1 (a) Uranium atoms do not always have the same number of neutrons.
What are atoms of the same element that have different numbers of neutrons called?

.....

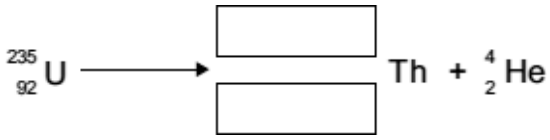
(1)

(b) By emitting an alpha particle, an atom of uranium-235 decays into an atom of thorium.

An alpha particle, which is the same as a helium nucleus, is represented by the symbol $^{4}_{2}He$.

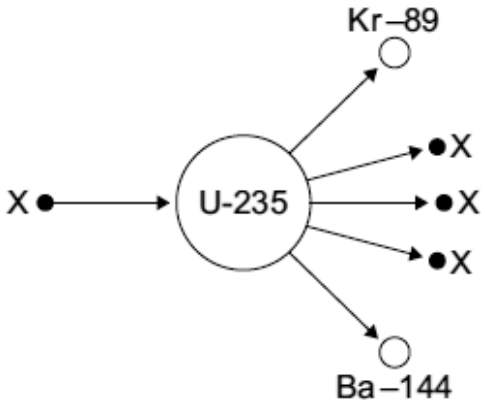
The decay can be represented by the equation below.

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



(2)

(c) The diagram shows an atom of uranium-235 being split into several pieces.



(i) Name the process shown in the diagram.

.....

(1)

(ii) Name the particles labelled **X**.

.....

(1)

(d) Uranium-235 is used as a fuel in some nuclear reactors.
Name another substance used as a fuel in some nuclear reactors.

.....

(1)
(Total 6 marks)

2 Every star goes through a 'life cycle'.

(a) Describe how a star forms.

.....

.....

.....

.....

.....

(2)

(b) During a long period of its life, a star remains in a stable state.

Explain why a star remains stable.

.....

.....

.....

.....

.....

(2)

(c) Some stars are much more massive than the Sun.

Describe what will happen to a star, originally much more massive than the Sun, after it reaches its red giant stage.

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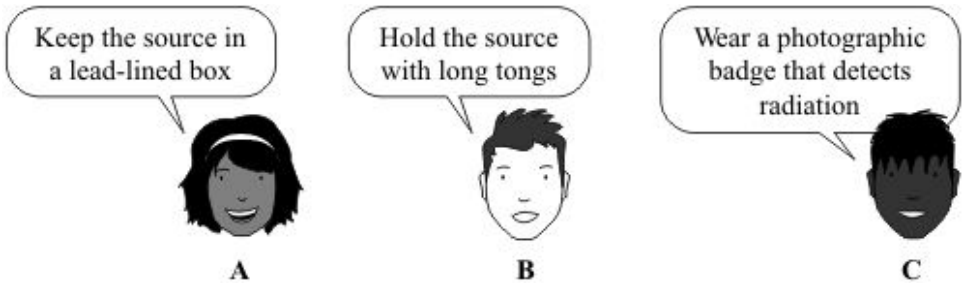
(2)
(Total 6 marks)

3 Before using a radioactive source, a teacher asked her students to suggest safety procedures that would reduce her exposure to the radiation. The students made the following

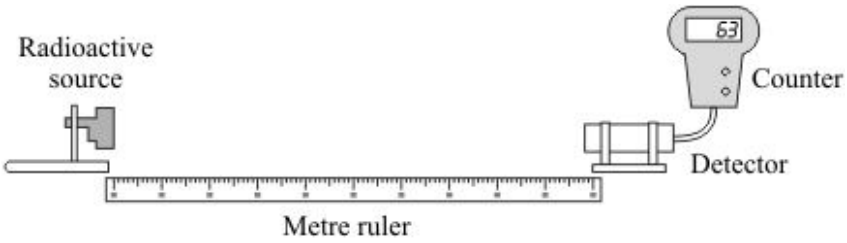


(a) Which suggestion, **A**, **B** or **C**, would **not** reduce the exposure of the teacher to radiation?

.....

(1)

(b) The diagram shows how the teacher measured the distance that the radiation traveled from the source. The count-rate at different distances from the source was measured and recorded in the table.



Distance from source to detector in cm	Count-rate in counts per minute
20	85
40	81
60	58
80	53
100	23

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

.....

Explain the reasons for your choice.

.....

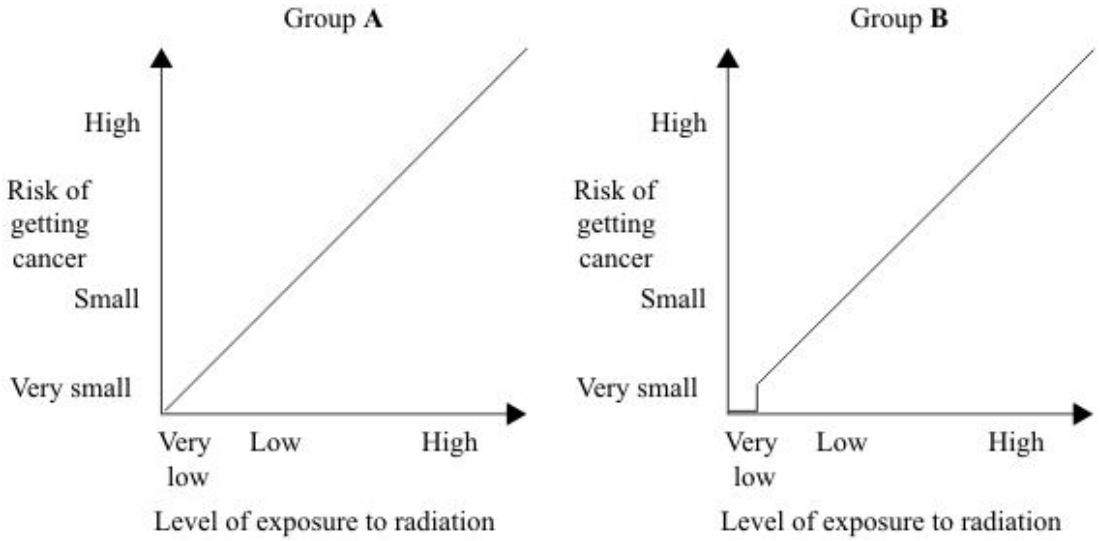
.....

.....

.....

(3)

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



(i) Complete the following sentence using a word or phrase from the box.

decreases	**has no effect on**	**increases**

Both groups of scientists agree that a high level of exposure to radiation

..... the risk of getting cancer.

(1)

(ii) Use the graphs to describe carefully how the two groups of scientists disagree when the level of exposure to radiation is very low.

.....

.....

.....

.....

(2)
(Total 7 marks)

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

(a) What is meant by the terms:

(i) *isotopes*

.....

.....

(1)

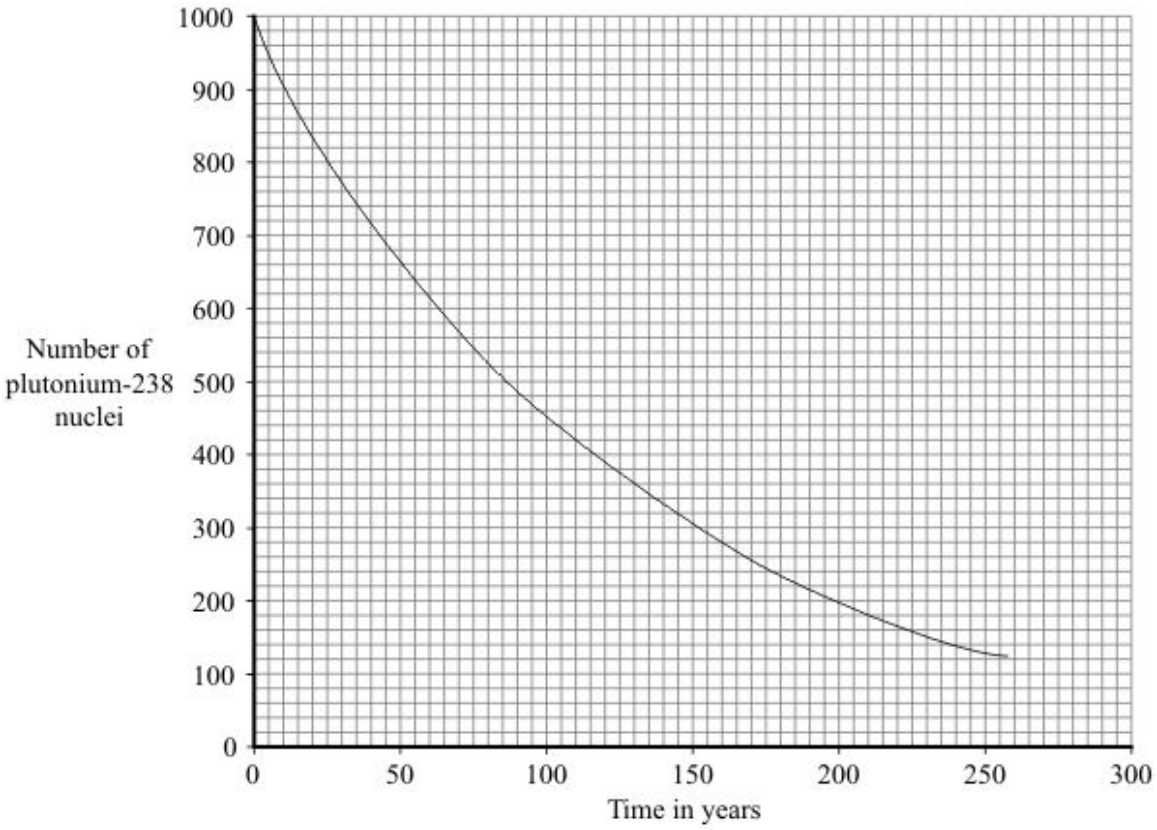
(ii) *radioactive*?

.....

.....

(1)

(b) The graph shows how the number of nuclei in a sample of the radioactive isotope plutonium-238 changes with time.



Use the graph to find the half-life of plutonium-238.

Show clearly on the graph how you obtain your answer.

Half-life = ... years

(2)

(c) The Cassini spacecraft launched in 1997 took seven years to reach Saturn.

The electricity to power the instruments on board the spacecraft is generated using the heat produced from the decay of plutonium-238.

(i) Plutonium-238 decays by emitting alpha particles.

What is an alpha particle?

.....

(1)

(ii) During the 11 years that Cassini will orbit Saturn, the output from the generators will decrease.

Explain why.

.....

.....

.....

.....

(2)

(d) Plutonium-238 is highly dangerous. A tiny amount taken into the body is enough to kill a human.

(i) Plutonium-238 is unlikely to cause any harm if it is outside the body but is likely to kill if it is inside the body.

Explain why.

.....

.....

.....

.....

(2)

(ii) In 1964, a satellite powered by plutonium-238 was destroyed, causing the release of radioactive material into the atmosphere.

Suggest why some environmental groups protested about the launch of Cassini.

.....

.....

(1)
(Total 10 marks)

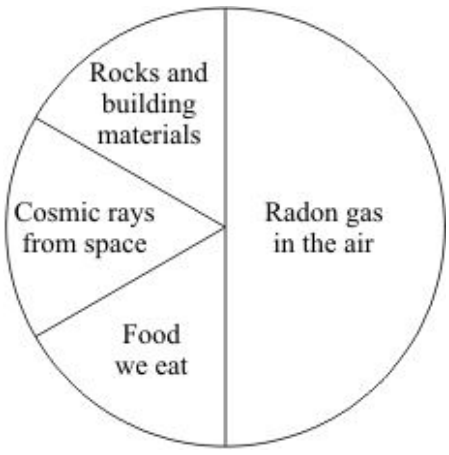
5 Four different processes are described in **List A**. The names of these processes are given in **List B**.

Draw a line to link each description in **List A** to its correct name in **List B**.
Draw only **four** lines.

List A	List B
the nuclei of two atoms joining together	gamma emission
the nucleus of an atom splitting into several pieces	electric current
an atom losing an electron	ionisation
an electric charge moving through a metal	nuclear fission
	nuclear fusion

(Total 4 marks)

6 (a) The pie chart shows the average proportions of natural background radiation from various sources in one part of the UK.



(i) What proportion of the background radiation comes from radon gas?

.....

(1)

(ii) Suggest why our bodies are slightly radioactive.

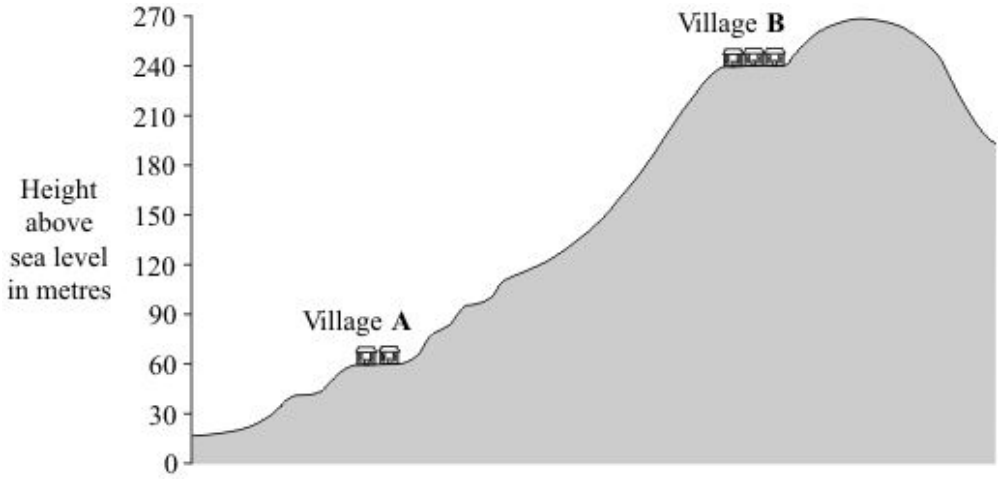
.....

.....

(1)

(b) The level of background radiation from cosmic rays is not the same everywhere. For every 30 metres above sea level, the amount of background radiation increases by one unit.

The diagram shows the position of two villages, **A** and **B**, built on a hill.



How is the amount of background radiation from cosmic rays different in village **A** compared to village **B**?

To obtain full marks you must include a calculation in your answer.

.....

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.....

.....

.....

.....

(3)
(Total 5 marks)

7 (a) Complete the following table for an atom of uranium-238 ($^{238}_{92}U$)

mass number	238
number of protons	92
number of neutrons	

(1)

(b) Complete the following sentence.

The name given to the number of protons in an atom is the proton number or the

..... .

