in good English. Put them into a sensible order and use the correct scientific words.

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(Total 4 marks)

26 (a) Complete the sentences about atoms.

In an atom, the number of electrons is equal to the number of ..... .

All atoms of an element have the same number of ..... .

Isotopes of the same element have different numbers of ..... .

(3)

(b) Complete the sentence.

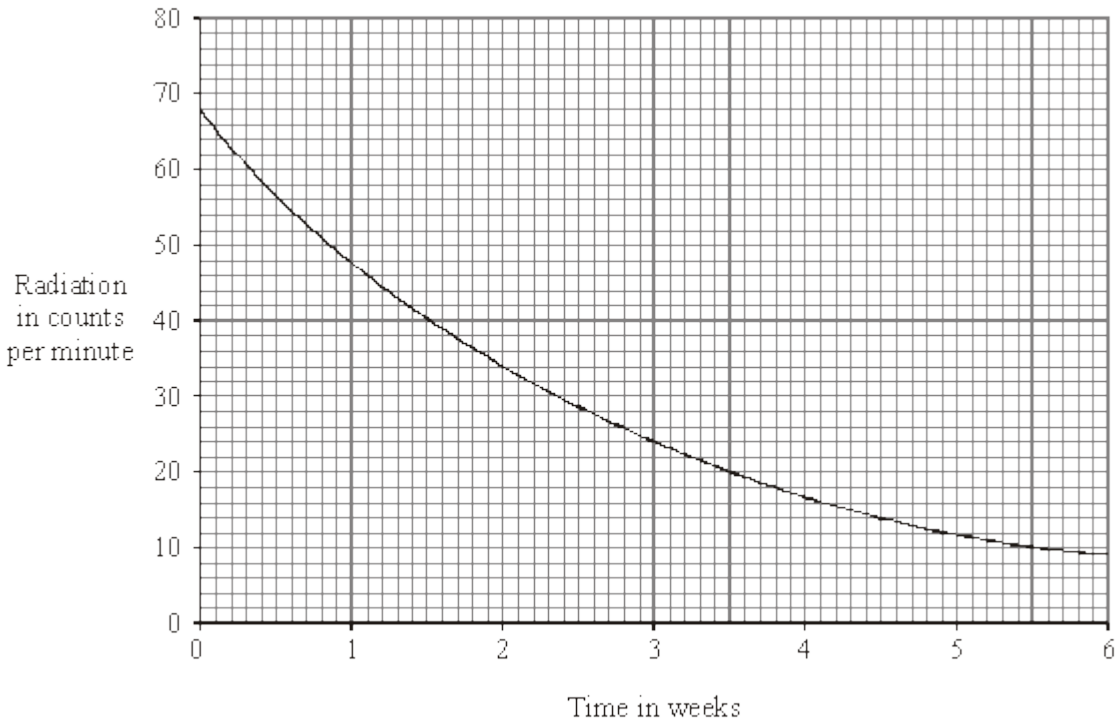
When an atom of a radioactive element emits alpha radiation, an atom of a different element is formed. A different element is formed because the radioactive element has lost

..... .

(1)
(Total 4 marks)

27 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)

28 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)

29 $^{99}_{43}Tc$ (technetium) is produced by the radioactive decay of $^{99}_{42}Mb$ (molybdenum).

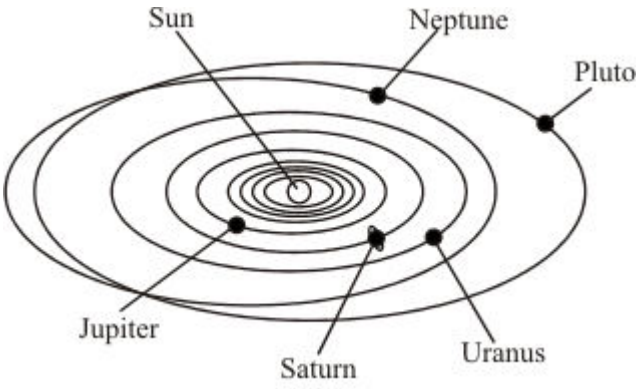
What change occurs in the nucleus of a molybdenum atom when this happens?

