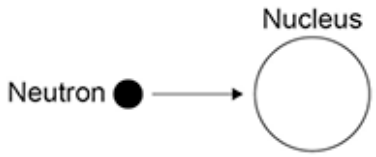
1 Electricity is generated in a nuclear power station.

Fission is the process by which energy is released in the nuclear reactor.

(a) **Figure 1** shows the first part of the nuclear fission reaction.

Complete **Figure 1** to show how the fission process starts a chain reaction.

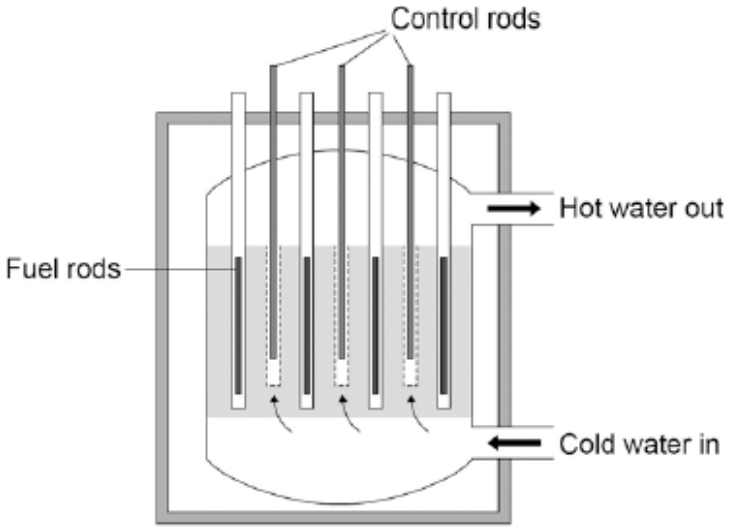
Figure 1



(3)

(b) **Figure 2** shows the inside of a nuclear reactor in a nuclear power station.

Figure 2



In a nuclear reactor a chain reaction occurs, which causes neutrons to be released.

The control rods absorb neutrons.

The control rods can be moved up and down.

Explain how the energy released by the chain reaction is affected by moving the control rods.

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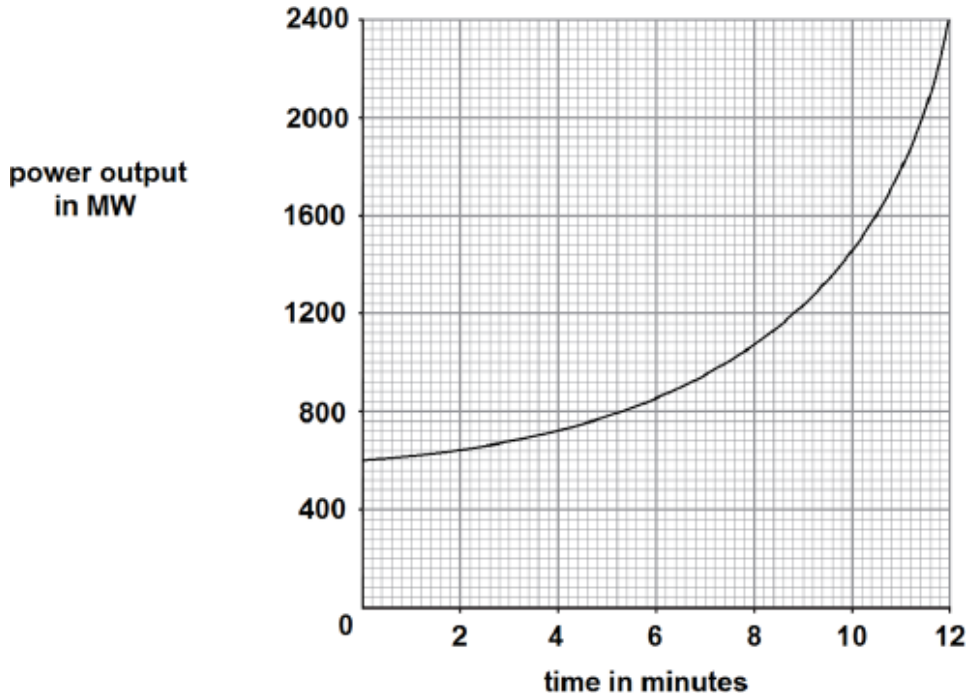
(2)

(c) **Figure 3** shows how the power output of the nuclear reactor would change if the control rods were removed.

Figure 3



Calculate the rate of increase of power output at 10 minutes.

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Rate of increase of power output = ... MW / minute

(2)

(Total 7 marks)

2 Different radioactive isotopes have different values of half-life.

(a) What is meant by the 'half-life' of a radioactive isotope?

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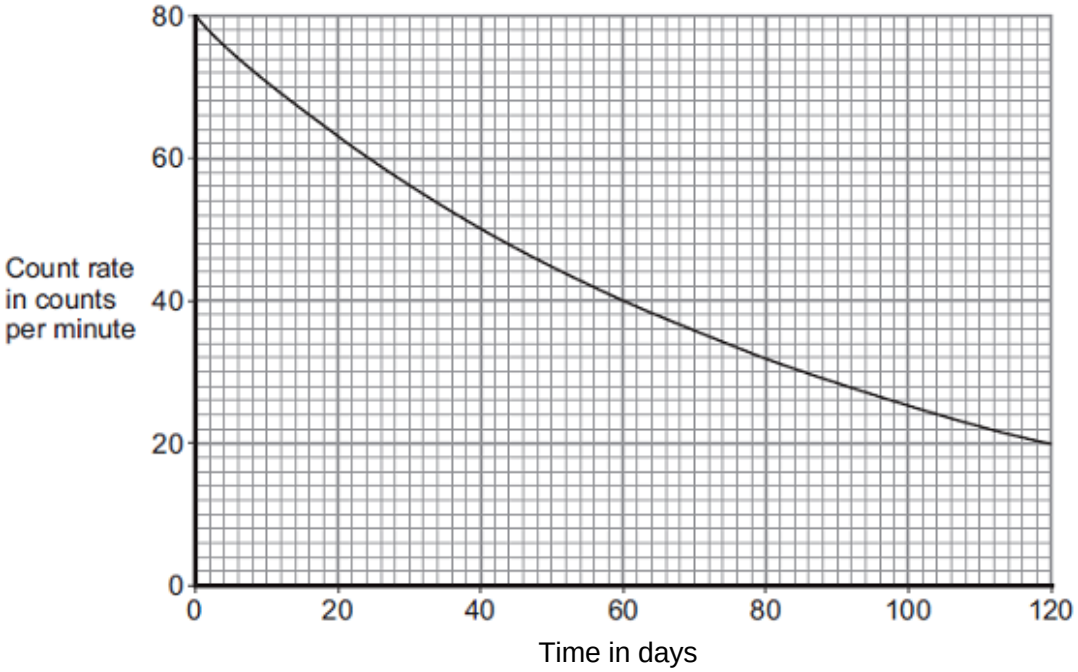
(1)

(b) **Figure 1** shows how the count rate from a sample of a radioactive isotope varies with time.

Figure 1



Use information from **Figure 1** to calculate the half-life of the radioactive isotope.

Show clearly on **Figure 1** how you obtain your answer.

Half-life = ... days

(2)

(c) The table below shows data for some radioactive isotopes that are used in schools.

Radioactive isotope	**Type of radiation emitted**	**Half-life in years**
Americium-241	Alpha and gamma	460
Cobalt-60	Gamma	5
Radium-226	Alpha, beta and gamma	1600
Strontium-90	Beta	28
Thorium-232	Alpha and beta	1.4×10^{10}

(i) State which radioactive isotope in the table above emits only radiation that is **not** deflected by a magnetic field.

Give a reason for your choice.

.....

.....

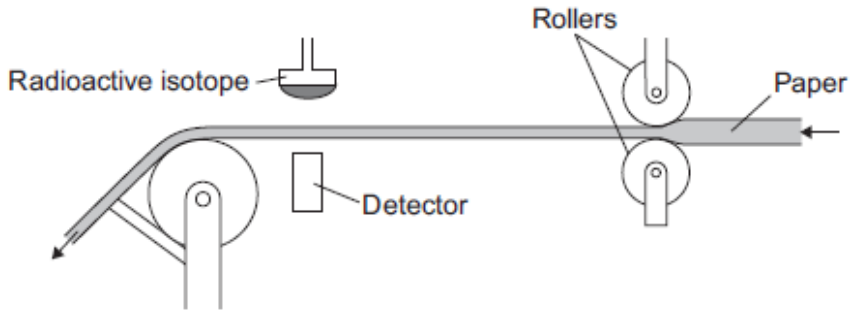
.....

.....

(2)

(ii) **Figure 2** shows a radioactive isotope being used to monitor the thickness of paper during production.

Figure 2



State which radioactive isotope in the table should be used to monitor the thickness of the paper.

Explain your choice.

.....

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(3)

All the radioactive isotopes in the table have practical uses.

State which source in the table would need replacing most often.

Explain your choice.

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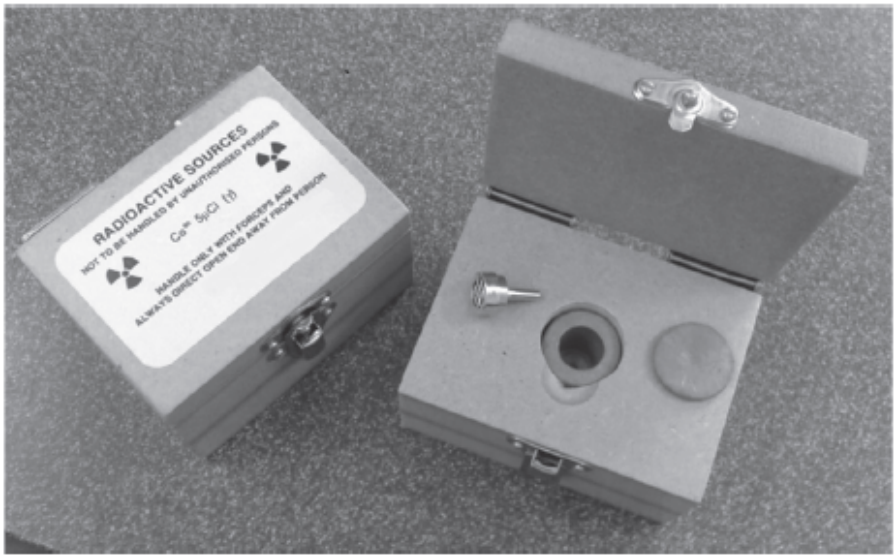
(3)

(iii) When the radioactive isotopes are not in use, they are stored in lead-lined wooden boxes.