(1)

(c) An atom of uranium-238 ($^{238}_{92}U$) decays to form an atom of thorium-234 ($^{234}_{90}Th$).

(i) What type of radiation, alpha, beta or gamma, is emitted by uranium-238?

.....

(1)

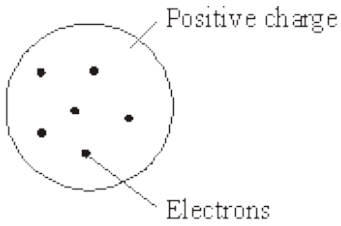
(ii) Why does an atom that decays by emitting alpha or beta radiation become an atom of a different element?

.....

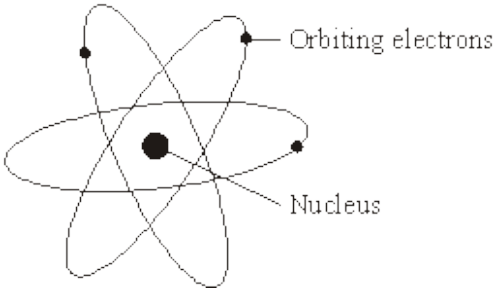
.....

(1)
(Total 4 marks)

8 In the early part of the 20th century, scientists used the 'plum pudding' model to explain the structure of the atom.



Following work by Rutherford and Marsden, a new model of the atom, called the 'nuclear' model, was suggested.



(a) Describe the differences between the two models of the atom.

.....

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.....

.....

.....

.....

.....

.....

(4)

(b) In their investigation, Rutherford and Marsden fired positively charged alpha particles at a very thin sheet of gold. Over a period of several months, the scientists made over 100 000 measurements. These measurements showed that:

- a very small number of alpha particles were deflected backwards from the gold foil.

Use the nuclear model to explain this experimental result.

.....

.....

.....

.....

(2)

(c) Why did the work of Rutherford and Marsden convince many scientists that the 'plum pudding' model of the atom was incorrect?

.....

.....

.....

.....

(2)
(Total 8 marks)

9 Read this statement from a website.

> Immediately after the 'big bang', at the start of the Universe, there were only atoms of the element hydrogen (H).
>
> Now the Universe contains atoms of over one hundred elements.

(a) Explain how atoms of the element helium (He) are formed in a star.

.....

.....

.....

.....

(2)

(b) Explain how atoms of very heavy elements, such as gold (Au), were formed.

.....

.....

.....

.....

(2)

(c) Explain how, and when, atoms of different elements may be distributed throughout the Universe.

.....

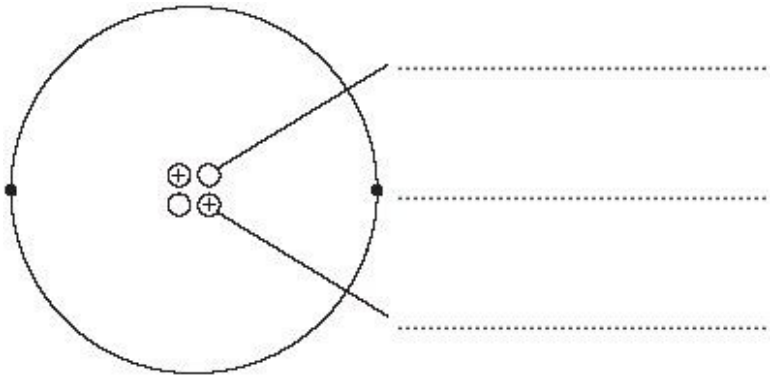
.....

.....

.....

(2)
(Total 6 marks)

10 The diagram shows a helium atom.



(a) (i) Use the words in the box to label the diagram.

electron	**neutron**	**proton**

(2)

(ii) An alpha particle is the same as the nucleus of a helium atom.

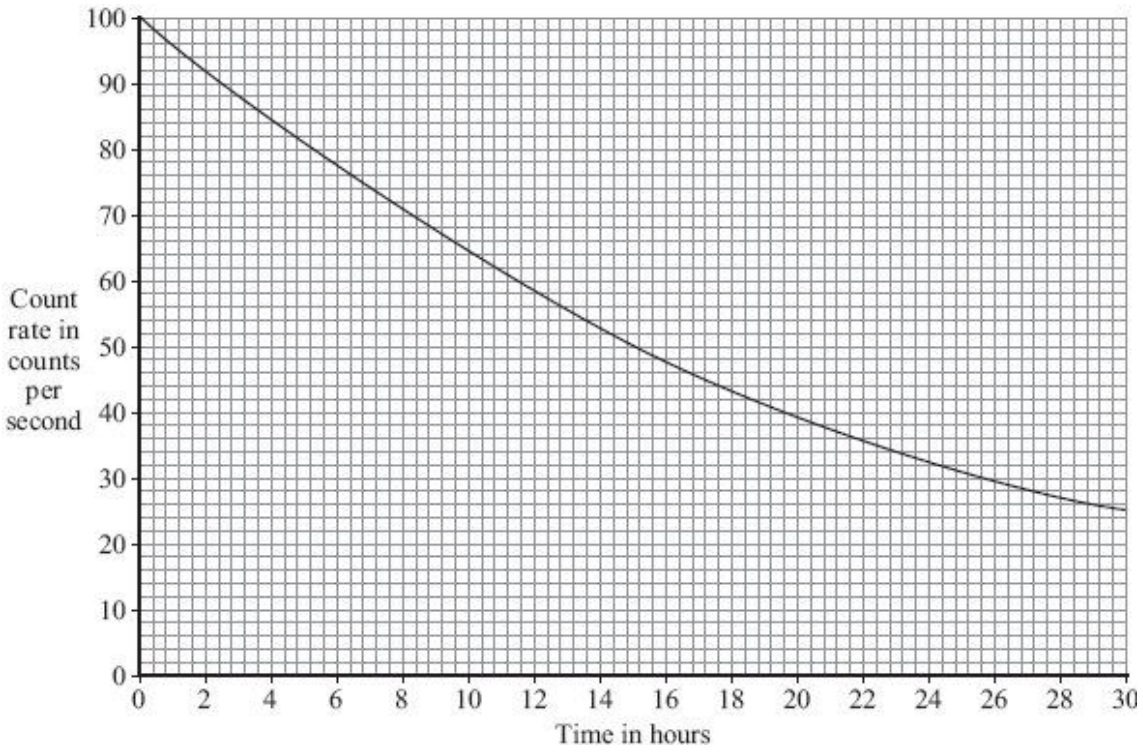
How is an alpha particle different from a helium atom?

.....

.....

(1)

(b) The graph shows how the count rate from a sample of radioactive sodium-24 changes with time.



(i) How many hours does it take for the count rate to fall from 100 counts per second to 50 counts per second?

Time = ... hours

(1)

(ii) What is the half-life of sodium-24?

Half-life = ... hours

(1)

(c) A smoke detector contains a small amount of americium-241.

Americium-241 is a radioactive substance which emits alpha particles. It has a half-life of 432 years.

(i) Which **one** of the following statements gives a reason why the americium-241 inside the smoke detector will **not** need replacing?

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

The alpha particles have a low energy. ☐

People replace smoke detectors every few years. ☐

Americium-241 has a long half-life. ☐

(1)

(ii) The diagram shows the label on the back of the smoke detector.

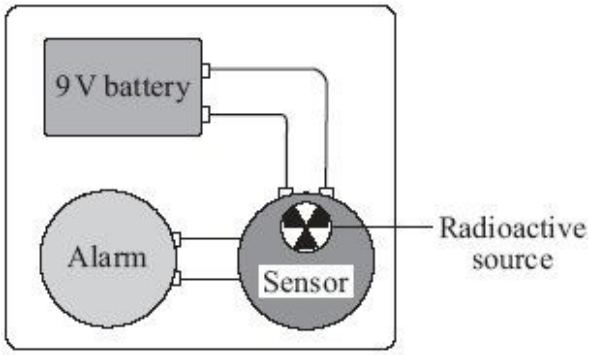
Why do people need to know that the smoke detector contains a radioactive material?

.....

.....

(1)
(Total 7 marks)

11 (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.

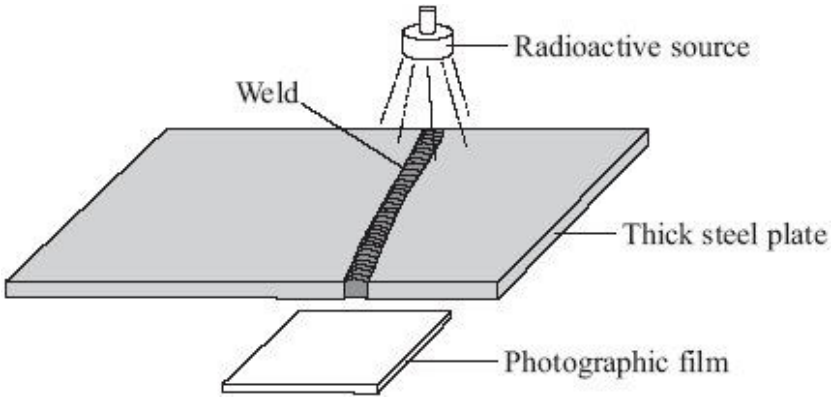
How is an atom of curium-242 different from an atom of curium-244?

.....

.....

(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.

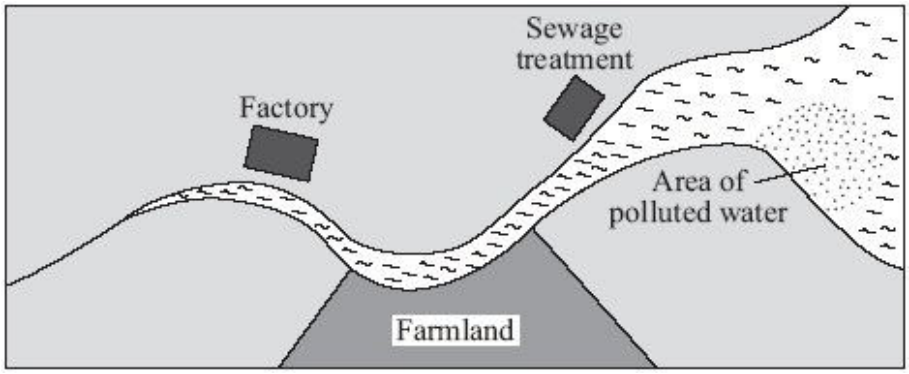
.....

.....

(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.

.....

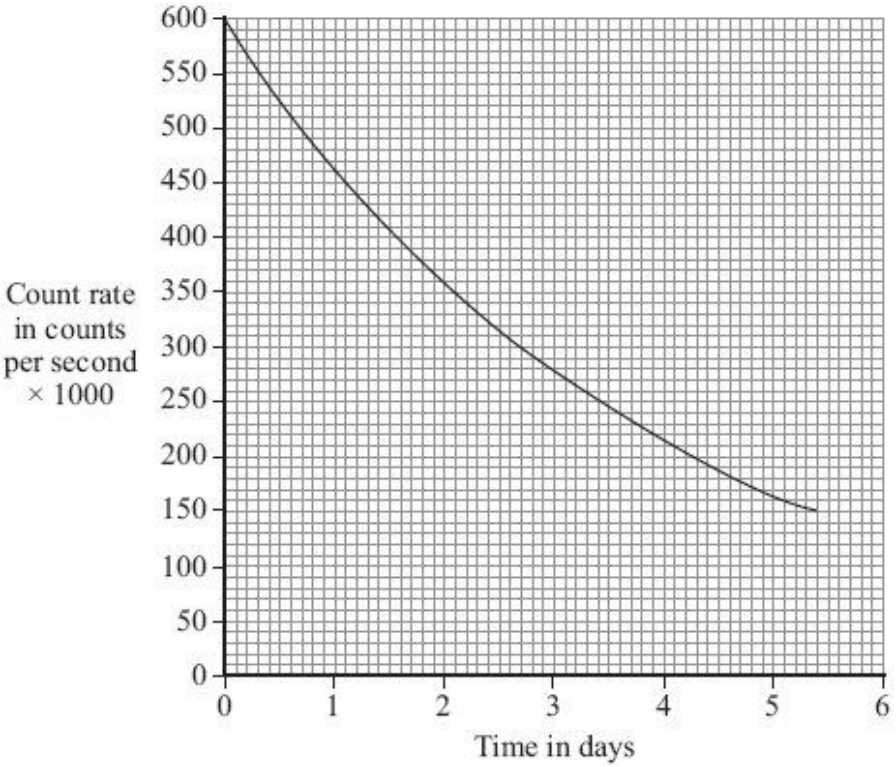
.....

.....

.....

(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)

12 The table gives information about the three types of particle that make up an atom.

Particle	Relative mass	Relative charge
Proton		+1
Neutron	1	
Electron	very small	–1

(a) Complete the table by adding the **two** missing values.

(2)

(b) Use the information in the table to explain why an atom has no overall electrical charge.

.....

.....

.....

.....

(2)

(c) Uranium has two natural isotopes, uranium-235 and uranium-238.
Uranium-235 is used as a fuel inside a nuclear reactor.
Inside the reactor, atoms of uranium-235 are split and energy is released.

(i) How is the structure of an atom of uranium-235 different from the structure of an atom of uranium-238?

.....

.....

(1)

(ii) The nucleus of a uranium-235 atom must absorb a particle before the atom is able to split.

What type of particle is absorbed?

.....

(1)

(iii) The nucleus of an atom splits into smaller parts in a reactor.

What name is given to this process?

.....

(1)
(Total 7 marks)

13 This passage is from a science magazine.

> *A star forms when enough dust and gas are pulled together. Masses smaller than a star may also be formed when dust and gas are pulled together.*

(a) What is the force which pulls the dust and gas together?

.....

(1)

(b) Complete the sentences.

(i) The smaller masses may be attracted by the star and become

..... .

(1)

(ii) Our nearest star, the Sun, is stable because the gravitational forces

and the radiation pressure are ..... .