.....

.....

(Total 1 mark)

30 The Sun at the centre of our solar system is a star.



(a) The Sun contains nuclei of the heaviest elements. Atoms of these heaviest elements are also present in the planets of the solar system. What does this suggest about the material from which the solar system is formed?

.....

.....

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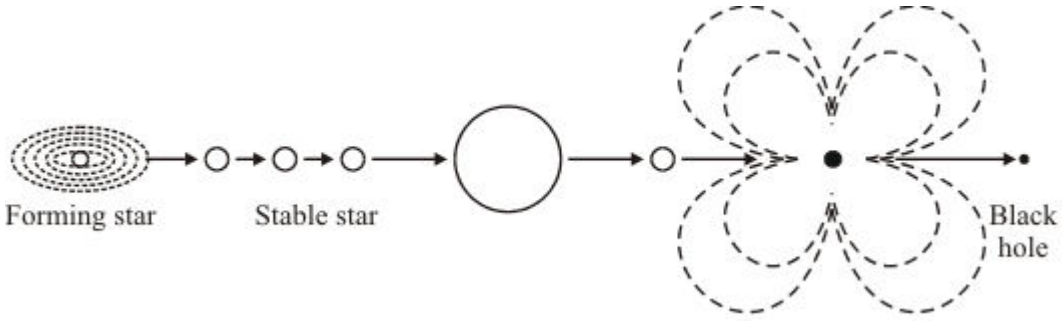
(1)

(b) Stars form from gas (mostly hydrogen) and dust.



Describe, in as much detail as you can, what forces allow a stable star to exist and how the star may eventually form a black hole.

To gain full marks in this question you should write your ideas in good English. Put them into a sensible order and use the correct scientific words.