The boxes reduce the level of radiation that reaches the surroundings.

Figure 3 shows two of these boxes.

Figure 3



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State **one** source from the table which emits radiation that could penetrate the box.

Explain your answer.

.....

.....

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.....

.....

(3)
(Total 14 marks)

3 Nuclear fission and nuclear fusion are two processes that release energy.

(a) (i) Use the correct answer from the box to complete each sentence.

Geiger counter	**nuclear reactor**	**star**

Nuclear fission takes place within a ..... .

Nuclear fusion takes place within a ..... .

(2)

(ii) State **one** way in which the process of nuclear fusion differs from the process of nuclear fission.

.....

.....

(1)

(b) The following nuclear equation represents the fission of uranium-235 (U-235).

$$^{1}_{0}n + {}^{235}_{92}U \longrightarrow {}^{236}_{92}U \longrightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3\,{}^{1}_{0}n + \text{energy}$$

Chemical symbols:

Ba - barium

Kr - krypton

(i) Use the information in the equation to describe the process of nuclear fission.

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(4)

(ii) An isotope of barium is Ba-139.
Ba-139 decays by beta decay to lanthanum-139 (La-139).

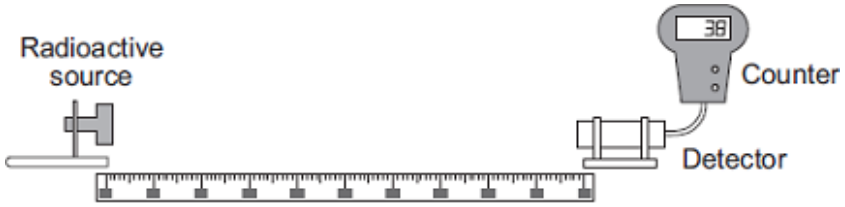
Complete the nuclear equation that represents the decay of Ba-139 to La-139.

$$^{139}Ba \longrightarrow {}^{139}La + \text{.....}$$

(.....) (.....) (.....)

(3)
(Total 10 marks)

4 A teacher used the equipment shown in the diagram to measure the count rate at different distances from a radioactive source.



(a) Her results are shown in **Table 1**.

Table 1

Distance in metres	Count rate in counts per minute	Corrected count rate in counts per minute
0.4	143	125
0.6	74	56
0.8	49	31
1.0	38	20
1.2	32	14
1.4	28	10
1.6	18	0
1.8	18	0
2.0	18	0

The background count rate has been used to calculate the corrected count rate.

(i) What is the value of the background count rate?

Background count rate = ... counts per minute

(1)

(ii) What information does the corrected count rate give?

.....

.....

(1)

(iii) The radioactive source used in the demonstration emits only one type of radiation.

The radioactive source is **not** an alpha emitter.

How can you tell from the data in the table?

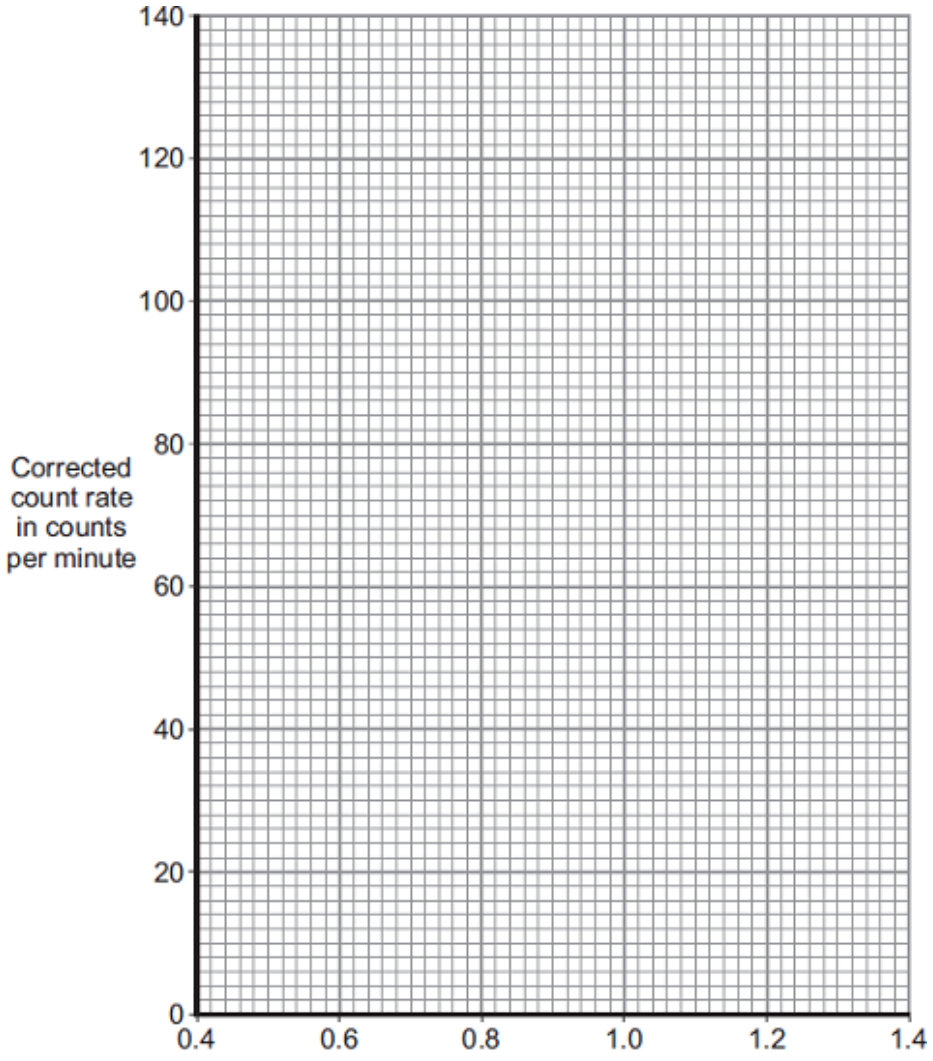
.....

.....

(1)

(iv) Plot a graph of corrected count rate against distance for distances between 0.4 m and 1.4 m.

Draw a line of best fit to complete the graph.



(3)

(v) The ‘half-distance’ is the distance a detector has to be moved away from a radioactive source for the corrected count rate to halve.

A student has the hypothesis:
A radioactive source has a constant ‘half-distance’.

Table 1 has been repeated for your information.

Table 1

Distance in metres	Count rate in counts per minute	Corrected count rate in counts per minute
0.4	143	125
0.6	74	56
0.8	49	31
1.0	38	20
1.2	32	14
1.4	28	10
1.6	18	0
1.8	18	0
2.0	18	0

Use **Table 1** to determine if the hypothesis is correct for this radioactive source.

You should use calculations in your answer.

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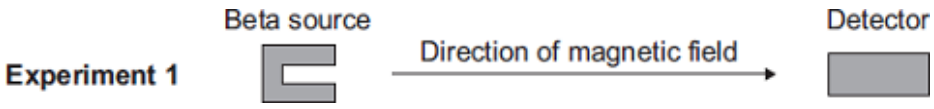
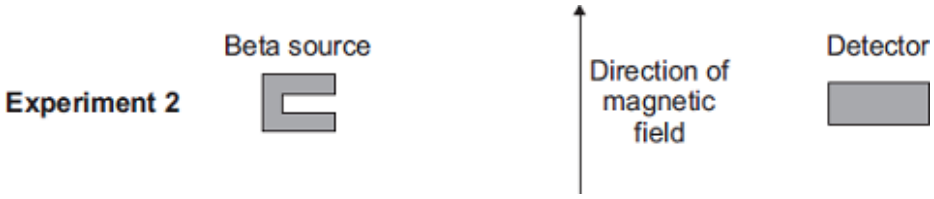
(3)

(b) A teacher places a beta source and a detector in a magnetic field.

The arrangement of the magnetic field is shown.



.....The teacher repeated the experiment with the magnetic field in a different direction.



A set of results is shown in **Table 2**.

Table 2

Distance between source and detector in metres	Count rate in counts per minute without magnetic field	Count rate in counts per minute in Experiment 1	Count rate in counts per minute in Experiment 2
0.8	48	48	32

(i) Describe **and** explain the effect of the magnetic field on the count rate detected by the detector.

.....

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.....

(2)

(ii) The experiment is repeated with a different distance between the source and the detector.

Table 3 shows the repeated results.

Table 3

Distance between source and detector in metres	Count rate in counts per minute without magnetic field	Count rate in counts per minute in Experiment 1	Count rate in counts per minute in Experiment 2
1.8	19	18	20

Explain these results.

.....

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.....

.....

(2)
(Total 13 marks)

5 (a) Sources of background radiation are either natural or man-made.

Which **two** of the sources listed in the box are *natural* sources of background radiation?

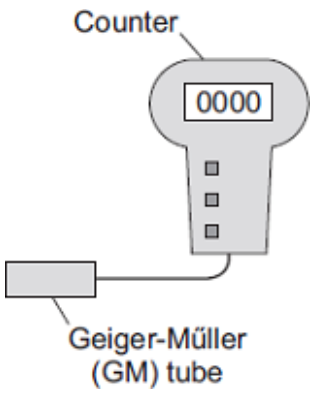
Draw a ring around each of your answers.

cosmic rays	**nuclear accidents**	**X-rays**	**radon gas**

(2)

(b) A teacher used a Geiger-Műller (GM) tube and counter to measure the background radiation in her laboratory. The teacher reset the counter to zero, waited one minute and then took the count reading. The teacher repeated this two more times.