(1)

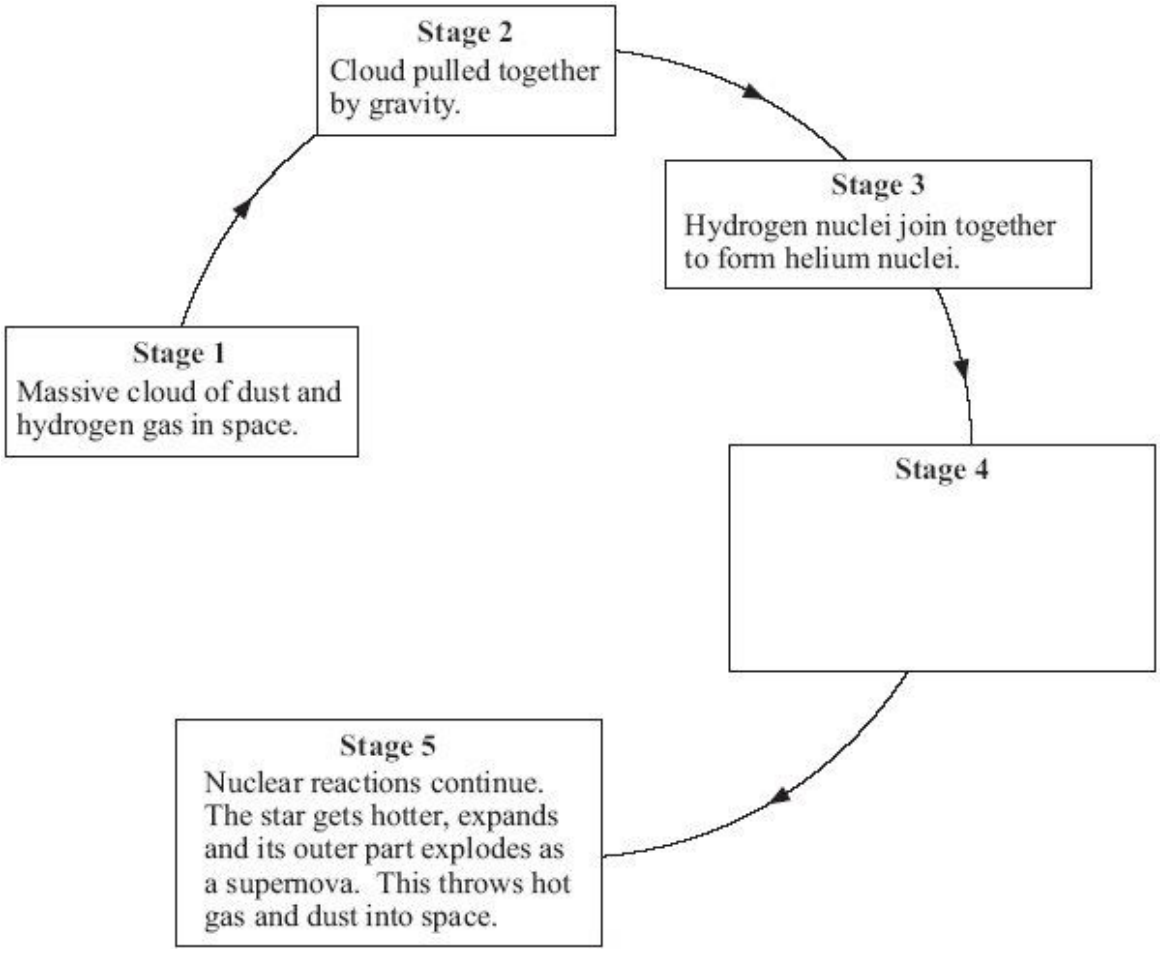
(iii) The Sun is one of billions of stars in the galaxy called the

..... .

(1)

(Total 4 marks)

14 The diagram shows part of the life cycle of a star which is much bigger than the Sun.



(a) (i) What is the relationship between the masses of the dust and gas in the cloud in **Stage 2** and the force of gravity between them?

.....

.....

(1)

(ii) What is the relationship between the distance apart of the dust and gas in the cloud in **Stage 2** and the force of gravity between them?

.....

.....

(1)

(b) In **Stage 3** the star remains stable for millions of years.

Explain why.

.....

.....

.....

.....

.....

(2)

(c) What happens in **Stage 4**?

.....

.....

.....

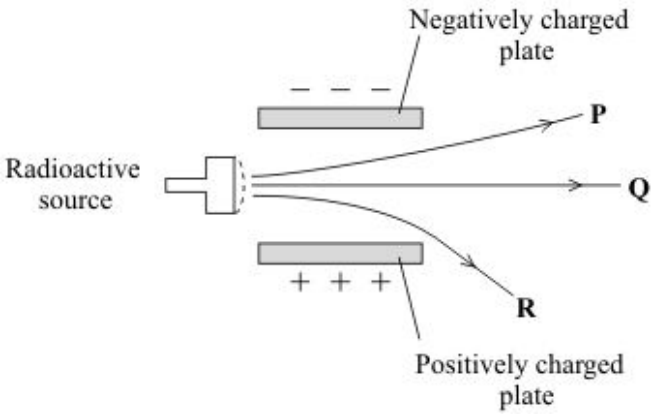
.....

.....

(2)
(Total 6 marks)

15 A radioactive source emits alpha (α), beta (β) and gamma (γ) radiation. The diagram shows what happens to the radiation as it passes between two charged metal plates.

Diagram 1



(a) Which line **P**, **Q** or **R** shows the path taken by:

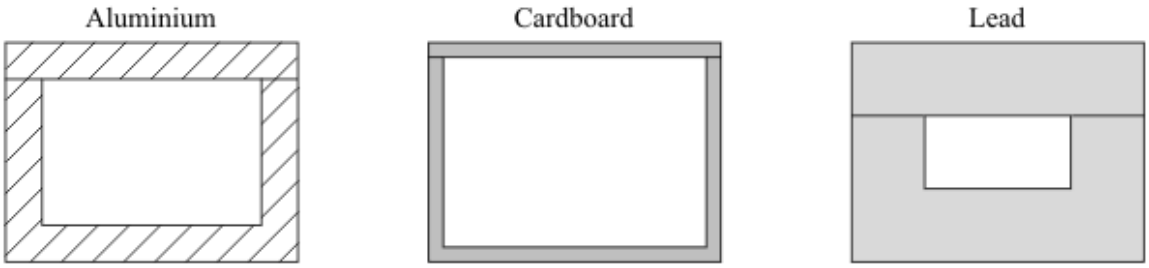
(i) alpha radiation .....

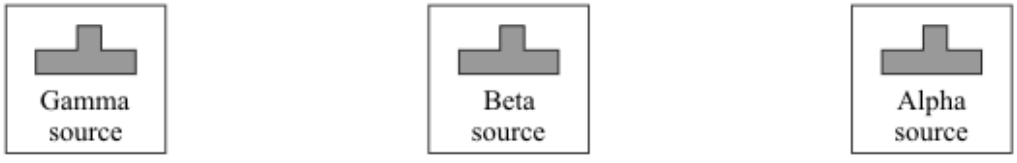
(1)

(ii) gamma radiation? .....

(1)

(b) The diagram shows three different boxes and three radioactive sources. Each source emits only one type of radiation and is stored in a different box. The box reduces the amount of radiation getting into the air.

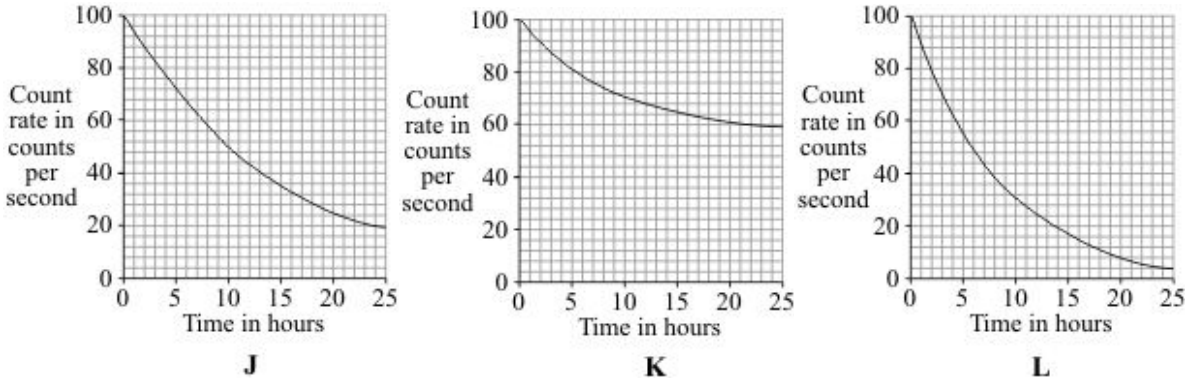




Draw **three** lines to show which source should be stored in which box so that the minimum amount of radiation gets into the air.

(2)

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



(i) Which source, **J, K**, or **L**, has the highest count rate after 24 hours?

.....

(1)

(ii) For source **L**, what is the count rate after 5 hours?

..... counts per second

(1)

(iii) Which source, **J, K,** or **L**, has the longest half-life?

.....

(1)

(iv) A radioactive source has a half-life of 6 hours.

What might this source be used for?

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

To monitor the thickness of paper as it is made in a factory ☐

To inject into a person as a medical tracer ☐

To make a smoke alarm work ☐

(1)

(Total 8 marks)

16 (a) A radioactive source emits alpha (α), beta (β) and gamma (γ) radiation.

(i) Which **two** types of radiation will pass through a sheet of card?

.....

(1)

(ii) Which **two** types of radiation would be deflected by an electric field?

.....

(1)

(iii) Which type of radiation has the greatest range in air?

.....

(1)

(b) A student suggests that the radioactive source should be stored in a freezer at – 20 °C. The student thinks that this would reduce the radiation emitted from the source.

Suggest why the student is wrong.

.....

.....

(1)

(c) Phosphorus-32 is a radioactive isotope that emits beta radiation.

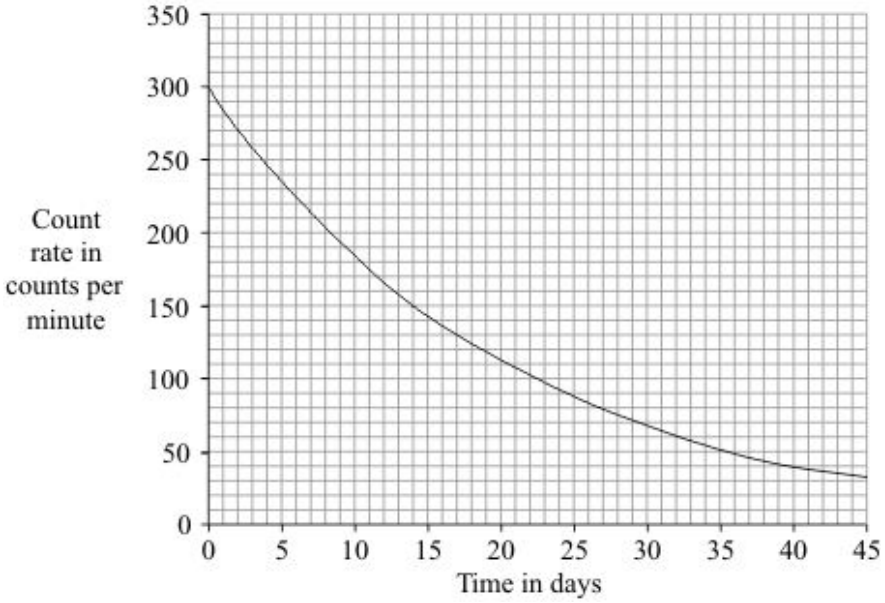
(i) How is an atom of phosphorus-32 different from an atom of the stable isotope phosphorus-31?

.....

.....

(1)

(ii) The graph shows how the count rate of a sample of phosphorus-32 changes with time.



Use the graph to calculate the half-life of phosphorus-32.

Show clearly how you used the graph to obtain your answer.

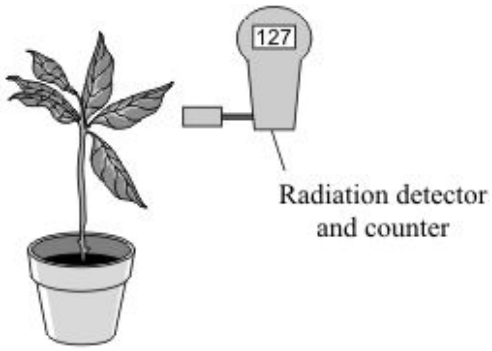
.....

.....

Half-life = ... days

(2)

(iii) Plants use phosphorus compounds to grow. Watering the root system of a plant with a solution containing a phosphorus-32 compound can help scientists to understand the growth process.



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

.....

.....

.....

.....

(2)
(Total 9 marks)

17 The table shows the average background radiation dose from various sources that a person living in Britain receives in one year.

Source of background radiation	Average amount each year in dose units
Buildings	50
Food anddrink	300
Medicaltreatments (including X-rays)	300
Radon gas	1250
Rocks	360
Space(cosmic rays)	240
TOTAL	2500

(a) Only **two** of the following statements are true.

Tick (✓) the boxes next to the true statements.

Half the average background radiation dose comes from radon gas.	☐
Everyone receives the same background radiation dose.	☐
Cosmic rays produce less background radiation than food and drink.	☐

(1)

(b) Most sources of background radiation are natural but some are artificial (man-made).

Which source of background radiation given in the table is artificial?

.....

(1)

(c) Each time a dental X-ray is taken, the patient receives about 20 units of radiation.

How many dental X-rays would give the yearly average dose for medical treatments?

.....

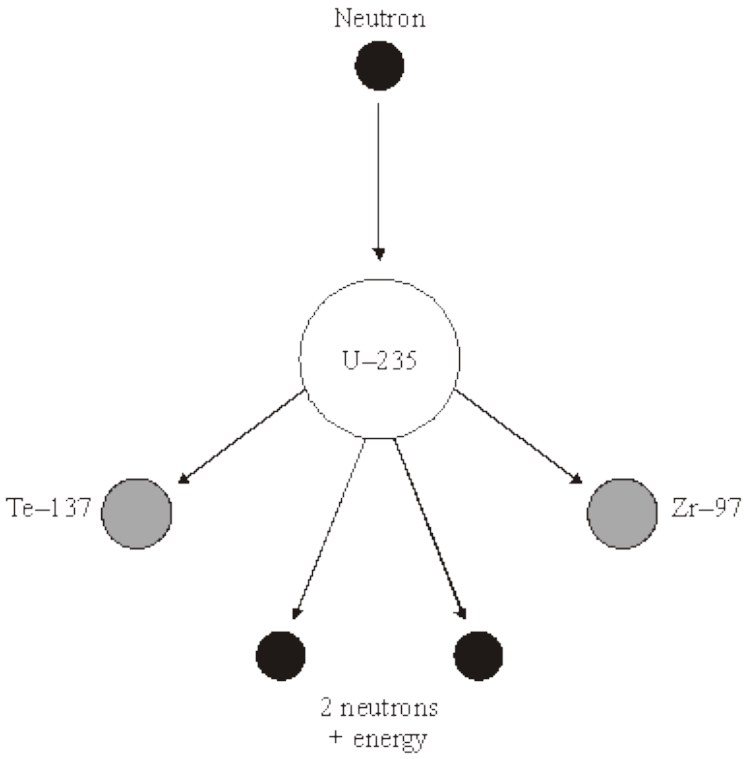
.....