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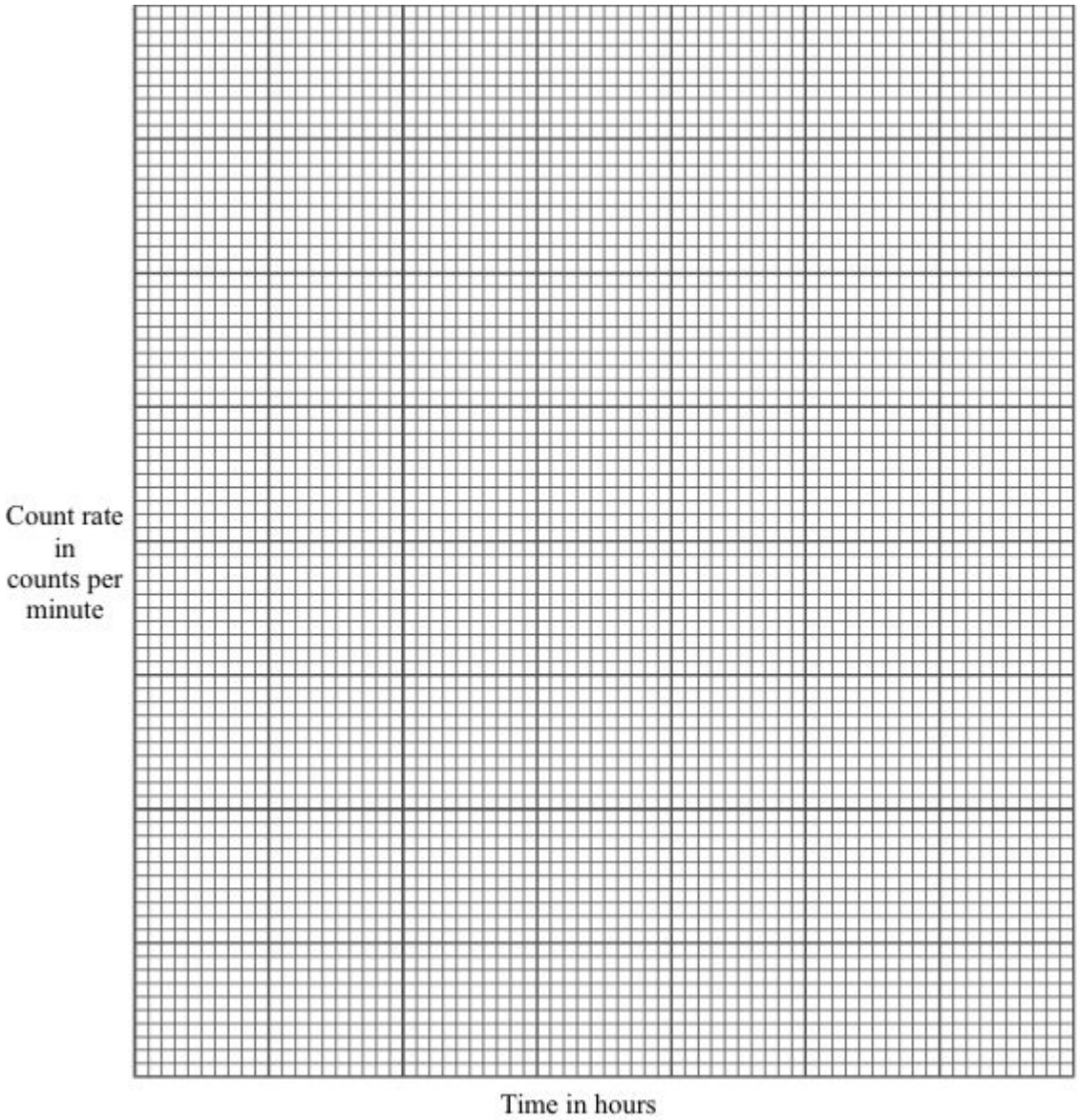
(6)
(Total 7 marks)

31 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

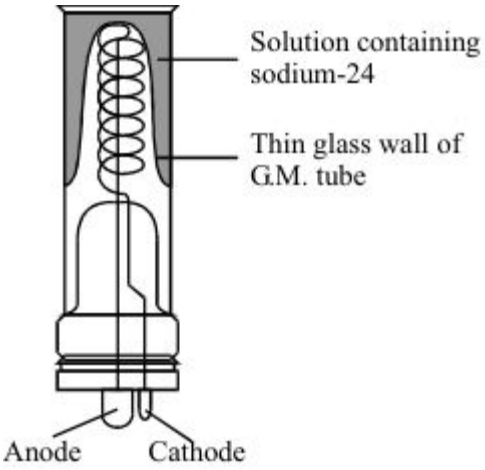
(a) Draw a graph of the results and find the half-life for the isotope. On the graph show how you obtain the half-life.



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)

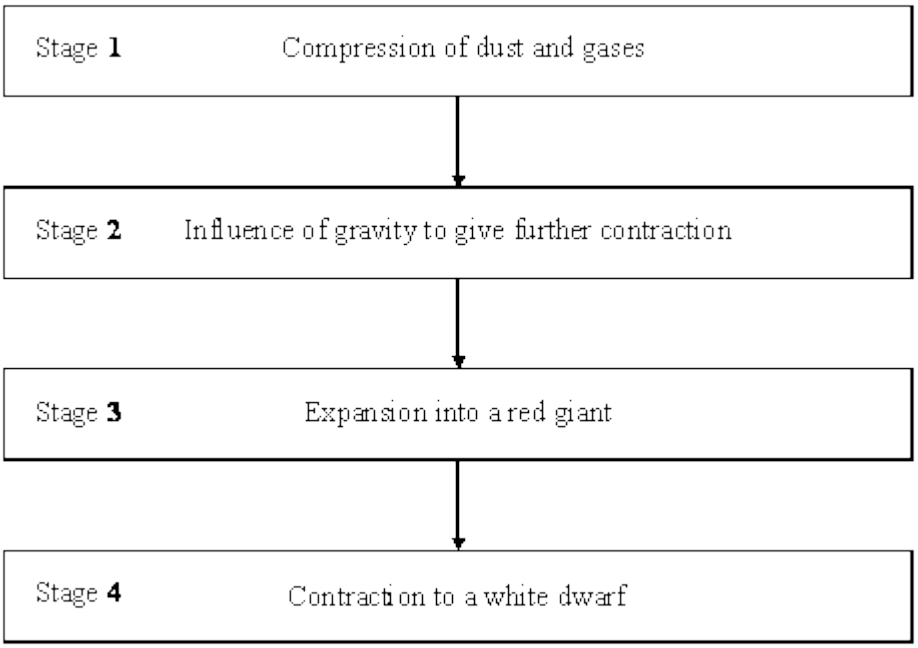
(ii) five seconds. .....