The three readings taken by the teacher are given in the table.



Count
17
21
19

(i) The three readings are different.

What is the most likely reason for this?

Tick (✓) **one** box.

The teacher did not reset the counter to zero. ☐

Radioactive decay is a random process. ☐

The temperature in the laboratory changed. ☐

(1)

(ii) Calculate the mean (average) value of the three readings given in the table.

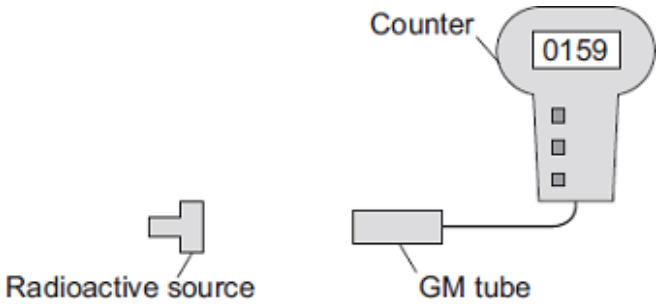
.....

Mean (average) value = ... counts

(1)

(iii) The diagram shows how the teacher used the GM tube and counter to measure the radiation emitted from a radioactive source.

The counter was reset to zero. The count after one minute was 159.



Calculate how many counts were due to the radiation from the radioactive source.

.....

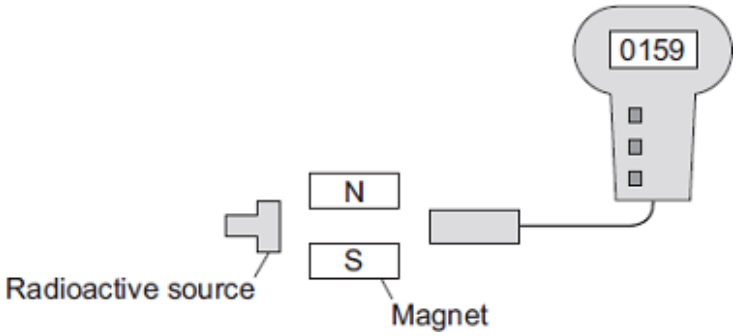
.....

Counts due to the radiation from the radioactive source = ...

(1)

(iv) The teacher then put a powerful magnet between the radioactive source and the GM tube.

The counter was reset to zero. The number on the counter shows the count after one minute.



What type of radiation was being emitted from the radioactive source?

Draw a ring around your answer.

alpha **beta** **gamma**

Explain the reason for your answer.

.....

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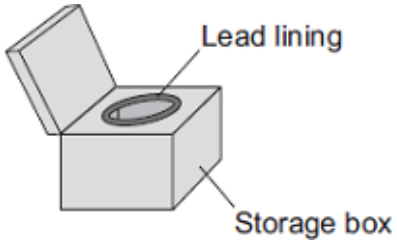
.....

.....

(3)

(c) At the end of the lesson the teacher put the radioactive source back inside its storage box.



Why is the inside of the box lined with lead?

.....

.....

(1)

(d) Which **one** of the following questions **cannot** be answered by scientific study?

Tick (✓) **one** box.

Where does background radiation come from? ☐

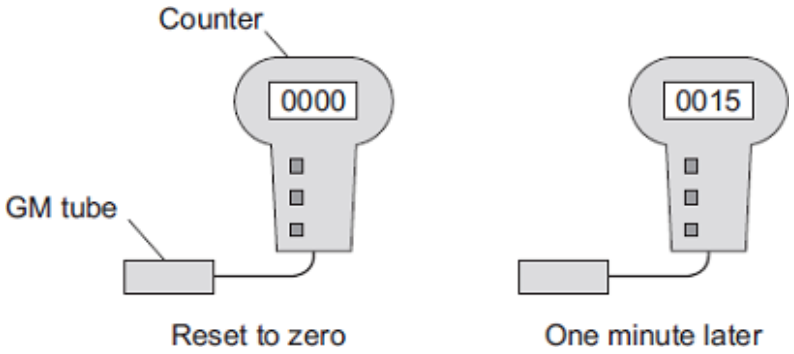
What is meant by the half-life of a radioactive source? ☐

Should radioactive waste be dumped in the oceans? ☐

(1)
(Total 10 marks)

6 (a) A teacher used a Geiger-Műller (GM) tube and counter to measure the *background radiation* in her laboratory.

The teacher reset the counter to zero, waited one minute and then took the count reading. The teacher repeated the procedure two more times.



(i) Background radiation can be either from natural sources or from man-made sources.

Name **one man-made** source of background radiation.

.....

(1)

(ii) The three readings taken by the teacher are given in the table.

Count after one minute
15
24
18

The readings given in the table are correct.

Why are the readings different?

.....

.....

(1)

(b) Some scientists say they have found evidence to show that people living in areas of high natural background radiation are less likely to develop cancer than people living in similar areas with lower background radiation.

The evidence these scientists found does not definitely mean that the level of background radiation determines whether a person will develop cancer.

Suggest a reason why.

.....

.....

(1)

(c) An atom of the isotope radon-222 emits an alpha particle and decays into an atom of polonium.

An alpha particle is the same as a helium nucleus. The symbol below represents an alpha particle.

$$^{4}_{2}\mathrm{He}$$

(i) How many protons and how many neutrons are there in an alpha particle?

Number of protons = ...

Number of neutrons = ...

(2)

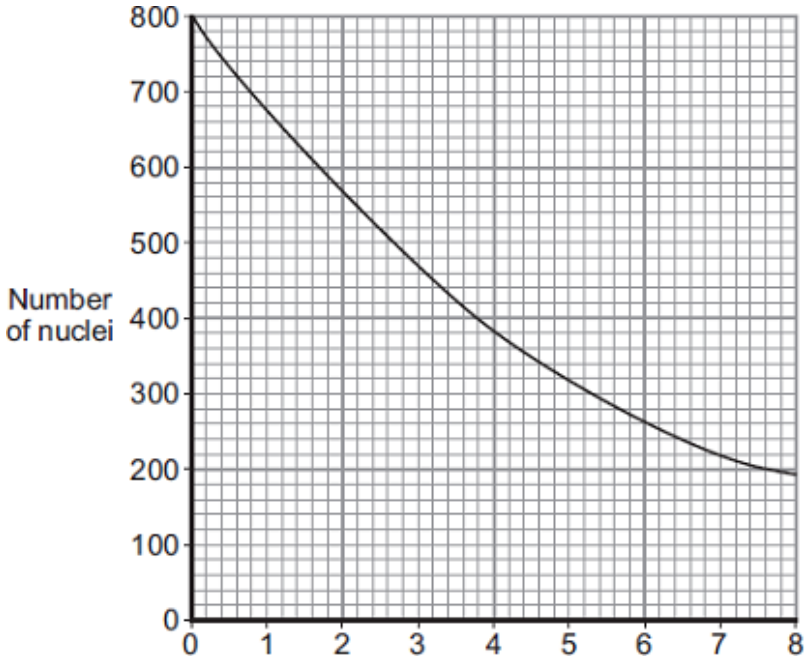
(ii) The decay of radon-222 can be represented by the equation below.

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

$$^{222}_{86}\mathrm{Rn} \longrightarrow \square \quad \square + \text{Po} + \text{alpha particle}$$

(2)

(d) The graph shows how, in a sample of air, the number of radon-222 nuclei changes with time.



Use the graph to find the half-life of radon-222.

Show clearly on the graph how you obtain your answer.

Half-life = ... days

(2)

(Total 9 marks)

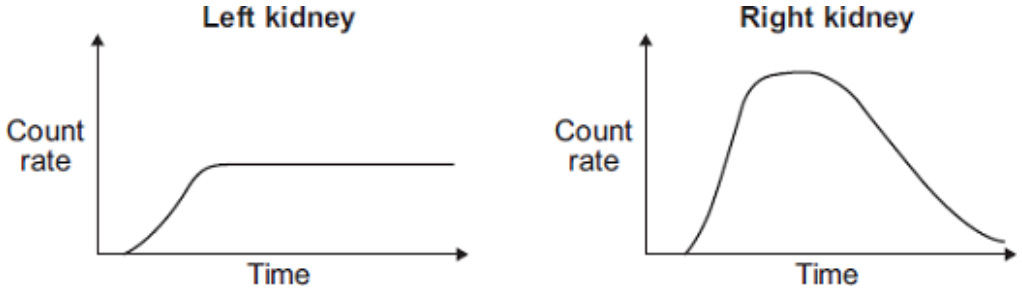
7 A doctor uses the radioactive isotope technetium-99 to find out if a patient's kidneys are working correctly.

The doctor injects a small amount of technetium-99 into the patient's bloodstream. Technetium-99 emits gamma radiation.

If the patient's kidneys are working correctly, the technetium-99 will pass from the bloodstream into the kidneys and then into the patient's urine.

Detectors are used to measure the radiation emitted from the kidneys.

The level of radiation emitted from each kidney is recorded on a graph.



(a) How do the graphs show that technetium-99 is passing from the bloodstream into each kidney?

.....

.....

(1)

(b) By looking at the graphs, the doctor is able to tell if there is a problem with the patient's kidneys.

Which **one** of the following statements is correct?

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

Only the right kidney is working correctly. ☐

Only the left kidney is working correctly. ☐

Both kidneys are working correctly. ☐

Explain the reason for your answer.

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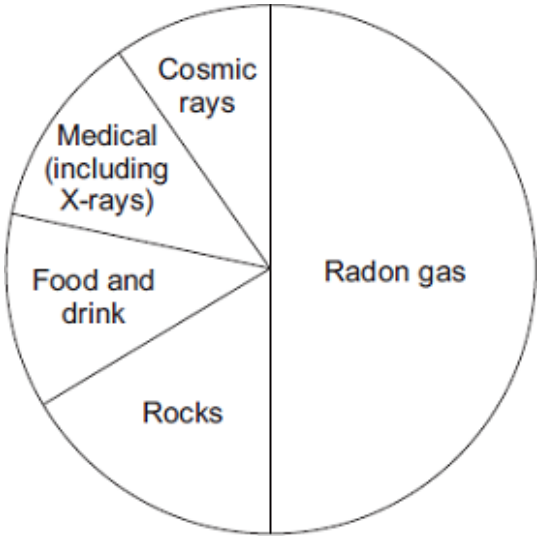
(3)
(Total 4 marks)

8 The pie chart shows the average proportions of background radiation from various sources in the UK.



(a) Three sources of background radiation are given in **List A**.
Statements about sources of background radiation are given in **List B**.