Number of X-rays = ...

(2)

(Total 4 marks)

18 (a) The diagram shows what can happen when the nucleus of a uranium atom absorbs a neutron.



(i) What name is given to the process shown in the diagram?

.....

(1)

(ii) Explain how this process could lead to a chain reaction.

You may wish to add further detail to the diagram to help your answer.

.....

.....

.....

.....

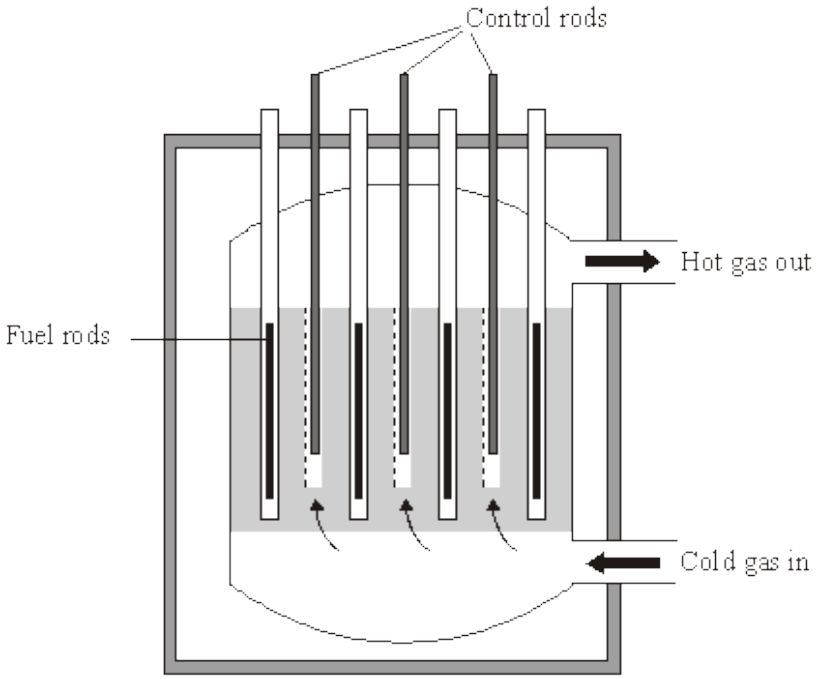
(2)

(iii) How does the mass number of an atom change when its nucleus absorbs a neutron?

.....

(1)

(b) Uranium-235 is used as a fuel in some nuclear reactors.



Source: adapted from 'Physics Matters', by Nick England. Published by Hodder and Stoughton, 1989. Reproduced by permission of Hodder and Stoughton Ltd.

The reactor contains control rods used to absorb neutrons.

Suggest what happens when the control rods are lowered into the reactor.

.....

.....

.....

.....

(2)
(Total 6 marks)

19 Read the passage.

> In the SolarSystem, the inner planets, such as the Earth, contain elements which are eavierthan the elements hydrogen and helium.
>
> Our star,the Sun, is a medium sized star. If a star is much more massive than the Sunit will eventually swell into a red giant, start to contract, continue tocontract and finally explode.

(a) What is the explosion called?

.....

(1)

(b) Explain why scientists believe that the Solar System was formed from the material produced when earlier stars exploded.

.....

.....

.....

.....

.....

.....

(3)
(Total 4 marks)

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

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

List A Type of nuclear radiation	**List B** Property of radiation
alpha	not deflected by an electric field
beta	stopped by thin metal but not paper
gamma	the most strongly ionising
	will not harm living cells

(3)

(b) Nuclear radiation is given out from the centre of some types of atom.

What name is given to the centre of an atom? .....

(1)

(c) One of the substances in the table is used as a radioactive tracer. A hospital patient breathes in air containing the tracer. The radiation given out is measured by a doctor using a detector outside the patient's body.

Substance	Radiation given out	Solid, liquid or gas
X	alpha	gas
Y	gamma	gas
Z	gamma	solid

Which **one** of the substances, **X**, **Y** or **Z**, should be used as the tracer? .....

Give **two** reasons for your answer.

1 .....

.....

2 .....

.....

(3)

(d) Radiation can also be used to kill the bacteria on fresh food.

Give **one** reason why farmers, shop owners or consumers may want food to be treated with radiation.

.....

.....

(1)
(Total 8 marks)

21 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.

.....

.....

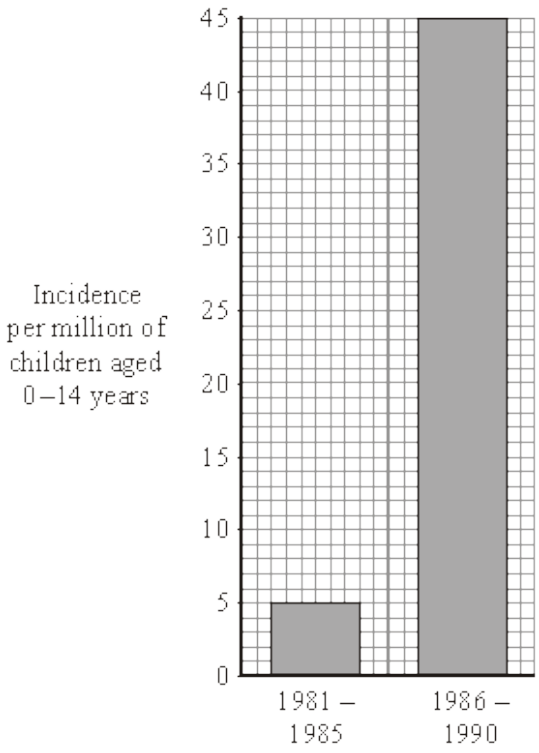
.....

.....

.....

(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)

22 (a) The table gives information about the radioactive isotope, radon-222.

mass number	222
atomic number	86
radiation emitted	alpha particle

(i) Complete the following sentence.

The mass number is the total number of ..... and

..... inside an atom.

(2)

(ii) Radon-222 is an isotope of radon.

How many protons are there in an atom of radon-222?

.....

(1)

(iii) When an atom of radon-222 emits an alpha particle, the radon-222 changes into an atom of polonium-218.

An alpha particle consists of 2 protons and 2 neutrons.

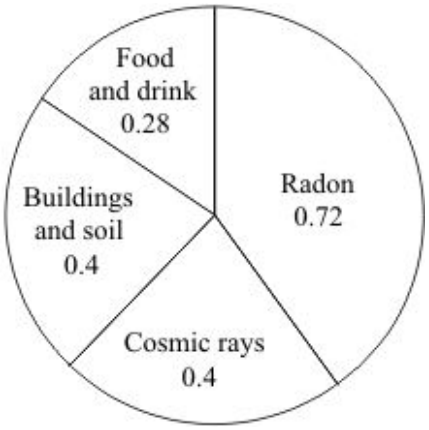
How is the structure of the nucleus of a polonium-218 atom different from the structure of the nucleus of a radon-222 atom?

.....

(1)

(b) The pie chart shows the average radiation dose that a person in the UK receives each year from natural background radiation.

The doses are measured in millisieverts (mSv).



(i) Calculate the proportion of natural background radiation that comes from radon.
Show clearly how you work out your answer.

.....

.....

Proportion of radon = ...

(2)

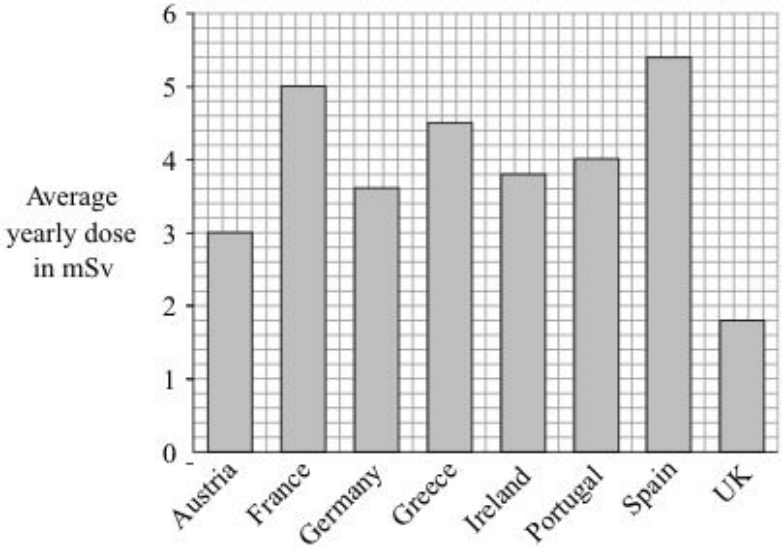
(ii) Not all background radiation is from natural sources.

Name **one** source of background radiation that is not natural.

.....

(1)

(c) The bar chart shows the average yearly dose from natural background radiation in different European countries.



(i) How many times bigger is the average annual background dose in Germany compared to the UK?

.....

(1)

(ii) The following table gives the effects of different radiation doses on the human body.

Radiation dose in mSv	Effects
10 000	Immediate illness; death within a few weeks
1 000	Radiation sickness; unlikely to cause death
50	Lowest dose with evidence of causing cancer

A family goes to Germany for a two-week holiday. Should they be concerned about the higher level of background radiation in Germany?

Draw a ring around your answer.

Yes **No**

Explain your answer.

.....

.....

.....

.....

(2)

(Total 10 marks)

23 (a) Complete the **two** spaces in the sentence.

Stars form when enough ..... and gas from ..... are pulled together by gravitational attraction.

(2)

(b) How are stars able to give out energy for millions of years?

Put a tick (✓) next to the answer.

By atoms joining together ☐

By atoms splitting apart ☐

By burning gases ☐

(1)

(c) There are many billions of stars in our galaxy. Our Sun is one of these stars. What is the name of our galaxy?

.....

(1)

(d)

Why was the Universe created?

We cannot expect scientists to answer this question. What is the reason for this?

Put a tick (✓) next to the reason.

It will take too long to collect the scientific evidence. ☐

The answer depends on beliefs and opinions, not scientific evidence. ☐

There is not enough scientific evidence. ☐

(1)

(Total 5 marks)

24 The statement in the box is from an article in a science magazine.

Scientists think that all the elements on Earth are also present throughout the Universe.

(a) (i) Name the process by which these elements were formed.

.....

(1)

(ii) Where did the elements form?

.....

(1)

(iii) What caused these elements to be distributed throughout the Universe?

.....

(1)

(b) Scientists have only examined a tiny fraction of the Universe. What is the basis for the statement in the science magazine?

.....

.....

(1)

(Total 4 marks)

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

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

List A **Type of radiation**	**List B** **Property of radiation**
	not dangerous
alpha (α)	
	stopped by paper
beta (β)	
	travels at 300 000 000 m/s
gamma (γ)	
	travels up to 1 metre in air

(3)

(b) This sign warns people that a radioactive source is being used in a laboratory.

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

.....

.....

(1)

(c) To study the blood flow in a patient's lungs, a doctor injects some technetium-99 compound into the patient. The gamma radiation given out by the technetium-99 atoms is detected using a gamma camera outside the patient's body.

Which statement gives the reason why gamma radiation is used? Put a tick (✓) in the box next to your choice.

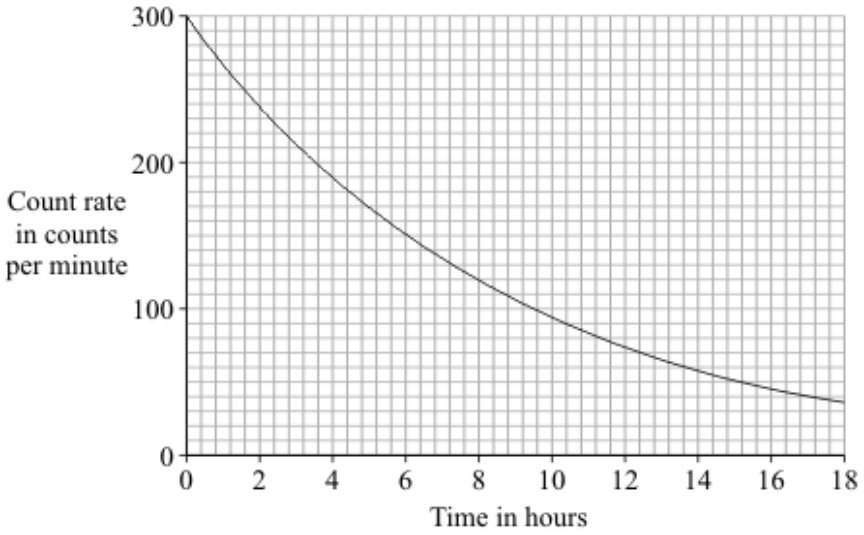
It can travel through a vacuum. ☐

It is not affected by a magnet. ☐

It can pass through the human body. ☐

(1)

(d) The graph shows how the count rate from a sample of technetium-99 changes with time.



26 (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?

.....

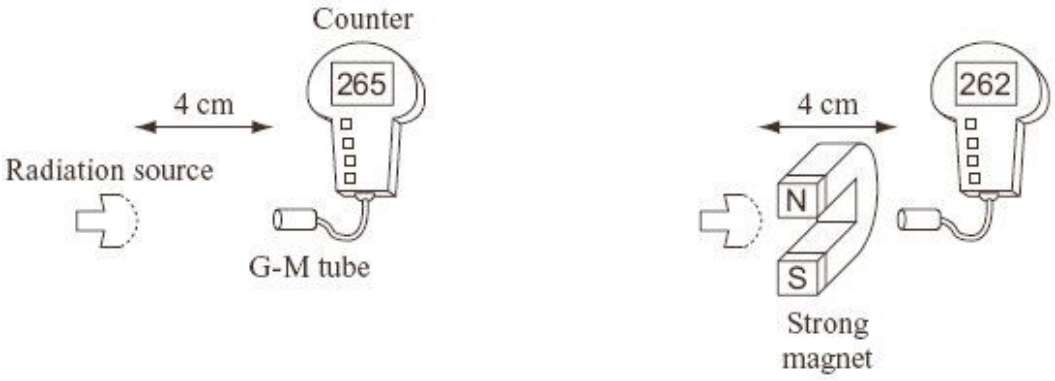
(1)

(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.

.....

.....

.....

.....

(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.

.....

.....

.....

.....

(2)
(Total 7 marks)

27 Some types of food are treated with *gamma* radiation. Low doses of radiation slow down the ripening of fresh fruit and vegetables while higher doses of radiation kill the bacteria that make the food go off.

(a) (i) What is *gamma* radiation?

.....

(1)

(ii) Food packed in crates or boxes can be treated using this method.

Why must a source that emits *gamma* radiation be used?