.....

(1)

(Total 8 marks)

32 The flowchart shows four stages thought to occur in the evolution of a star such as our Sun.



At a particular time a star might have reached one of these stages or be between stages or be at a further stage. What period in its evolution has our star, the Sun, reached?

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(Total 1 mark)

33 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?

.....

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Time = ... hours

(2)

(Total 7 marks)

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

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

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

(2)

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

(2)

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

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

.....

(1)

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

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(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?

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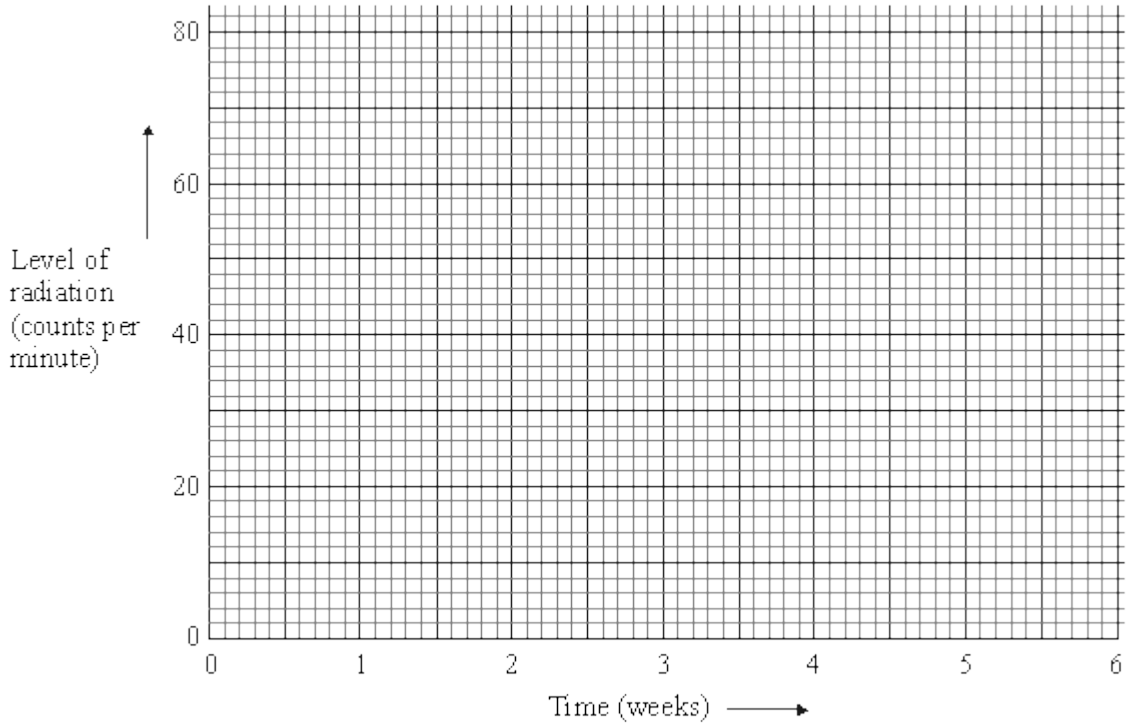
(1)
(Total 8 marks)

35 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?