Draw **one** line to link each source of background radiation in **List A** to the statement about that source given in **List B**.

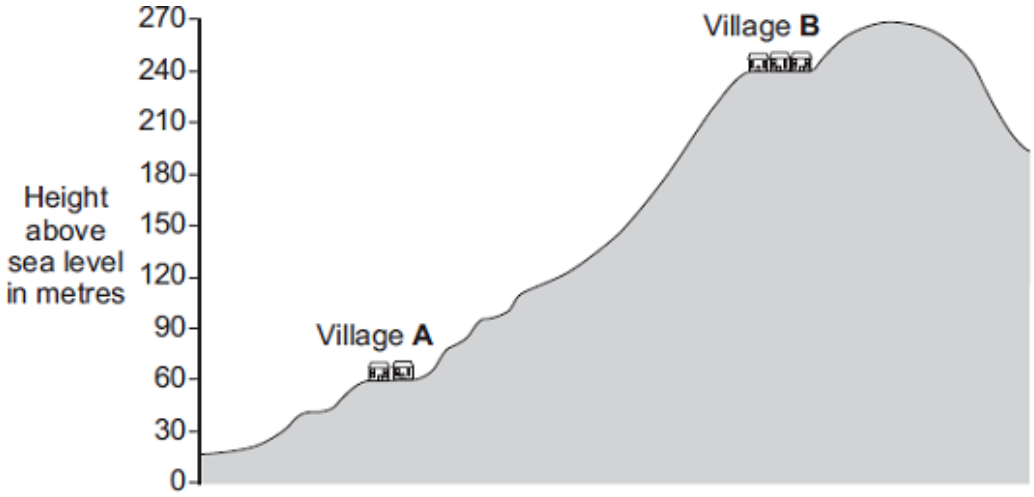
Draw only **three** lines.

List A	**List B**
	Are used to show broken bones.
X-rays	
	The radiation comes from outer space.
Cosmic rays	
	Comes from soil containing a radioactive isotope of potassium.
Radon gas	
	On average gives 50% of all background radiation.

(3)

(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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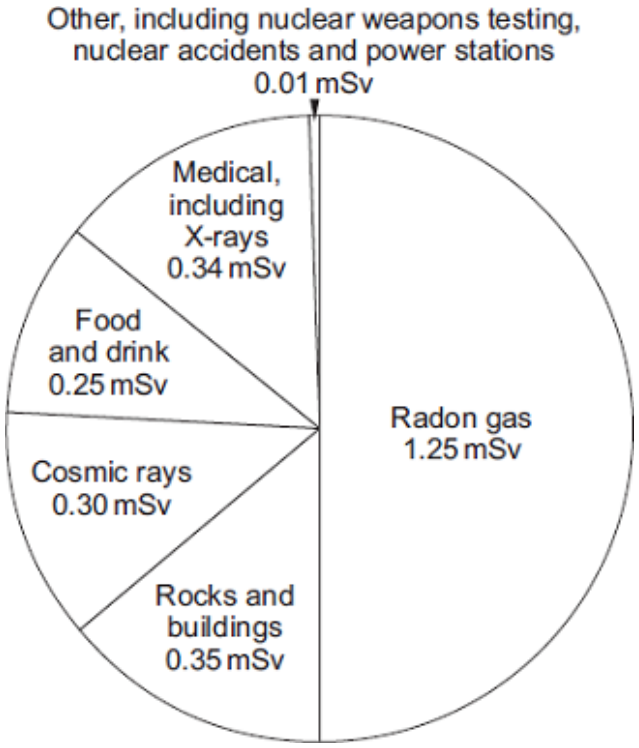
(3)
(Total 6 marks)

9 The pie chart shows the sources of the background radiation and the radiation doses that the average person in the UK is exposed to in one year.
Radiation dose is measured in millisieverts (mSv).



(a) (i) What is the total radiation dose that the average person in the UK receives?

.....

.....

Total radiation dose = ... mSv

(1)

(ii) A student looked at the pie chart and then wrote down three statements.

Which **one** of the following statements is a correct conclusion from this data?

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

In the future, more people will be exposed to a greater proportion of radon gas. ☐

People that have never had an X-ray get 50 % of their radiation dose from radon gas. ☐

The radiation dose from natural sources is much greater than from artificial sources. ☐

(1)

(b) The concentration of radon gas inside a home can vary from day to day.

The table gives data for the radiation measured in homes in four different parts of the UK. The radiation was measured using two detectors, one in the living room and one in the bedroom. The measurements were taken over 3 months.

Area of the UK	Number of homes in the area	Number of homes in the sample	Average radiation in Bq/m^3	Maximum radiation in Bq/m^3
A	590 000	160	15	81
B	484 000	130	18	92
C	221 000	68 000	162	10 000
D	318 000	35 300	95	6 900

(i) Give **one** reason why the measurements were taken over 3 months using detectors in different rooms.

.....

.....

(1)

(ii) Use information from the table to suggest why a much higher proportion of homes were sampled in areas **C** and **D** than in areas **A** and **B**.

.....

.....

.....

(2)
(Total 5 marks)

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

Source of background radiation	Average radiation dose received each year in dose units
Cosmic rays (from space)	300
Food and drink	250
Medical treatments (including X-rays)	350
Radon gas	1250
Rocks	350
TOTAL	2500

(a) (i) A student looked at the data in the table and then wrote down four statements.

Only **two** of the statements are true.

Put a tick (✓) in the boxes next to the **two** true statements.

More than half of the average radiation dose comes from radon gas. ☐

On average, cosmic rays produce less background radiation than rocks. ☐

Everyone living in the UK receives the same background radiation dose. ☐

Having no X-rays reduces a person's radiation dose. ☐

(2)

(ii) Each time a chest X-ray is taken, the patient receives about 100 units of radiation.

How many chest X-rays would just exceed the yearly average dose for medical treatments?

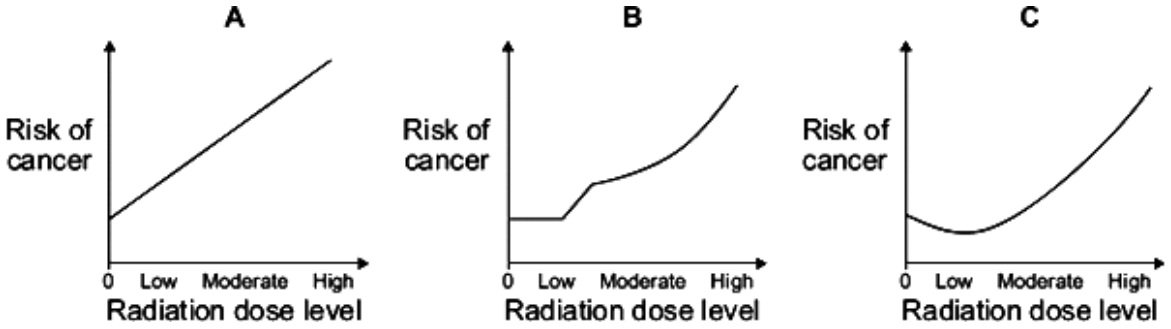
.....

Number of chest X-rays = ...

(2)

(b) Exposure to radiation can cause cancer.

The graphs, **A**, **B** and **C**, show three different ways that the exposure to radiation and the risk of getting cancer could be linked.



(i) What do all three of these graphs suggest happens to the risk of getting cancer when the radiation dose goes from moderate to high?

.....

.....

(1)

(ii) Some scientists believe that exposure to **low** radiation doses reduces the chance that a person will get cancer. This effect is called 'radiation hormesis'.

Which one of the graphs, **A**, **B** or **C**, shows 'radiation hormesis'?

Write your answer in the box.

Give a reason for your answer.

.....

.....

.....

(2)

(c) Scientists did an experiment in which mice were exposed to different doses of radiation.

The results from the experiment are given in the table.

Description of exposure	**Percentage of mice getting cancer**
Mice exposed to a low dose of radiation and then a high dose of radiation.	16%
Mice exposed to a high dose of radiation only.	46%

(i) Do the results from this experiment provide evidence to support 'radiation hormesis'?

Draw a ring around your answer. NO YES

Explain the reason for your answer.

.....

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.....

(2)

(ii) Complete the following sentence by drawing a ring around the correct word in the box.

Using animals in scientific experiments raises

environmental
ethical
social

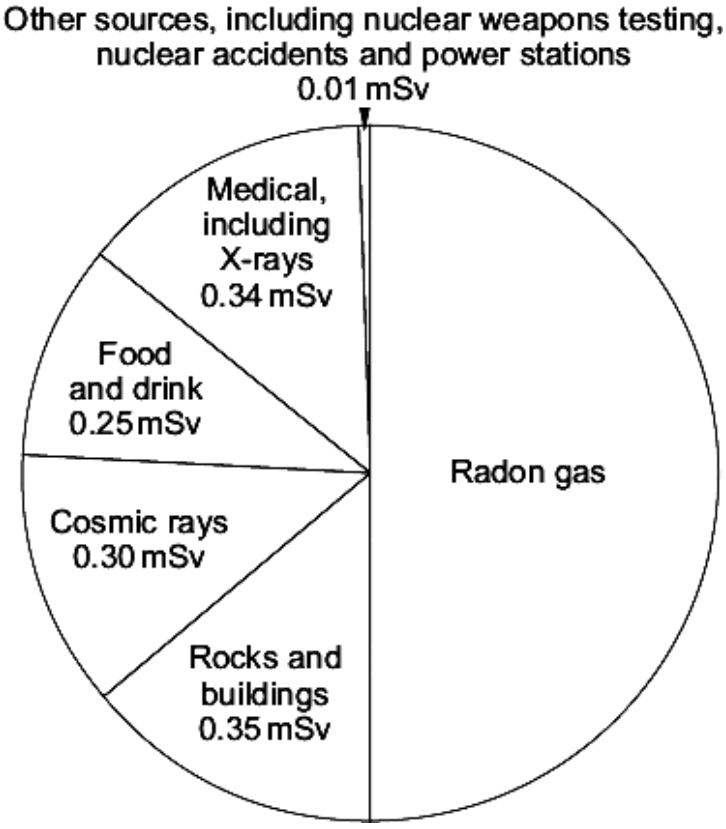
issues.