.....

.....

(1)

(iii) A suitable source of gamma radiation is the isotope caesium 137.

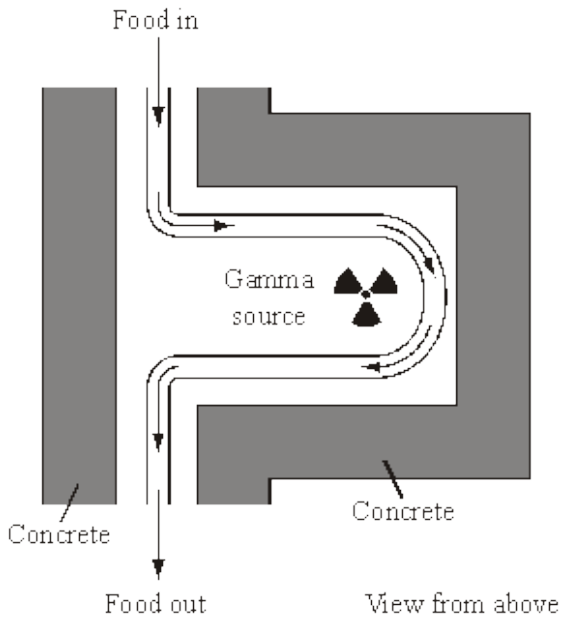
Complete the following sentence by choosing the correct word from the box.

electrons	**neutrons**	**protons**

An atom of caesium 137 has two more ..... than an atom of caesium 135.

(1)

(b) The diagram shows how a conveyor belt can be used to move food past the radioactive source.



(i) How do the concrete walls reduce the radiation hazard to workers outside the food treatment area?

.....

.....

(1)

(ii) Suggest **one** way that the dose of radiation received by the food could be increased other than by changing the radioactive source.

.....

.....

(1)

(c) Some people may not like the idea of eating food treated with radiation.

(i) What evidence could a food scientist produce to show that food treated with radiation is safe to eat?

.....

.....

.....

.....

(2)

(ii) The diagram shows the sign displayed on food treated with radiation.

Why is it important for people to know which foods have been treated with radiation?

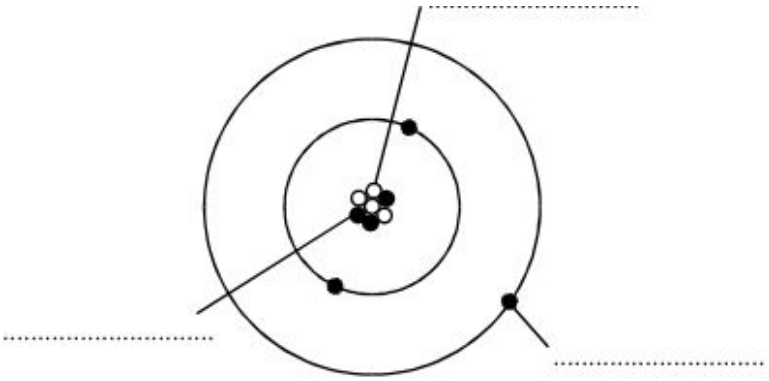
.....

.....

(1)

(Total 8 marks)

28 The diagram represents an atom of lithium.



(i) Complete the diagram by writing in the spaces the name of each type of particle. Use only words given in the box. Each word may be used once or not at all.

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

(3)

(ii) Which type of particle found inside the atom is uncharged?

.....

(1)

(iii) What is the mass number of this atom, 3, 4, 7 or 10?

.....

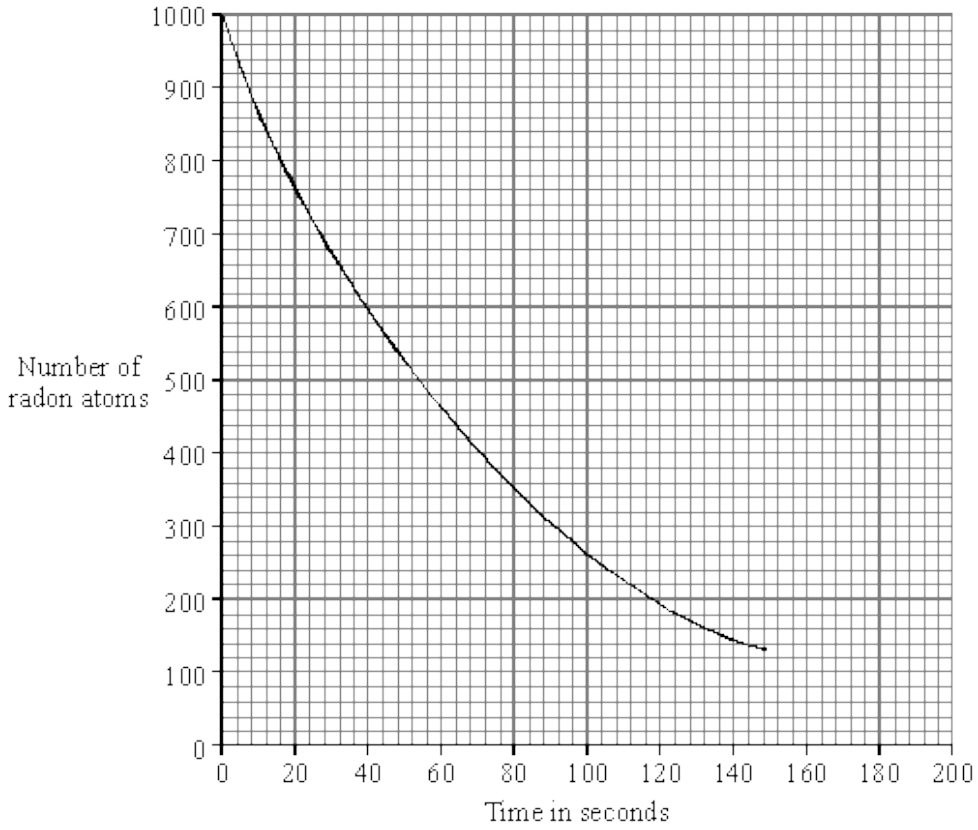
Give a reason for your choice.

.....

.....

(2)
(Total 6 marks)

29 Radon is a radioactive element. The graph shows how the number of radon atoms in a sample of air changes with time.



(i) How long did it take the number of radon atoms in the sample of air to fall from 1000 to 500?

Time = ... seconds

(1)

(ii) How long is the half-life of radon?

Half-life = ... seconds

(1)

(iii) Complete this sentence by crossing out the **two** lines in the box that are wrong.

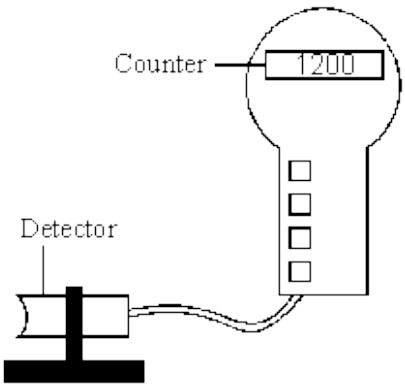
As a radioactive material gets older, it emits

less
a constant level of
more

radiation per second.

(1)
(Total 3 marks)

30 The diagram shows a radiation detector and counter being used to measure background radiation. The number shows the count ten minutes after the counter was reset to zero.



(i) Name **one** source of background radiation.

.....

(1)

(ii) Calculate the average background radiation level, in counts per second. Show clearly how you work out your answer.

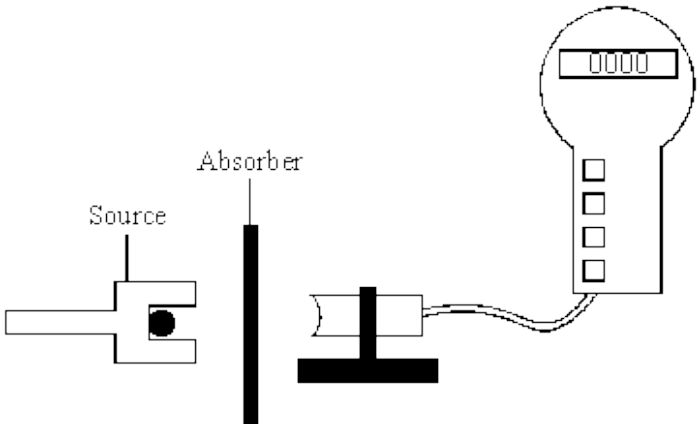
.....

.....

Background radiation level = ... counts per second

(2)
(Total 3 marks)

31 The detector and counter are used in an experiment to show that a radioactive source gives out alpha and beta radiation only.



Two different types of absorber are placed one at a time between the detector and the source. For each absorber, a count is taken over ten minutes and the average number of counts per second worked out. The results are shown in the table.

Absorber used	Average counts per second
No absorber	33
Card 1 mm thick	20
Metal 3 mm thick	2

Explain how these results show that alpha and beta radiation is being given out, but gamma radiation is **not** being given out.

.....

.....

.....

.....

.....

.....

(Total 3 marks)

32 *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.*

Explain briefly how stars like the Sun are thought to have been formed.

.....

.....

.....

.....

(Total 2 marks)

33 (a) The table gives information about six radioactive isotopes.

Isotope	Type of radiation emitted	Half-life
hydrogen-3	beta particle	12 years
iridium-192	gamma ray	74 days
polonium-210	alpha particle	138 days
polonium-213	alpha particle	less than 1 second
technetium-99	gamma ray	6 days
uranium-239	beta particle	24 minutes

(i) What is an alpha particle?

.....

(1)

(ii) Two isotopes of polonium are given in the table. How do the nuclei of these two isotopes differ?

.....

(1)

(iii) A doctor needs to monitor the blood flow through a patient's heart. The doctor injects a radioactive isotope into the patient's bloodstream. The radiation emitted by the isotope is then detected outside the body.

Which **one** of the isotopes in the table would the doctor inject into the bloodstream?

.....

Explain the reasons for your choice.

.....

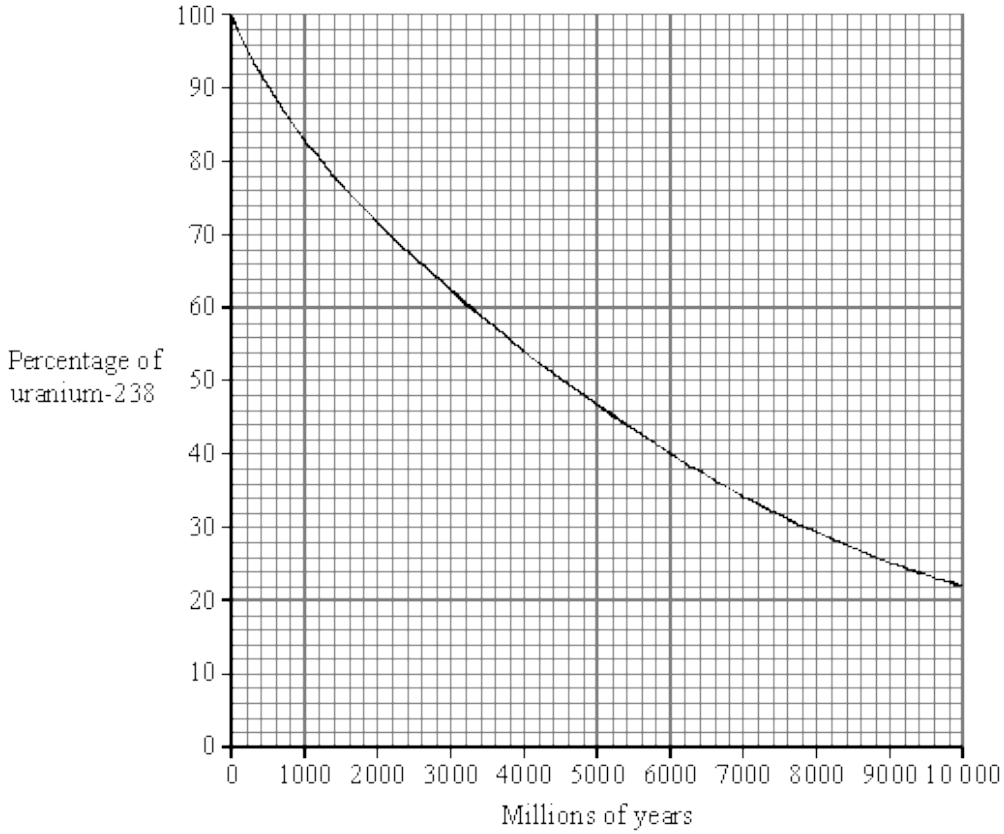
.....

.....

.....

(3)

(b) Igneous rock contains uranium-238 which eventually changes to the stable isotope lead-206. The graph shows how the percentage of uranium-238 nuclei present in an igneous rock changes with time.



A rock sample is found to have seven atoms of uranium-238 for every three atoms of lead-206. Use the graph to estimate the age of the rock. Show clearly how you obtain your answer.

.....

.....

Age of rock = ... million years

(2)

(Total 7 marks)

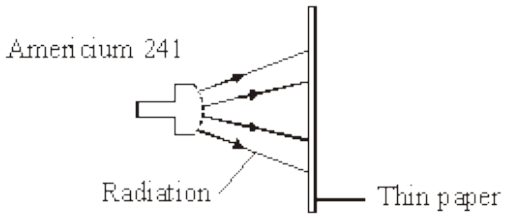
34 A smoke detector fitted inside a house contains a radioactive source, americium 241.

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

Number ofneutrons	146
Number ofprotons	95
Number ofelectrons	

(1)

(b) The diagram shows that the radiation given out by americium 241 does not go through paper.



Which type of radiation, alpha (α), beta (β), or gamma (γ) is given out by americium 241?

.....

(1)

(c) Explain why the radiation given out by the americium 241 is unlikely to do any harm to people living in the house.

.....

.....

.....

.....

(2)

(d) Complete the sentence by choosing an answer from the box.