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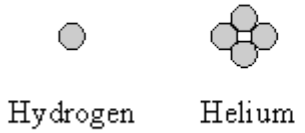
(3)
(Total 8 marks)

36 At the very high temperatures in the sun, hydrogen is converted into helium. It takes four hydrogen nuclei to produce one helium nucleus.

The table shows the relative masses of hydrogen and helium nuclei.



Nucleus	Relative Mass
hydrogen	1.007825
helium	4.0037

(a) Use these figures to calculate what happens to the mass of the sun as hydrogen is converted to helium.

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(3)

(b) Use your answer to part (a) to explain how the sun has been able to radiate huge amounts of energy for billions of years.

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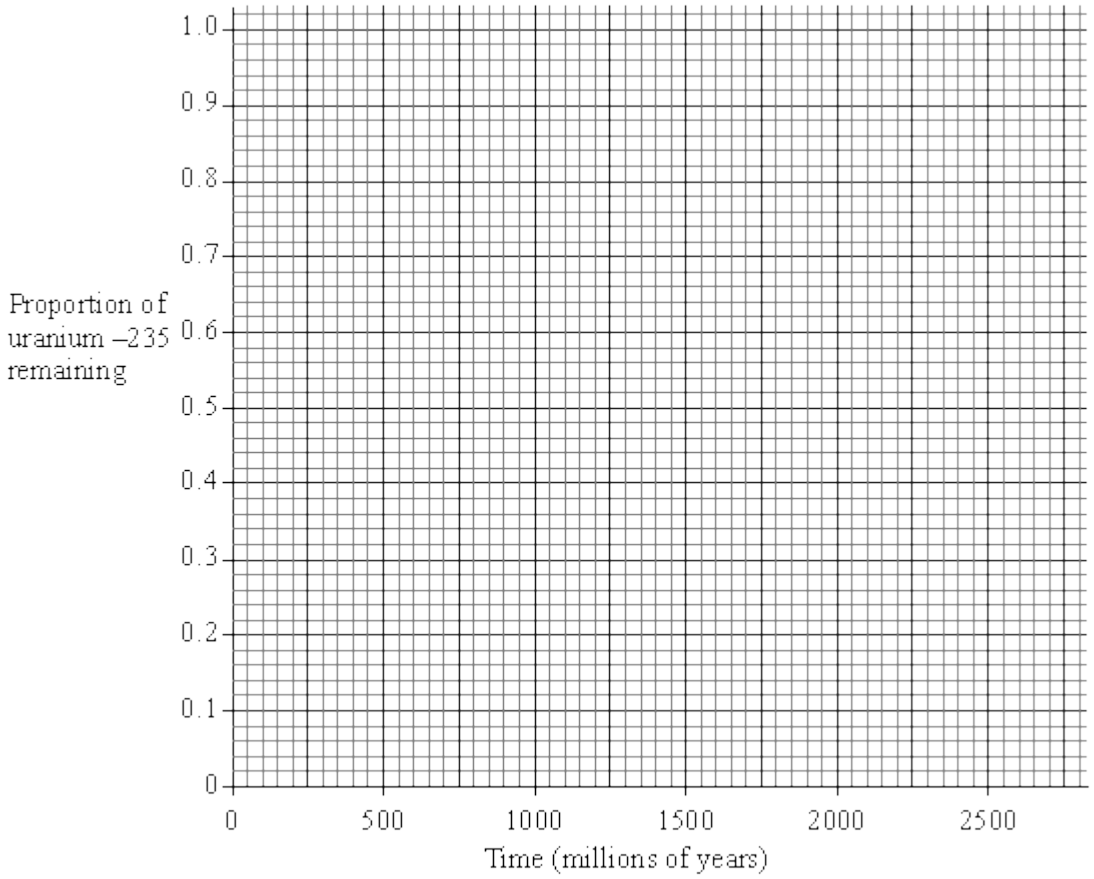
(2)
(Total 5 marks)

37 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?