(1)

(Total 10 marks)

11 The pie chart shows the sources of the background radiation and the radiation doses that the average person in the UK is exposed to in one year.

Radiation dose is measured in millisieverts (mSv).



(a) (i) What is the radiation dose that the average person in the UK receives from radon gas?

.....

.....

Radiation dose from radon gas = ... mSv

(1)

(ii) A person may receive a higher than average dose of radiation from background sources.

Suggest **two** reasons why.

1 .....

.....

2 .....

.....

(2)

(b) Exposure to radon gas can cause lung cancer.
A recent study has compared the risk of getting lung cancer, by the age of 75 years, for cigarette smokers and non-smokers.
The people in the study had been exposed throughout their lives to different levels of radon gas.
A summary of the data produced from the study is given in the table.

Exposure to radon gas	**Risk of lung cancer by age of 75**	
	Non-smoker	**Smoker**
No exposure	0.4 %	10 %
Moderate exposure	1.0 %	14 %
Very high exposure	1.5 %	32 %

(i) Why were people that have had **no exposure** to radon gas included in the study?

.....

.....

(1)

(ii) Using information from the table, what conclusions can be made about exposure to radon gas and the risk of getting lung cancer?

.....

.....

.....

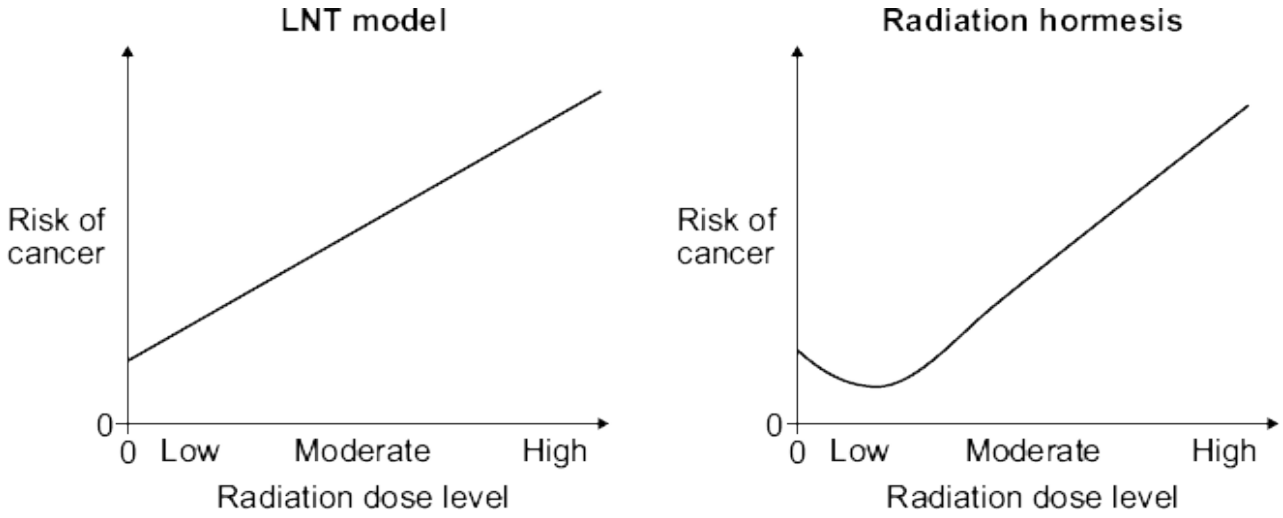
.....

.....

(2)

(c) At the moment, the regulations designed to protect people from over-exposure to radiation are based on a model called the 'linear no-threshold' (LNT) model.
Some scientists believe that the LNT model is too simple.These scientists believe that at low radiation levels a process called 'radiation hormesis' happens.

The graphs show that each model suggests a link between the risk of developing a cancer and exposure to low levels of radiation.



The link between the risk of developing cancer and exposure to low levels of radiation suggested by each of the models is different.

Describe how.

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(2)

(d) Scientists have conducted experiments in which mice have been exposed to different levels of radiation. The number of mice developing a cancer has then been measured.

Discuss whether it is ethical to use animals in scientific experiments.

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(2)
(Total 10 marks)

12 Food irradiation is a process that exposes food to radiation. Irradiation can be used to kill the bacteria that cause food poisoning or to slow down the ripening of fresh fruit and vegetables. Frozen foods and food inside packaging can also be irradiated.

(a) The table gives information about five radioactive isotopes.

Isotope	Half-life	Radiation emitted
Caesium-134	2.1 years	beta
Cobalt-60	5.3 years	gamma
Curium-242	160 days	alpha
Strontium-90	28 years	beta
Technetium-99	6 hours	gamma

Which of these radioactive isotopes would be most suitable for irradiating food?

.....

Explain the reasons for your choice.

.....

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(3)

(b) Many people think that food should not be irradiated. Consumer groups have said that they are worried about the nutritional value and safety of eating irradiated foods.

(i) Suggest **one** reason why some people may be concerned about the safety of eating irradiated food.

.....

.....

(1)

(ii) Independent scientific committees in several countries, including Sweden, Canada and the UK, have concluded that it is safe to eat irradiated food.

These scientific committees need to be independent from government influence.

Suggest why.

.....

.....

(1)

(iii) One group of scientists has compared the vitamin content of non-irradiated foods with irradiated foods.

The table below gives the data obtained for 1 kg of cooked chicken.

Vitamin	**Non-irradiated food in milligrams**	**Irradiated food in milligrams**
B6	1.22	1.35
B12	21.00	28.00
E	3.30	2.15
Niacin	58.00	55.50
Riboflavin	2.10	2.25

Considering only the data in the table, is it valid to conclude that irradiated food is less nutritional than non-irradiated food?

Explain your answer.

.....

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(2)

(iv) In a restaurant, meals with ingredients that have been irradiated must be clearly identified on the menu.

It is important that people eating in a restaurant are given this information.

Suggest why.

.....

.....

(1)

(c) The isotope caesium-137 decays by emitting beta radiation.
Caesium-137 has a half-life of 30 years.

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

.....

.....

(1)

(ii) A sample containing caesium-137 has a count rate of 600 counts per minute.

Calculate how long it would take for the count rate from the sample to fall to 75 counts per minute.

Show clearly how you work out your answer.

.....

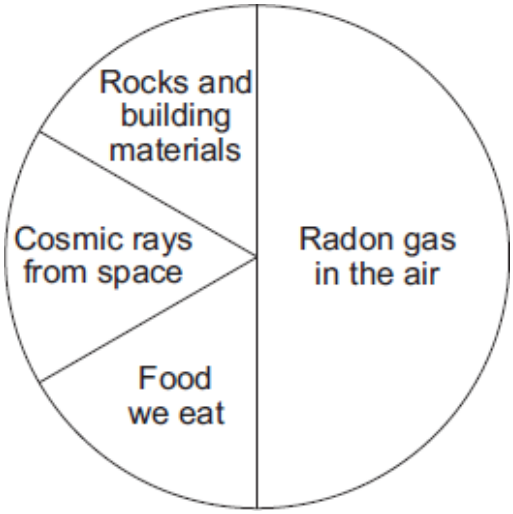
.....

.....

Time taken = ... years

(2)
(Total 11 marks)

13 The pie chart shows the average proportions of natural background radiation from various sources in the UK.



(a) (i) Complete the following sentence.

On average, ... of the natural background radiation in the UK comes from radon gas.

(1)

(ii) Radon gas is found inside homes.

The table shows the results from measuring the level of radon gas inside four homes in one area of the UK.

Home	Level of radon gas in Bq per m^3 of air
1	25
2	75
3	210
4	46
Mean	89

One of the homes has a much higher level of radon gas than the other three homes.

What should be done to give a more reliable mean for the homes in this area of the UK?

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

ignore the data for home number 3 ☐

measure the radon gas level in more homes in this area ☐

include data for homes from different areas of the UK ☐

(1)

(b) Each atom of radon has 86 protons and 136 neutrons.

(i) How many electrons does each atom of radon have?

Draw a ring around your answer.

50 **86** **136** **222**

(1)

(ii) How many particles are there in the nucleus of a radon atom?

Draw a ring around your answer.

50 **86** **136** **222**

(1)
(Total 4 marks)

14 (a) Background radiation is all around us all the time.

(i) Radon is a natural source of background radiation.

Name another natural source of background radiation.

.....

(1)

(ii) X-rays are an artificial source of background radiation.

Name another artificial source of background radiation.

.....

(1)

(iii) An atom of radon-222 decays by emitting an alpha particle.
The equation representing the decay is shown below.

$$^{222}_{86}\text{Rn} \longrightarrow {}^{218}_{84}\text{X} + \text{alpha particle}$$

How can you tell from the equation that 'X' is not an atom of radon?

.....

.....

(1)

(b) Having an X-ray taken increases your exposure to radiation.

The table gives:

- the radiation doses received for 6 different medical X-rays;
- the number of days' of exposure to natural background radiation each dose is equivalent to.

Medical X-ray	Radiation dose received (in arbitrary units)	Equivalent number of days of exposure to natural background radiation
Chest	2	2.4
Skull	7	8.4
Pelvis	22	26.4
Hip	44	52.8
Spine	140	
CT head scan	200	240

A hospital patient has an X-ray of the spine taken.
Calculate the number of days of exposure to natural background radiation that an X-ray of the spine is equivalent to.