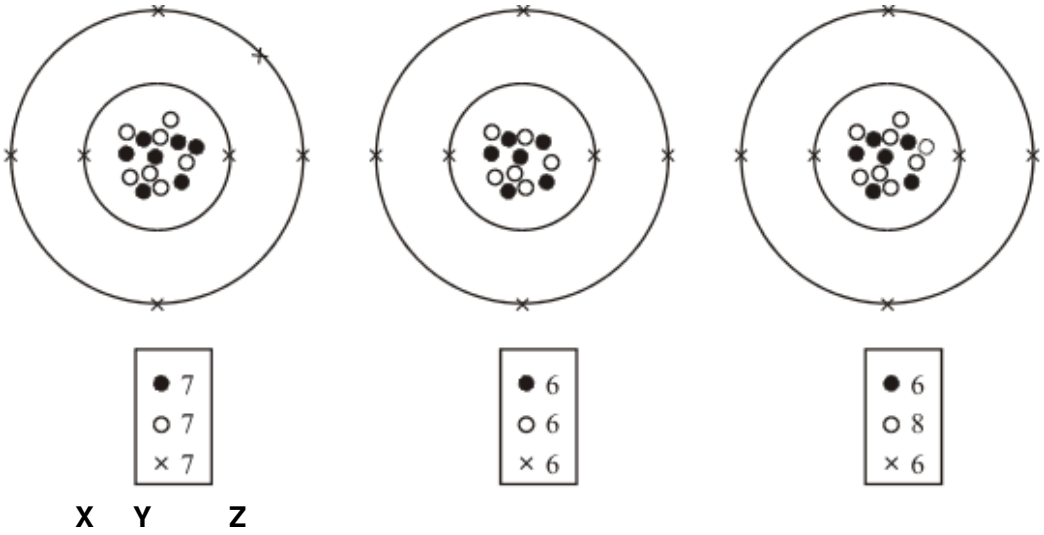
less than	more than	the same as

After many years the radiation emitted by americium 241 will be .....

when the smoke detector was new.

(1)
(Total 5 marks)

35 (a) The diagrams represent three atoms **X**, **Y** and **Z**.



X **Y** **Z**

Which **two** of the atoms are from the same element?

.....

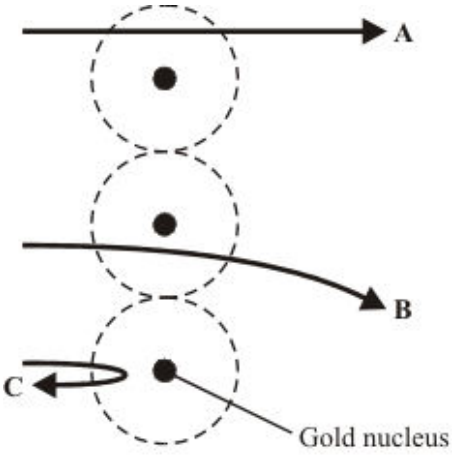
Give a reason for your answer.

.....

.....

(2)

(b) In the early part of the 20th century some scientists investigated the paths taken by positively charged alpha particles into and out of a very thin piece of gold foil. The diagram shows the paths of three alpha particles.



Explain the different paths **A**, **B** and **C** of the alpha particles.

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.

.....

.....

.....

.....

.....

(3)
(Total 5 marks)

36 (a) Nuclear power stations use the energy released by *nuclear fission* to generate electricity.

(i) Explain what is meant by *nuclear fission*.

.....

.....

.....

(2)

(ii) How does nuclear fission lead to a chain reaction?

You may give your answer as a labelled diagram.

.....

.....

(1)

(b) Although nuclear fuels are relatively cheap the total cost of generating electricity using nuclear fuels is expensive. Why?

.....

.....

(1)

(c) The table compares the energy released from 1 kg of coal and 1 kg of uranium.

Coal	29 MJ
Uranium	580 000 MJ

1 MJ = 1 000 000 joules

State **one** benefit to the environment of using a concentrated fuel like uranium to generate electricity rather than using the energy from coal.

.....

.....

(1)
(Total 5 marks)

37 (a) Explain how stars produce energy.

.....

.....

.....

.....

(2)

(b) What evidence is there to suggest that the Sun was formed from the material produced when an earlier star exploded?

.....

.....

(1)

(c) It is thought that gases from the massive star Cygnus X-1 are spiralling into a black hole.

(i) Explain what is meant by the term *black hole*.

.....

.....

(2)

(ii) What is produced as the gases from a star spiral into a black hole?

.....

(1)
(Total 6 marks)

38 A beta particle is a high-energy electron.

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

.....

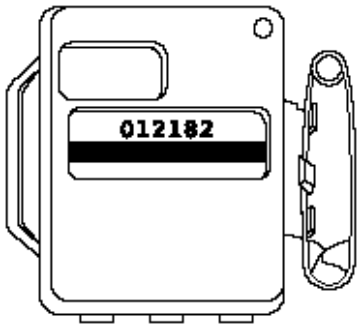
(1)

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

.....

(1)
(Total 2 marks)

39 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)

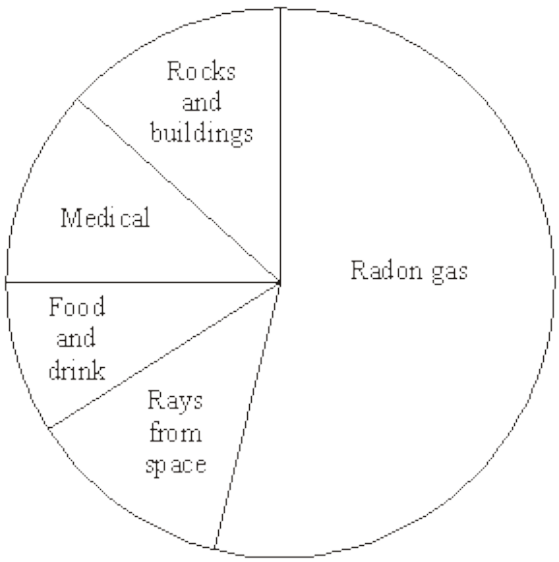
(iii) Why is it important to monitor the amount of radiation the worker has been exposed to?

.....

.....

(1)
(Total 3 marks)

40 Radiation is around us all of the time. The pie chart shows the sources of this radiation.



(i) What is the main source of this radiation?

.....

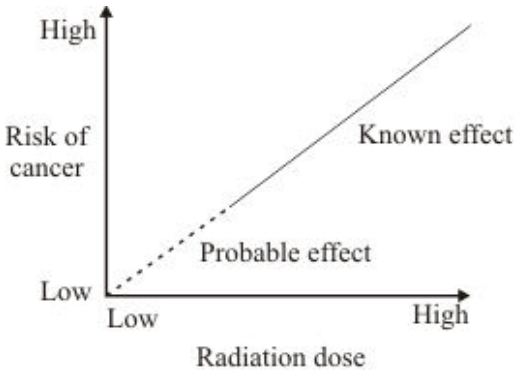
(1)

(ii) What name is given to the radiation that is around us all of the time?

.....

(1)
(Total 2 marks)

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

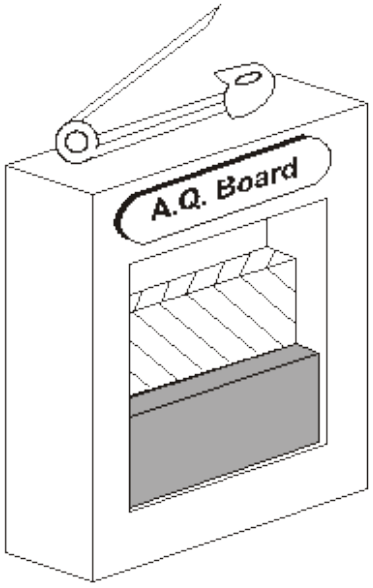


Complete the following sentence.

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.



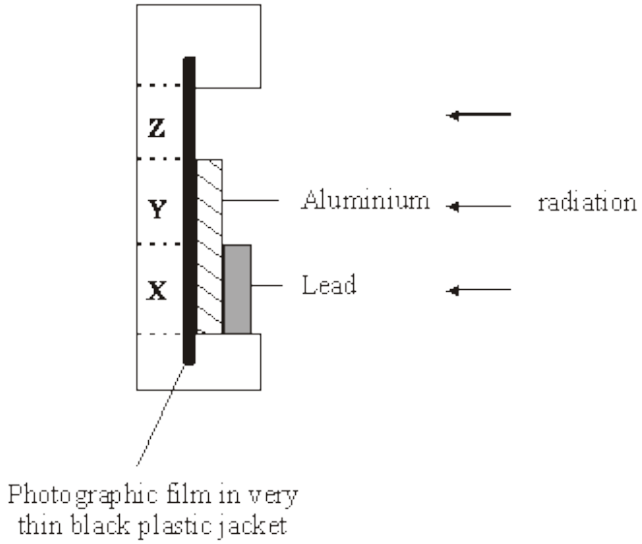


Diagram 1 **Diagram 2**

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.

.....

.....

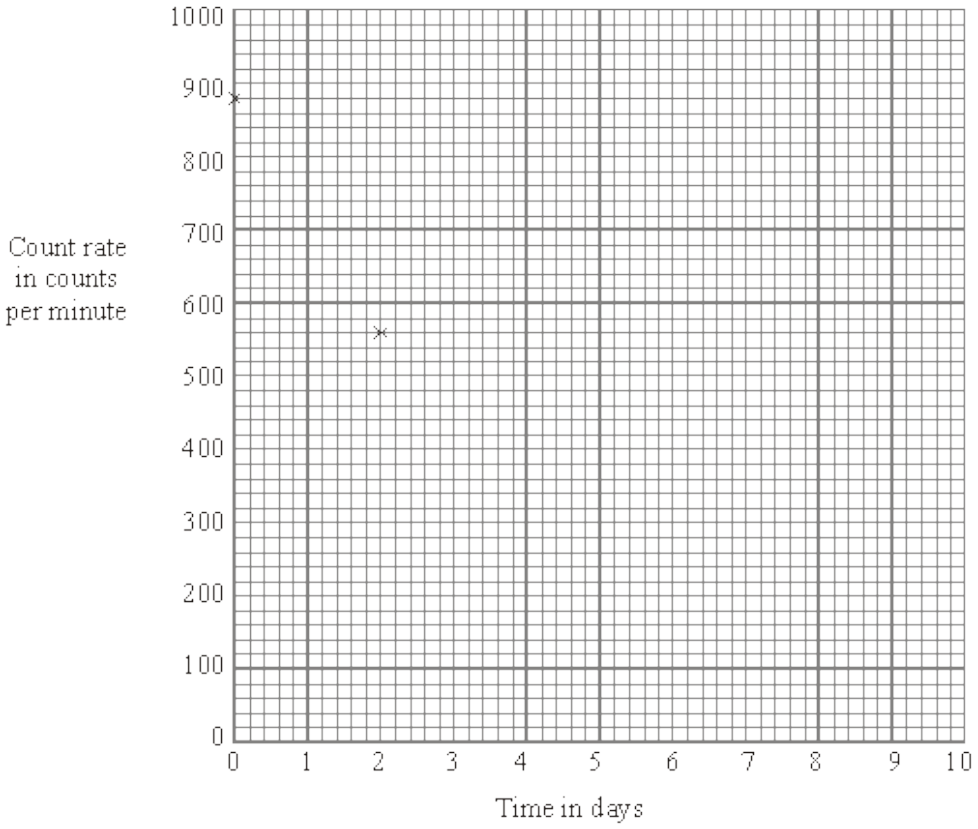
(2)
(Total 3 marks)

42 The table shows how the count rate from a radioactive substance changes in 10 days.

Time in days	0	2	4	6	8	10
Count rate in countsper minute	880	555	350	220	140	90

(a) Draw a graph of count rate against time.

The first two points have been plotted for you.



(3)

(b) (i) Use your graph to find out how long it takes for the count rate to fall from 880 counts per minute to 440 counts per minute.

Time = ... days

(1)

(ii) What is the half-life of this substance?

Half-life = ... days

(1)

(c) The table gives the half-life and type of radiation given out by four different radioactive isotopes.

Radioactive isotope	Half-life in days	Radiation given out
bismuth-210	5.0	beta
polonium-210	138.0	alpha and gamma
radon-222	3.8	alpha
thorium-234	24.1	beta and gamma

Some samples of each isotope have the same count rate today. Which sample will have the lowest count rate one month from today?

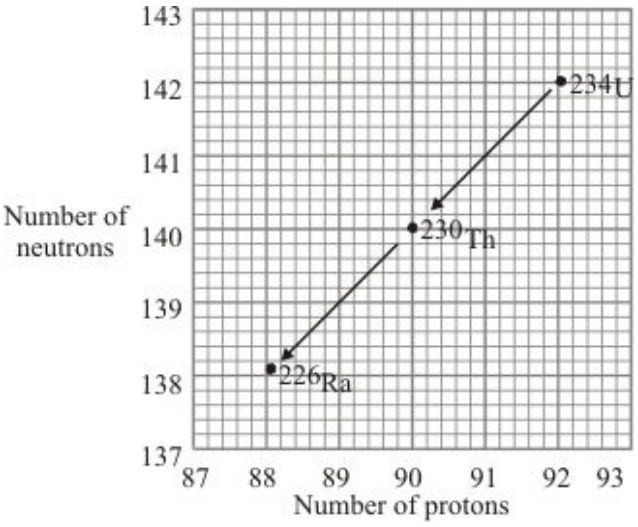
.....

Give a reason for your answer.

.....

(2)
(Total 7 marks)

43 (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.

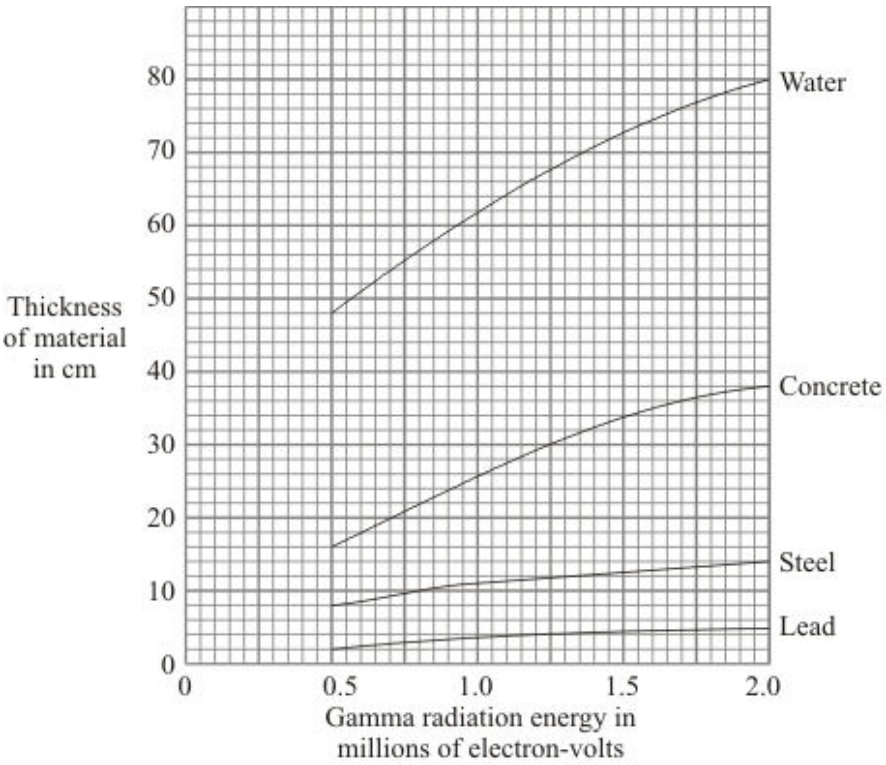
Why does the emission of gamma radiation **not** cause a new element to be formed?