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(2)
(Total 7 marks)

38 The energy radiated by a **main sequence** star like the Sun is released by a nuclear fusion reaction in its core.

Read the following information about this reaction then use it to answer the questions below.

- The net result of the nuclear fusion reaction is that four hydrogen nuclei produce one helium nucleus. There is a loss of mass of 0.7%.
- For nuclear fusion to occur nuclei must collide at very high speeds.
- The energy released during the reaction can be calculated as shown:

energy released [J] = loss of mass [kg] × (speed of light [m/s^2])

(The speed of light is 3×10^8 m/s)

(a) Calculate the energy released when 1g of hydrogen fuses to form helium.

(*Show your working.*)

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(4)

(b) The table shows the lifetimes and surface temperatures of main sequence stars with different masses.

MASS OF STAR [SUN = 1]	LIFETIME ON MAIN SEQUENCE [MILLION OF YEARS]	SURFACE TEMPERATURE * [KELVIN]
0.5	200 000	4000
1	10 000	6000
3	500	11 000
15	15	30 000

[* The higher the surface temperature of a star, the higher the temperature and pressure in its core.]

(i) Describe the relationship between the lifetime of a main sequence star and its mass.

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(2)

(ii) Suggest an explanation for this relationship.

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(3)
(Total 9 marks)

39 (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.

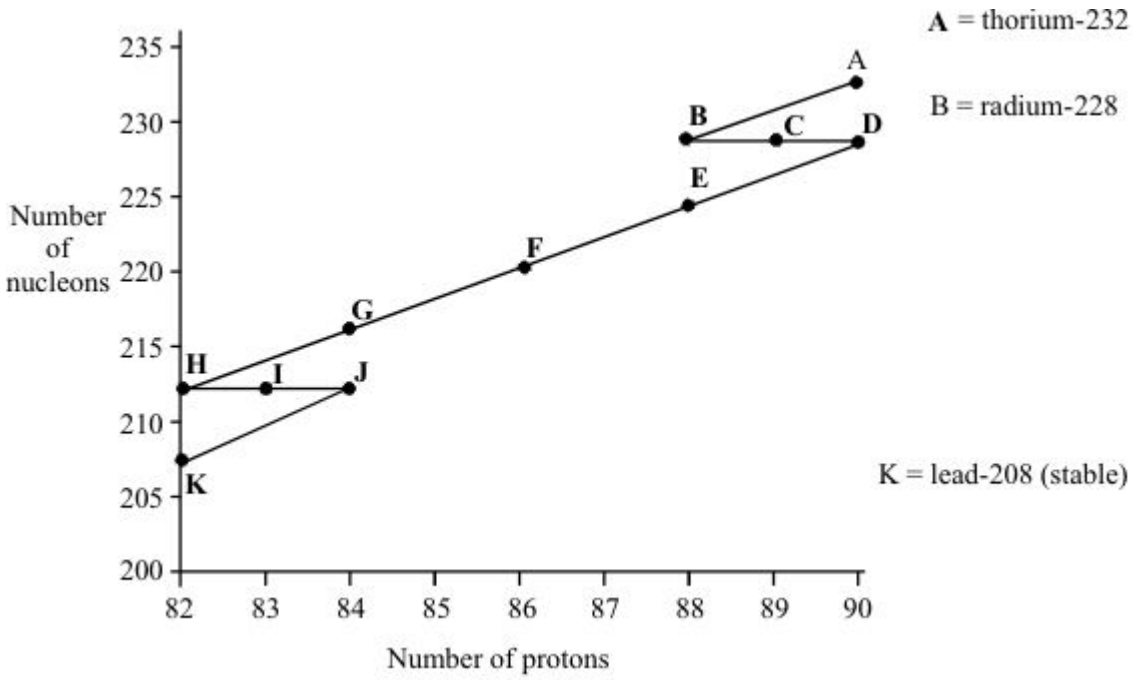
Complete the equation for this decay.