Show how you work out your answer.

.....

.....

.....

Equivalent number of days = ...

(2)

(c) Scientists have shown that X-rays increase the risk of developing cancer.
The scientists came to this conclusion by studying the medical history of people placed in one of two groups, **A** or **B**.
The group into which people were put depended on their X-ray record.

(i) Person **J** has been placed into group **A**.
Place each of the people, **K**, **L**, **M**, **N** and **O**, into the appropriate group, **A** or **B**.

Person	**J** 	**K** 	**L** 	**M** 	**N** 	**O** 
Medical X-ray record	3 arm	None	None	2 skull	None	4 leg

Group A	**Group B**
J	

(1)

(ii) To be able to make a fair comparison, what is important about the number of people in each of the two groups studied by the scientists?

.....

.....

(1)

(iii) What data would the scientists have compared in order to come to the conclusion that X-rays increase the risk of developing cancer?

.....

.....

(1)

(iv) The chance of developing cancer due to a CT head scan is about 1 in 10 000.
The chance of developing cancer naturally is about 1 in 4.

A hospital patient is advised by a doctor that she needs to have a CT head scan.
The doctor explains to the patient the risks involved.

Do you think that the patient should give her permission for the CT scan to be taken?

Draw a ring around your answer.

Yes **No**

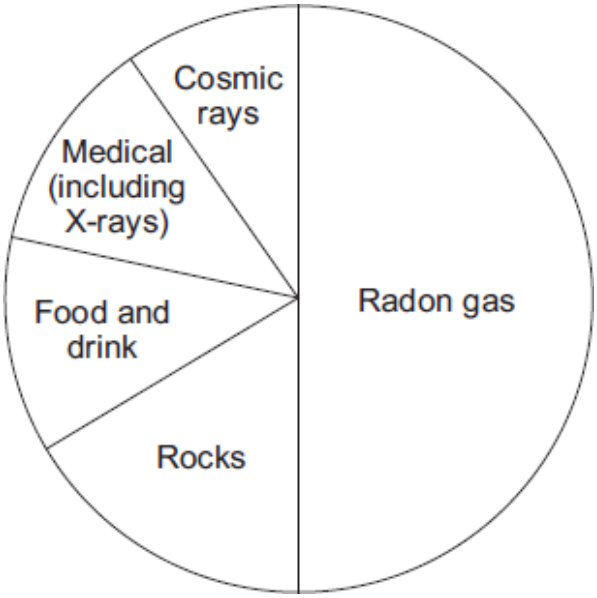
Give a reason for your answer.

.....

.....

(1)
(Total 9 marks)

15 The pie chart shows the average proportions of background radiation from various sources in the UK.



Three sources of background radiation are given in **List A**.
Statements about sources of background radiation are given in **List B**.

Draw **one** line to link each source of background radiation in **List A** to the statement about that source given in **List B**.

Draw only **three** lines.

List A	**List B**
	Are used to show broken bones.
X-rays	
	The radiation comes from outer space.
Cosmic rays	
	Comes from soil containing a radioactive isotope of potassium.
Radon gas	
	Gives about 50 % of all background radiation.

(Total 3 marks)

16 (a) A doctor uses the radioactive isotope technetium-99 to find out if a patient's kidneys are working correctly.

The doctor injects a small amount of technetium-99 into the patient's bloodstream.

Technetium-99 emits *gamma radiation.*

Give **two** reasons why an isotope that emits gamma radiation is injected into the patient rather than an isotope that emits alpha radiation.

1.....

.....

2.....

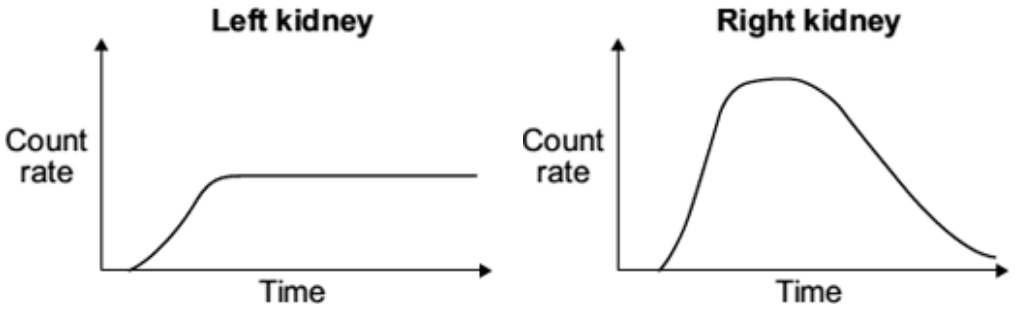
.....

(2)

(b) If the patient's kidneys are working correctly, the technetium-99 will pass from the bloodstream into the kidneys and then into the patient's urine.

Detectors are used to measure the radiation emitted from the kidneys.

The level of radiation emitted from each kidney is recorded on a graph.



(i) How do the graphs show that technetium-99 is passing from the bloodstream into each kidney?

.....

.....

(1)

(ii) By looking at the graphs, the doctor is able to tell if there is a problem with the patient's kidneys.

Which **one** of the following statements is correct?

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

Only the right kidney is working correctly. ☐

Only the left kidney is working correctly. ☐

Both kidneys are working correctly. ☐

Explain the reason for your answer.

.....

.....

.....

.....

(3)

(c) The patient was worried about having a radioactive isotope injected into their body. The doctor explained that the risk to the patient's health was very small as technetium-99 has a short *half-life.*

(i) What does the term *half-life* mean?

.....

.....

(1)

(ii) Explain why it is important that the doctor uses an isotope with a short half-life rather than an isotope with a long half-life.

.....

.....

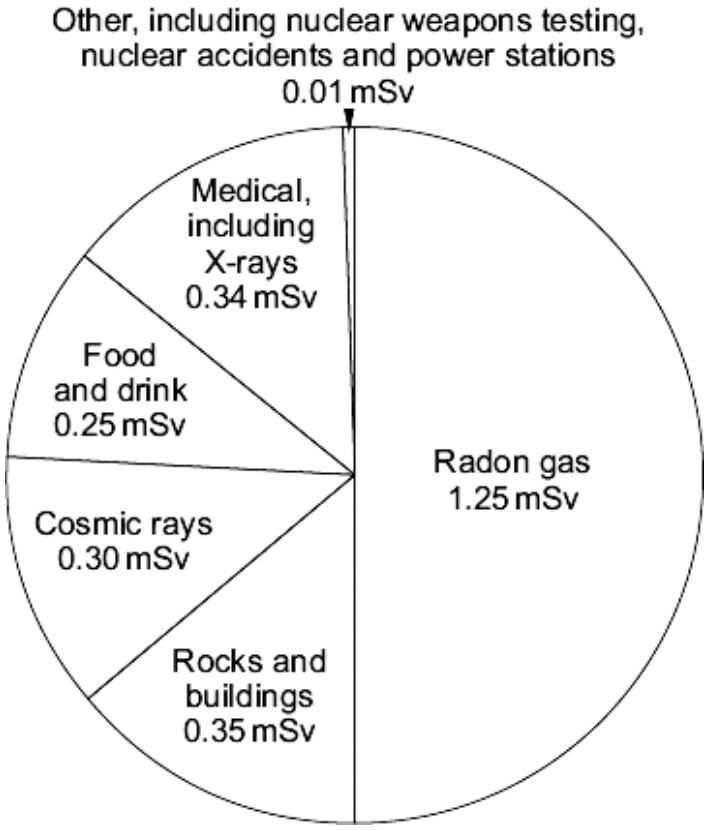
.....

.....

(2)

(Total 9 marks)

17 The pie chart shows the sources of the background radiation and the radiation doses that the average person in the UK is exposed to in one year.
Radiation dose is measured in millisieverts (mSv).



(a) (i) What is the total radiation dose that the average person in the UK receives?

.....

.....

Total radiation dose = ... mSv

(1)

(ii) A student looked at the pie chart and then wrote down three statements.

Which **one** of the following statements is a correct conclusion from this data?

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

In the future, more people will be exposed to a greater proportion of radon gas. ☐

People that have never had an X-ray get 50% of their radiation dose from radon gas. ☐

The radiation dose from natural sources is much greater than from artificial sources. ☐

(1)

(b) The concentration of radon gas inside a home can vary from day to day. In some homes, the level can build up to produce a significant health risk. It is estimated that each year 1000 to 2000 people die because of the effects of radiation from radon gas.

(i) It is not possible to give an exact figure for the number of deaths caused by the effects of radiation from radon gas. Why?

.....

.....

(1)

The table gives data for the radiation levels measured in homes in 4 different parts of the UK. The radiation levels were measured using two detectors, one in the living room and one in the bedroom. The measurements were taken over 3 months.

Area of the UK	Number of homes in the area	Number of homes in the sample	Average radiation level in Bq/m^3	Maximum radiation level in Bq/m^3
A	590 000	160	15	81
B	484 000	130	18	92
C	221 000	68 000	162	10 000
D	318 000	35 300	95	6 900

(ii) Give **one** reason why the measurements were taken over 3 months using detectors in different rooms.

.....

.....

(1)

(iii) Use information from the table to suggest why a much higher proportion of homes were sampled in areas **C** and **D** than in areas **A** and **B**.

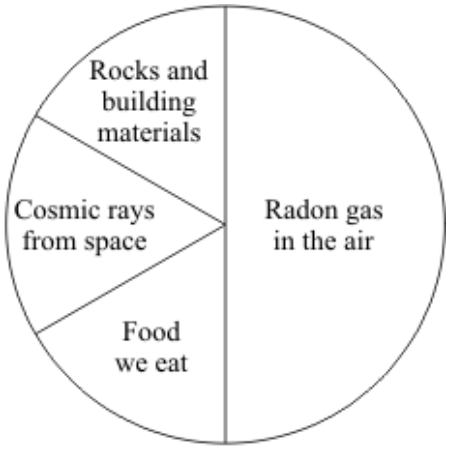
.....

.....

.....