.....

.....

(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.

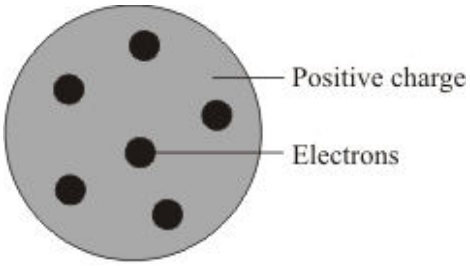
.....

.....

.....

(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)

44 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)

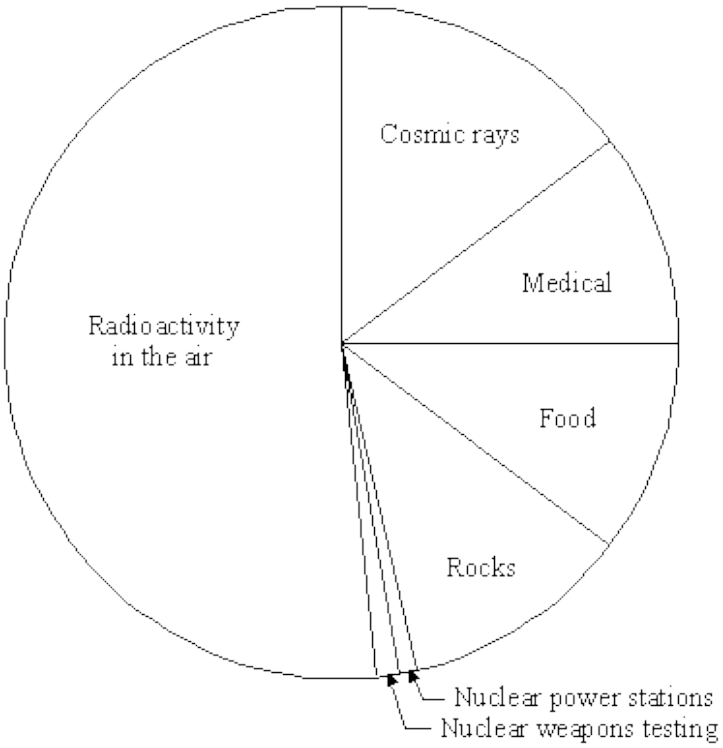
(ii) Calculate the age of the rock.

.....

Age of rock = ... million years

(1)
(Total 2 marks)

45 The different sources of radiation to which we are exposed are shown in the pie chart. Some sources are natural and some artificial.



(i) Name **one** natural source of radiation shown in the pie chart.

.....

(1)

(ii) Name **one** artificial source of radiation shown in the pie chart.

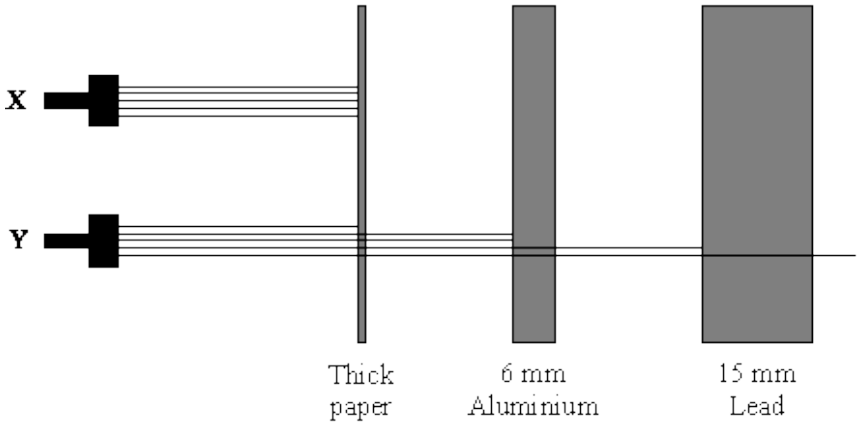
.....

(1)
(Total 2 marks)

46 (a) A radioactive source can give out three types of emission:

alpha particles
beta particles
gamma radiation.

The diagram shows the paths taken by the radiation emitted by two sources, **X** and **Y**.



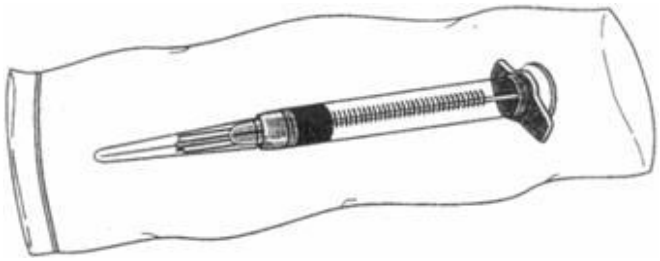
What types of radiation are emitted by each of the sources?

Source **X** emits .....

Source **Y** emits .....

(2)

(b) The diagram shows a disposable syringe sealed inside a plastic bag. After the bag has been sealed the syringe is sterilised using radiation.



Explain why radiation can be used to sterilise the syringe.

.....

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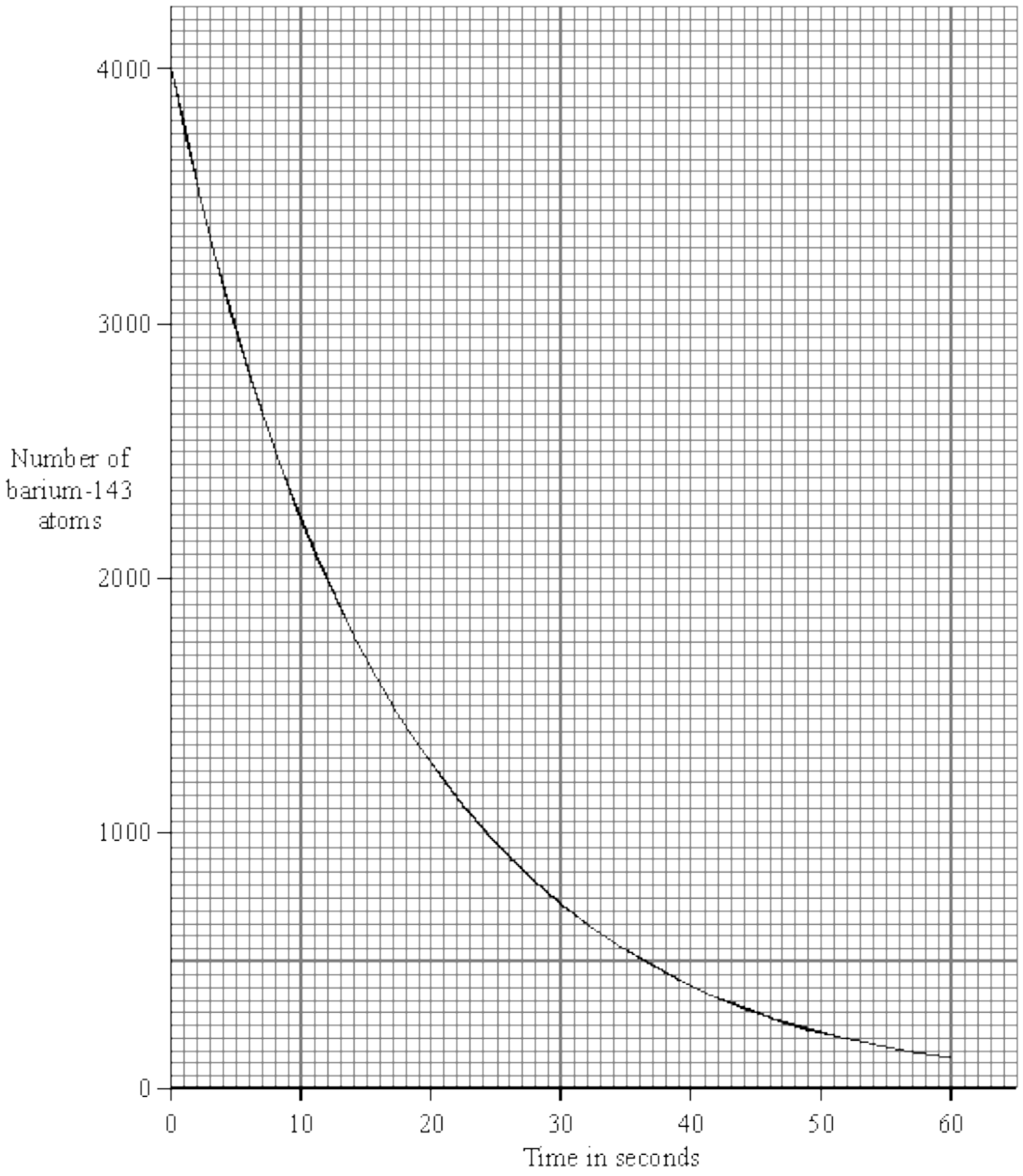
(3)
(Total 5 marks)

47 (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)

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

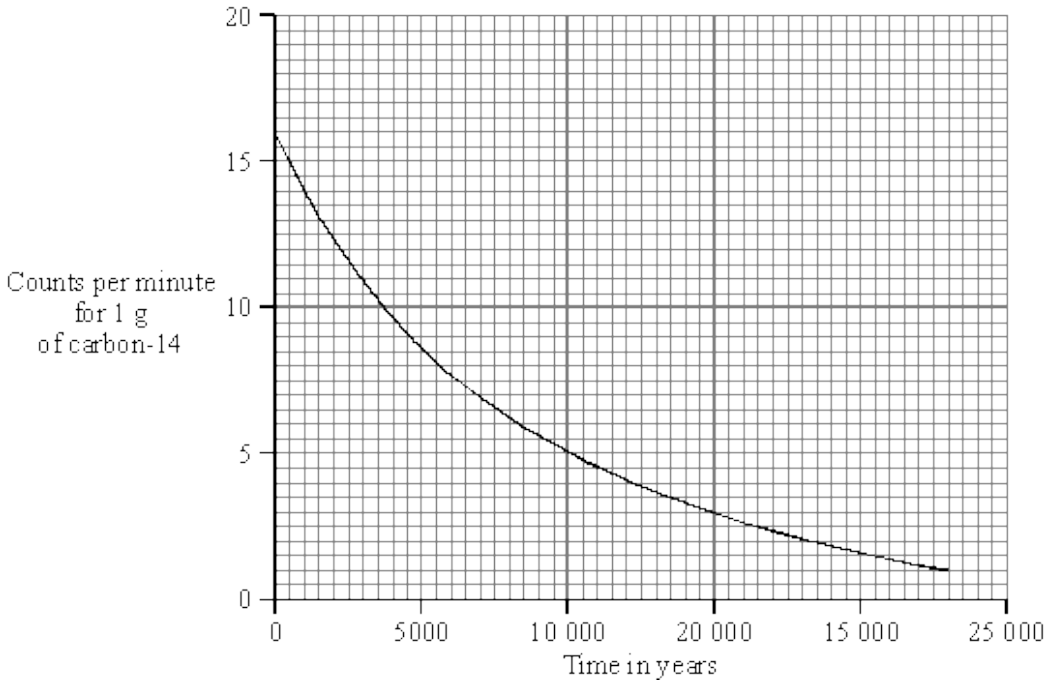
(a) What is a beta (β) particle?

.....

.....

(1)

(b) Plants absorb carbon-14 from the atmosphere. The graph shows the decay curve for 1 g of carbon-l4 taken from a flax plant.



Use the graph to find the half-life of carbon-l4. You should show clearly on your graph how you obtain your answer.

Half-life = ... years.

(2)

(c) Linen is a cloth made from the flax plant. A recent exhibition included part of a linen shirt, believed to have belonged to St. Thomas à Becket, who died in 1162. Extracting carbon-14 from the cloth would allow the age of the shirt to be verified.

If 1 g of carbon-14 extracted from the cloth were to give 870 counts in 1 hour, would it be possible for the shirt to have once belonged to St. Thomas à Becket? You must show clearly the steps used and reason for your decision.

.....

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.....

(3)
(Total 6 marks)

49 (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.

.....

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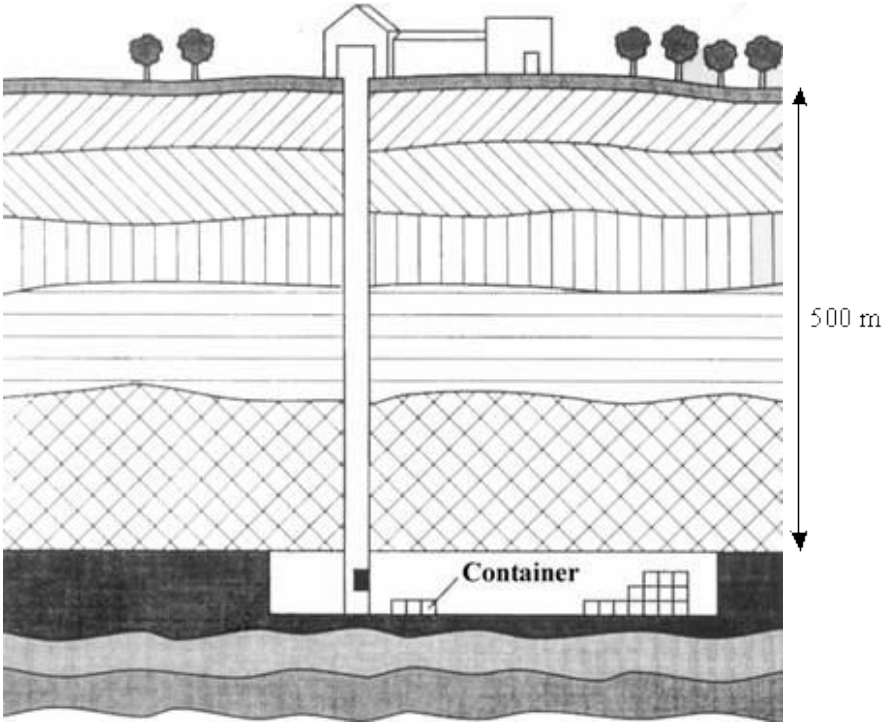
(3)

(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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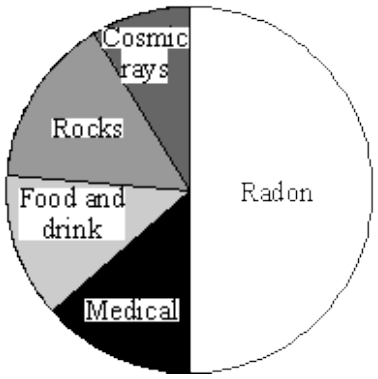
(3)
(Total 8 marks)

50 The pie chart shows the main sources of *background radiation.* Each source contributes to the average yearly radiation dose.