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

(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.

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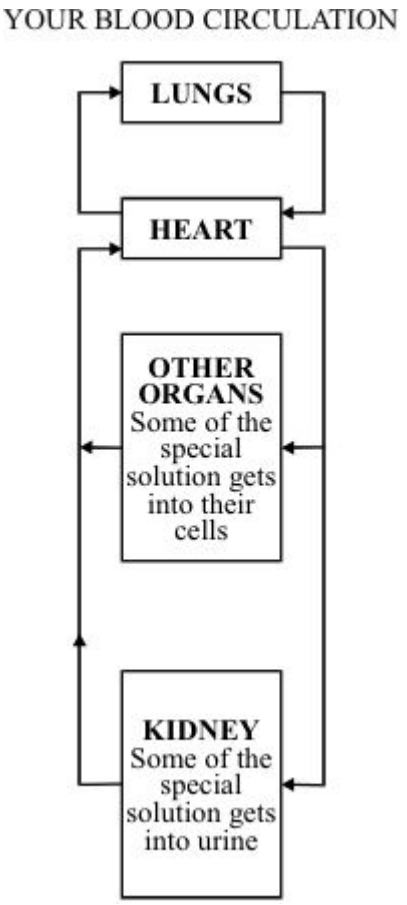
(3)
(Total 13 marks)

40 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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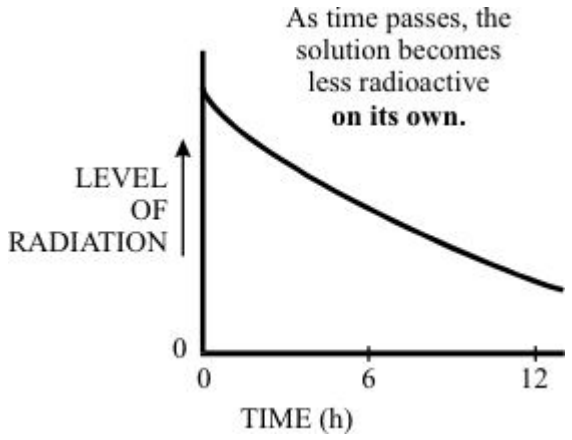
(4)



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.

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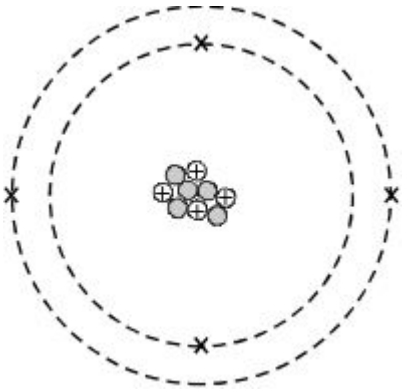
(2)
(Total 9 marks)

41 The diagram shows an atom.



How many protons are there in the nucleus of the atom? .....

What is the mass number of the atom? .....

(Total 2 marks)

42 (a) Sam and Kris are arguing about alpha and gamma radiation.

Sam says that alpha radiation is more dangerous.

Kris disagrees. He thinks that gamma radiation is more dangerous. What do you think? Explain your answer as fully as you can.

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(4)

(b) Cancer cells in a particular organ of the body can be killed by injecting a radioactive substance which is absorbed by that organ.

What other features must the radioactive substance have to make it suitable for this job?

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(2)

(c) Radon is a radioactive gas with a half-life of 3.6 days.
It often seeps into buildings from the ground.

Estimate how long it takes for 99% of a sample of radon gas to decay.
(Show your working.)