(2)
(Total 6 marks)

18 (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.

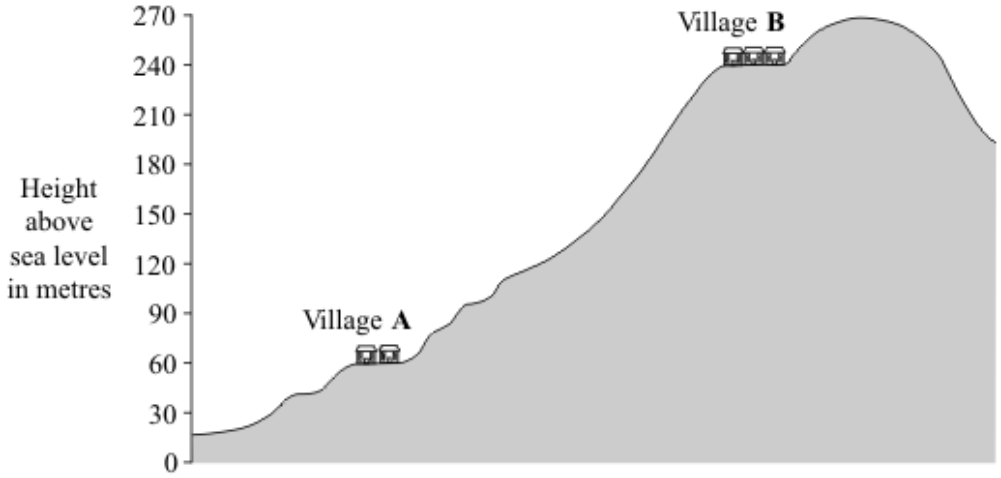
.....

.....

(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.

.....

.....

.....

.....

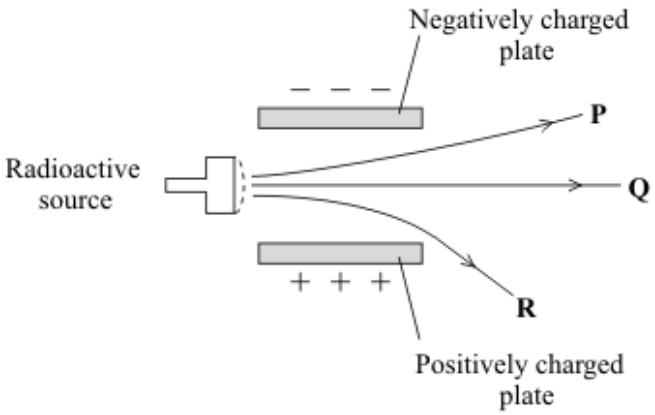
.....

.....

(3)
(Total 5 marks)

19 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:

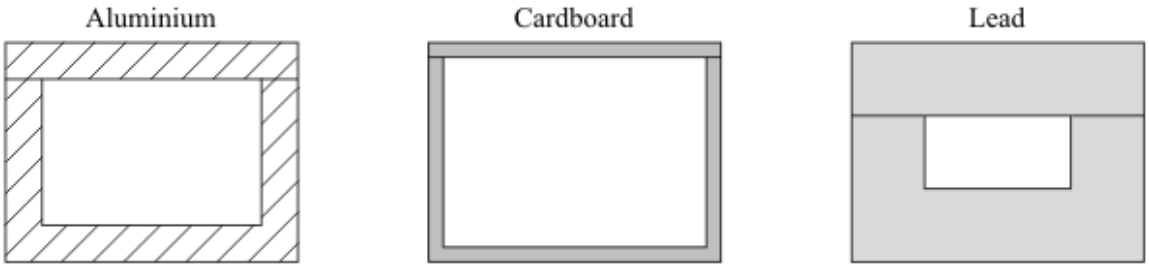
(i) alpha radiation .....

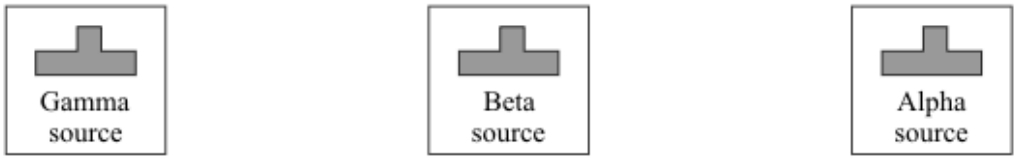
(1)

(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.

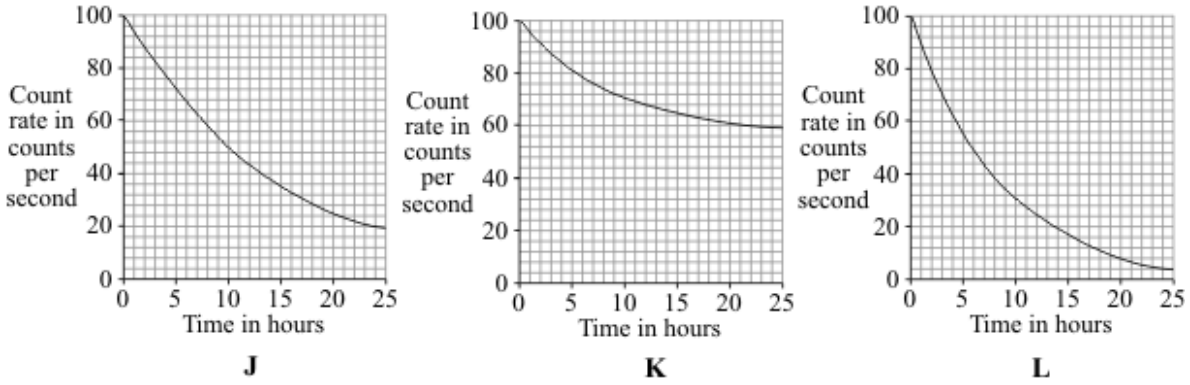




Draw **three** lines to show which source should be stored in which box so that the minimum amount of radiation gets into the air.

(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)

20 (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.

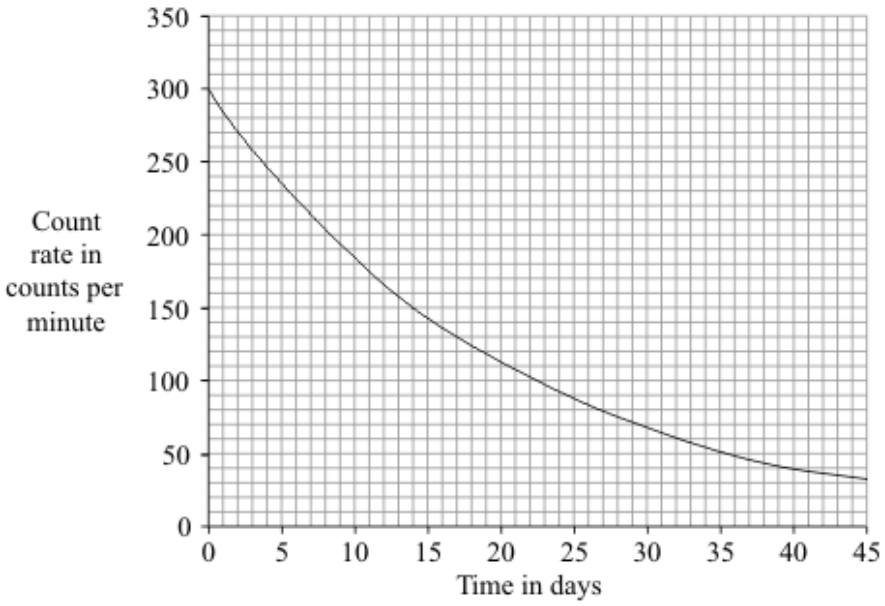
(i) How is an atom of phosphorus-32 different from an atom of the stable isotope phosphorus-31?

.....

.....

(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.

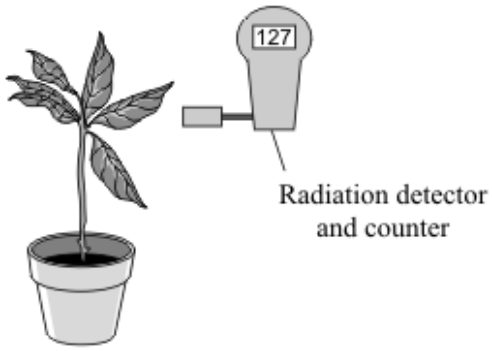
.....

.....

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)

21 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)

22 (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)

23 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.

.....

.....

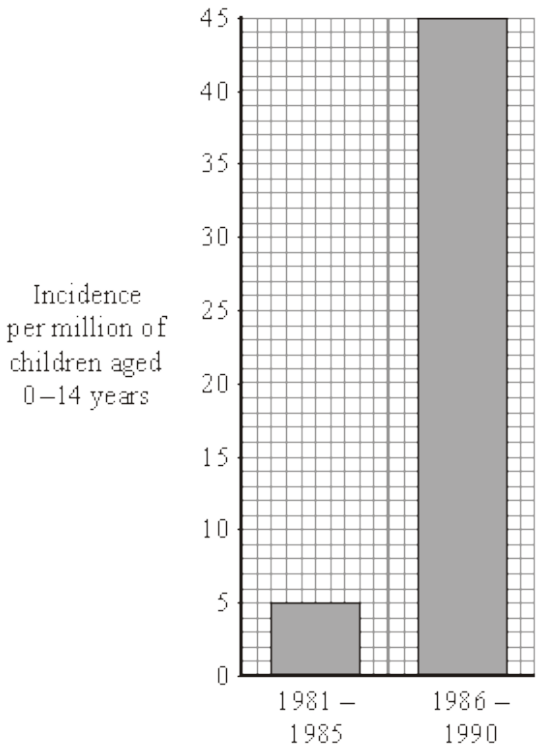
.....

.....

.....

(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)

24 (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.