(i) What is meant by the term *background radiation?*

.....

.....

(1)

(ii) Suggest why an airline pilot is likely to get a higher than average yearly radiation dose.

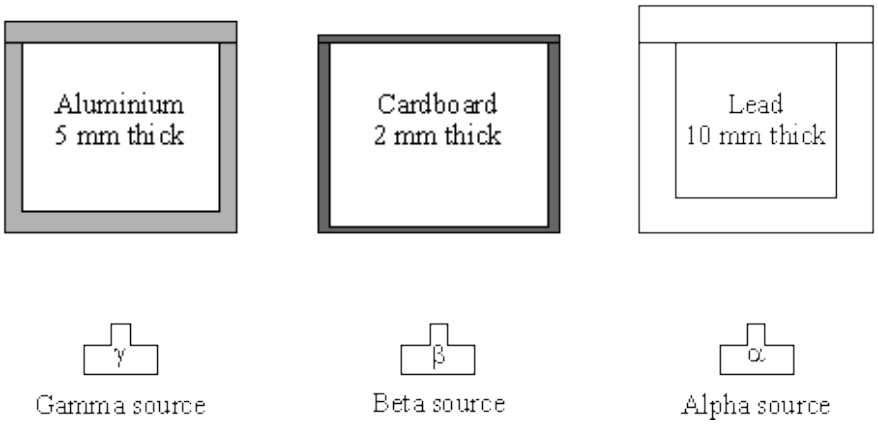
.....

.....

.....

(2)
(Total 3 marks)

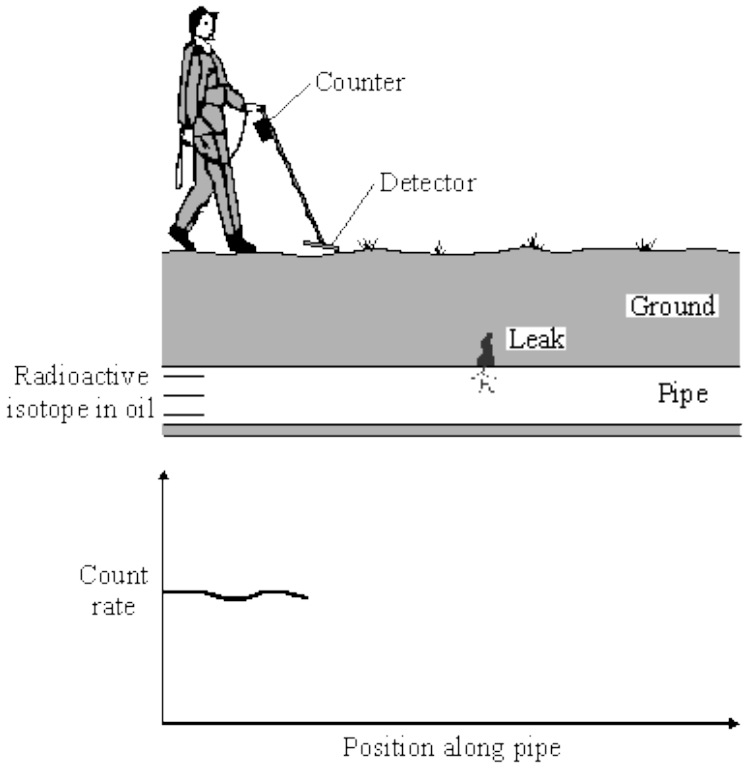
51 (a) The diagram shows three different boxes and three radioactive sources. Each source is stored in a different box.



Draw lines to show which source should be stored in each box so that the risk of radiation leakage is a minimum.

(2)

(b) A leak in an underground oil pipe can be found by injecting a radioactive isotope into the oil. The ground is then tested with a radiation detector and counter.



(i) State the type of detector used.

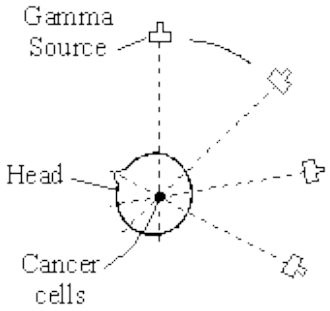
.....

(1)

(ii) Complete the sketch graph to show how the reading on the detector will change as it passes along the ground above the pipe.

(1)

(c) Gamma radiation can be used to kill cancer cells inside a person's head. During the treatment the patient is kept perfectly still while the source of gamma radiation moves in a circle.



(i) Why is a source of gamma radiation the most suitable for this treatment?

.....

(1)

(ii) Suggest why a moving source of radiation is used rather than one which is kept stationary.

.....

.....

.....

.....

(2)

(iii) Gamma radiation is an electromagnetic wave. Give **two** properties common to all electromagnetic waves.

1 .....

.....

2 .....

.....

(2)
(Total 9 marks)

52 (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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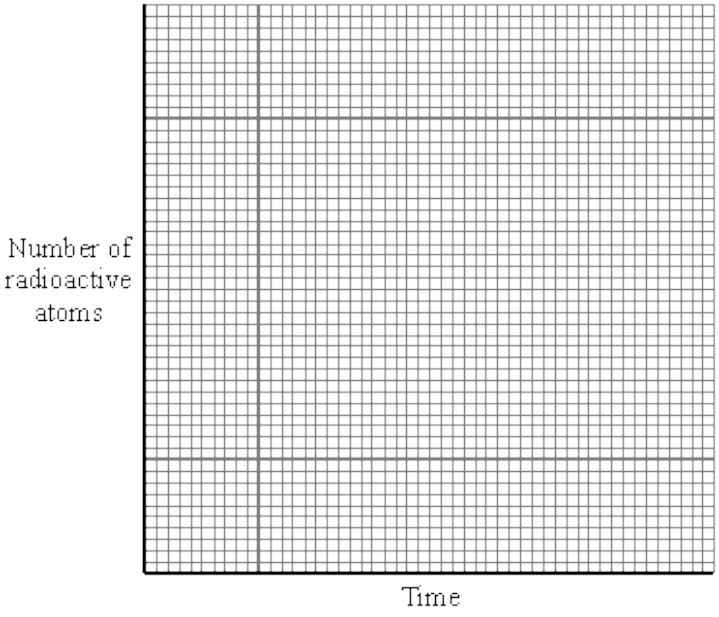
.....

(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)

53 (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.

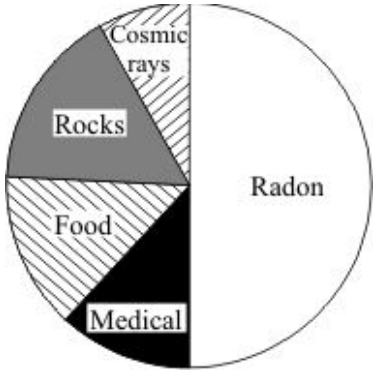
(i) The type of radiation that travels at the speed of light is .....

(1)

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

(1)
(Total 3 marks)

54 (a) The pie-chart shows the main sources of background radiation.



(i) Which source in the pie-chart adds the smallest amount of radiation to background levels?

.....

(1)

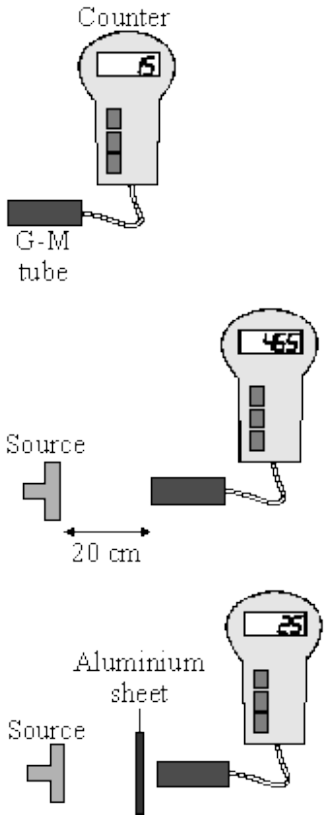
(ii) Name **two** natural sources of background radiation in the pie-chart.

1. .....

2. .....

(2)

(b) The diagrams show how a radiation detector and counter can be used to measure radiation levels. In each case the numbers show the count one minute after the counter is switched on.



(i) How many counts are just from background radiation?

.....

(ii) How many counts are just from the source?

.....

(iii) What type of radiation did the source give out?

.....

Give a reason for your answer.

.....

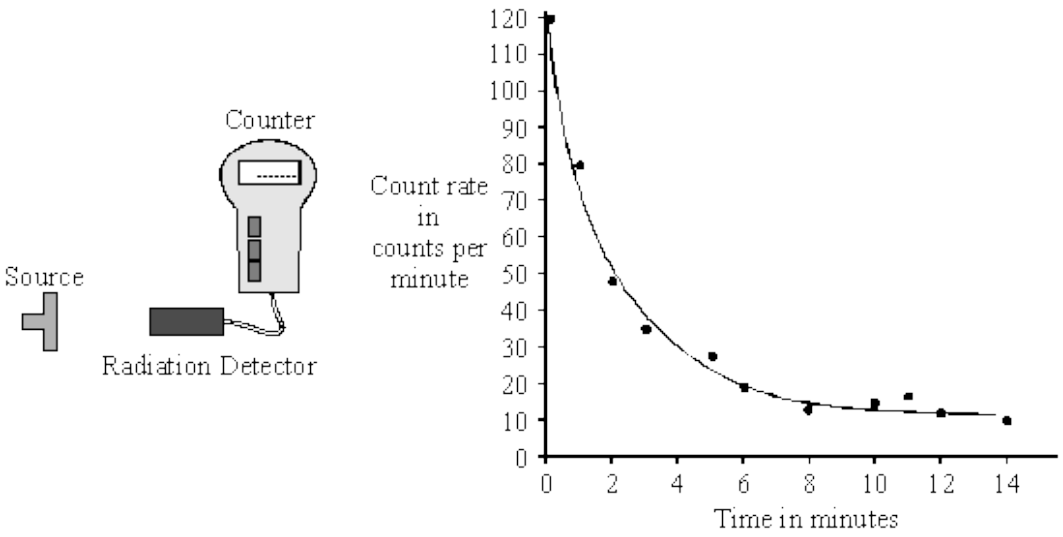
.....

.....

.....

(4)
(Total 7 marks)

55 (a) A radiation detector and counter were used to detect and measure the radiation emitted from a weak source. The graph shows how the number of counts recorded in one minute changed with time.



(i) Even though the readings from the counter were accurately recorded, not all the points fit the smooth curve. What does this tell us about the process of radioactive decay?

.....

(1)

(ii) After ten minutes the number of counts recorded each minute is almost constant. Explain why.

.....

.....

.....

(2)

(b) The radioactive isotope sodium-24 injected into the bloodstream can be used to trace blood flow to the heart. Sodium-24 emits both *beta particles* and *gamma rays*.

(i) What is a *beta particle*?

.....

(1)

(ii) What is a *gamma ray*?

.....

.....

(1)

(iii) The count rate from a solution containing sodium-24 decreases from 584 counts per minute to 73 counts per minute in 45 hours. Calculate the half-life of sodium-2.2. Show clearly how you work out your answer.

.....

.....

.....

Half-life = ... hours

(3)

(iv) Give **one** advantage of using sodium-24 to trace blood flow compared to using an isotope with a half-life of:

[A] ten years; .....

.....

(1)

[B] ten seconds. .....

.....

(1)
(Total 10 marks)

56 (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.

.....

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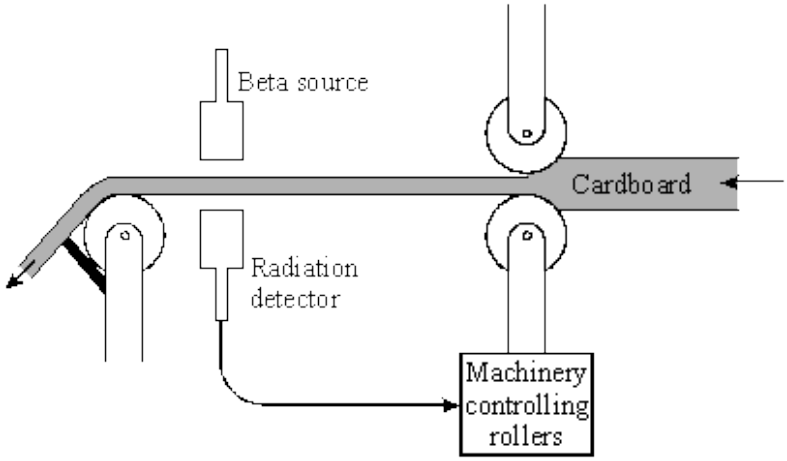
.....

(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)

57 (a) Most of the Sun is hydrogen. Inside the core of the sun, hydrogen is being converted to helium. What name is given to this process and why is the process so important?

.....

.....

.....

(2)

(c) Describe what will happen to the Sun as the core runs out of hydrogen.

.....

.....

.....

.....

.....

(3)

(Total 5 marks)

58 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*?

.....

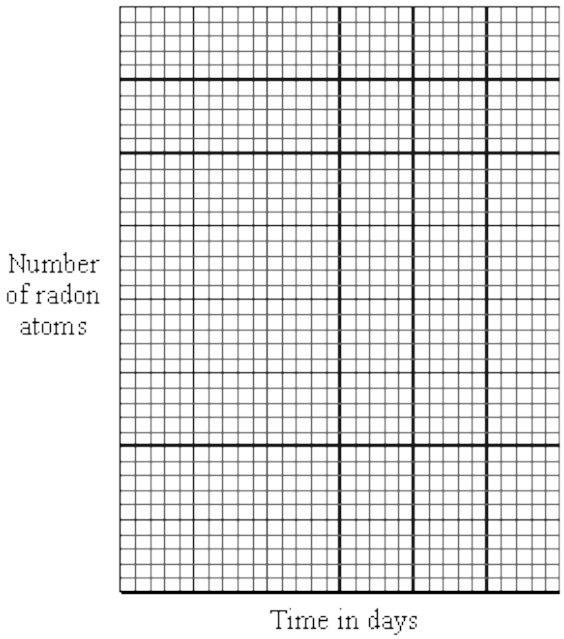
(1)

(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)

59 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 $\left({}^{235}_{92}\mathrm{U}\right)$ and uranium-238 $\left({}^{238}_{92}\mathrm{U}\right)$. 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.

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

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)

60 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)