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(2)
(Total 8 marks)

43 Describe, in as much detail as you can, the life history of a star like our Sun.

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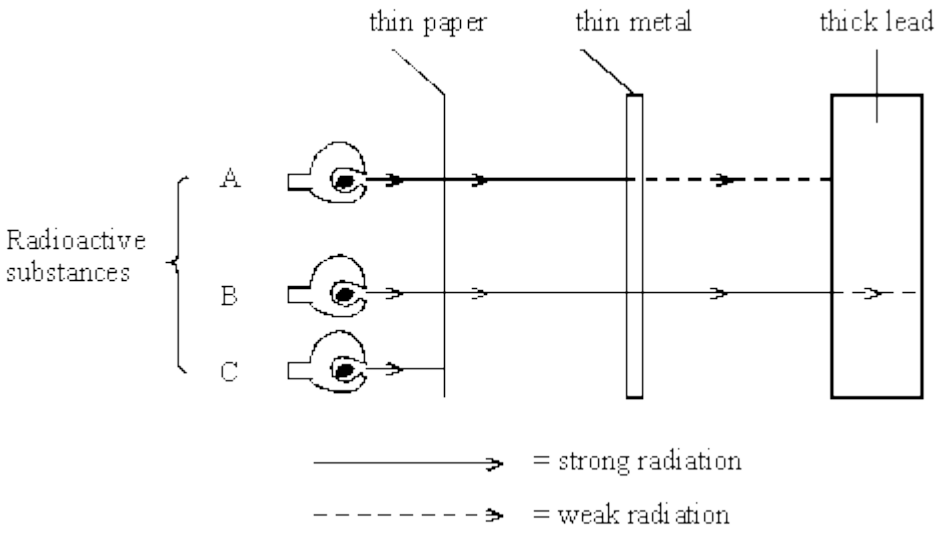
(Total 6 marks)

44 The diagram shows what happens to the radiation from three radioactive substances when different materials are put in the way.



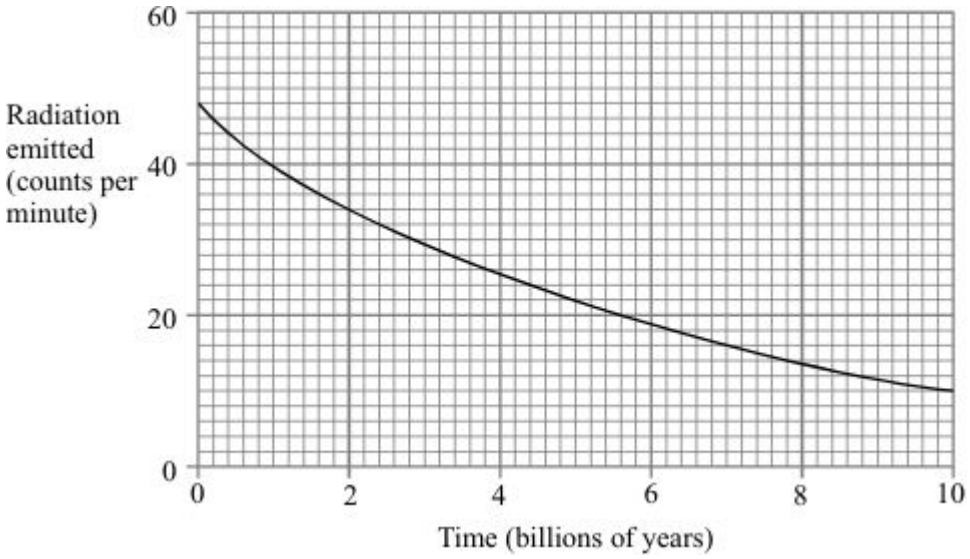
Choose types of radiation from this list to complete the table below.

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

RADIOACTIVE SUBSTANCE	TYPE OF RADIATION IT EMITS
A	
B	
C	

(Total 3 marks)

45 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.)

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Answer .....

(3)

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

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(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)

46 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?

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(2)
(Total 3 marks)