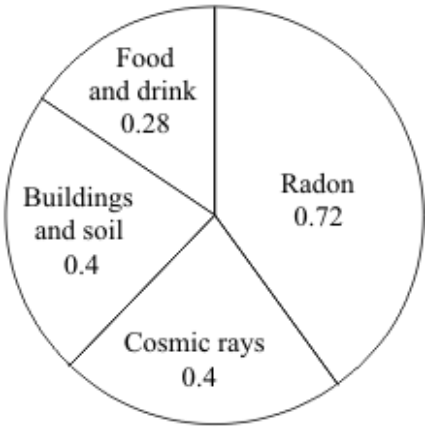
How is the structure of the nucleus of a polonium-218 atom different from the structure of the nucleus of a radon-222 atom?

.....

(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)

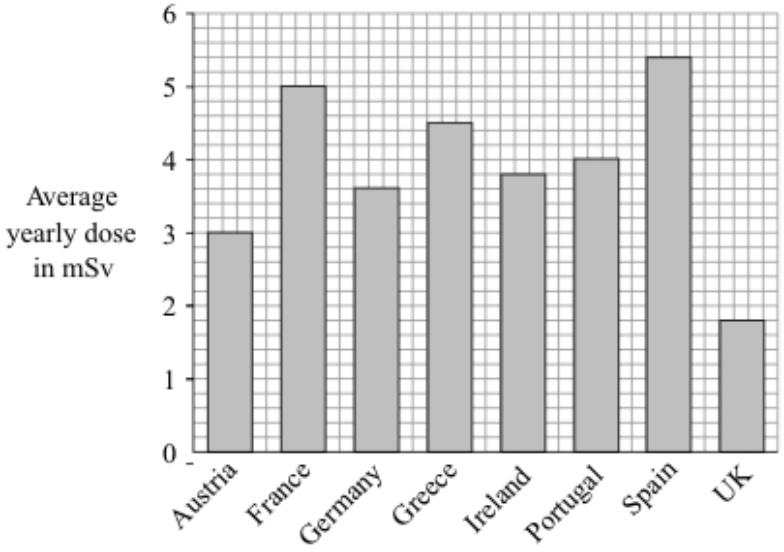
(ii) Not all background radiation is from natural sources.

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)

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.

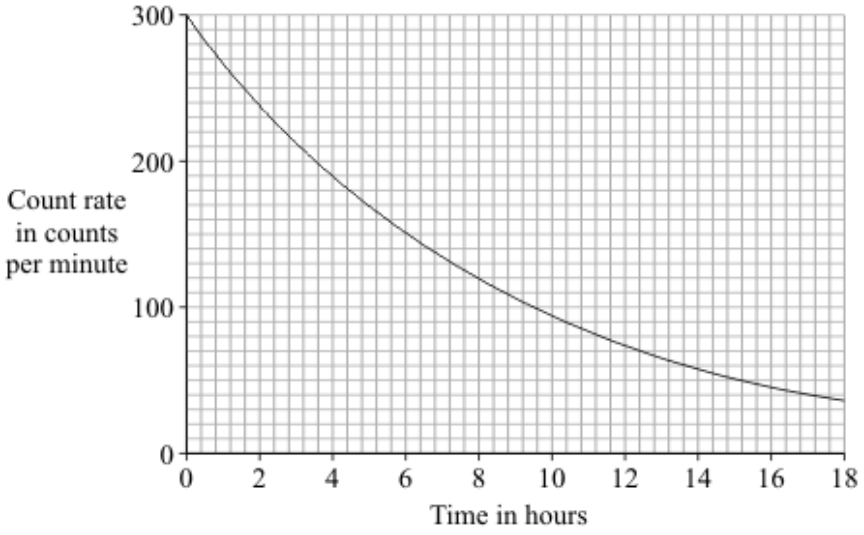
It can travel through a vacuum. ☐

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?

.....

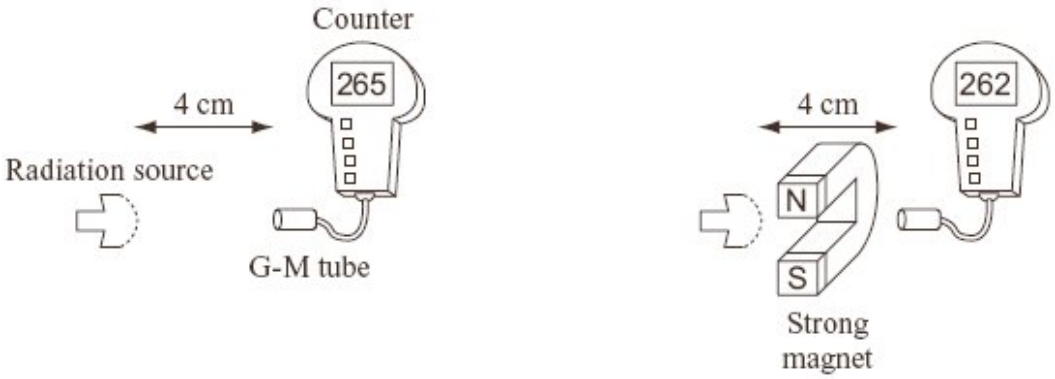
(1)

(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.

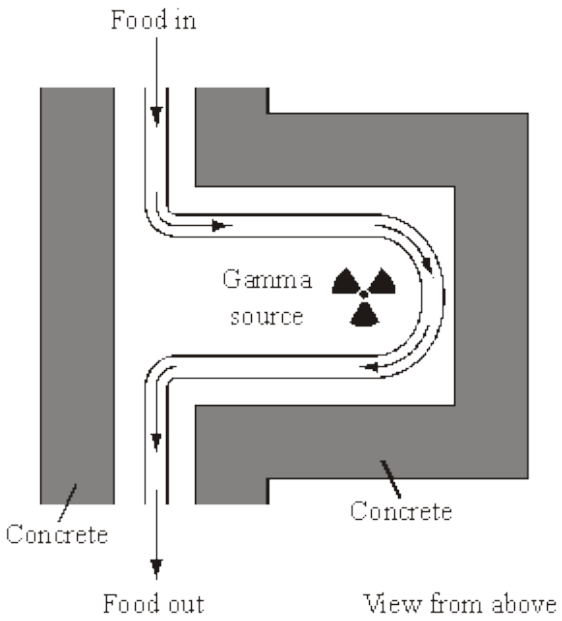
Complete the following sentence by choosing the correct word from the box.

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.

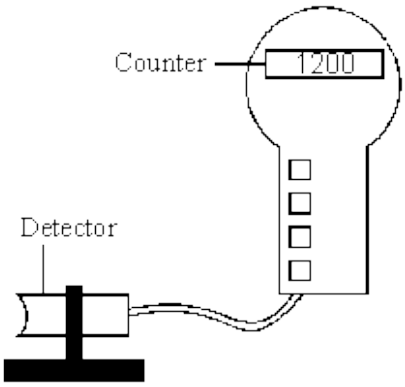
Why is it important for people to know which foods have been treated with radiation?

.....

.....

(1)
(Total 8 marks)

28 The diagram 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)

29 (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.

.....

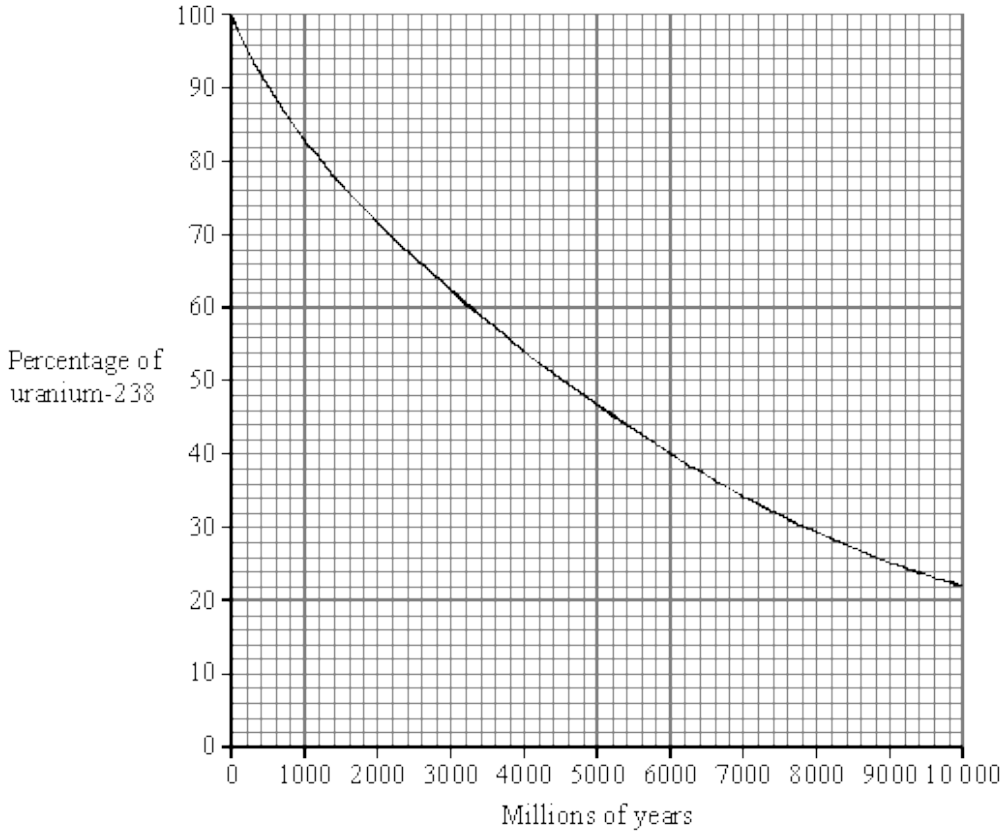
.....

.....

.....

(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.

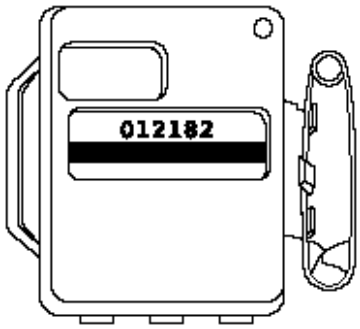
.....

.....

Age of rock = ... million years

(2)
(Total 7 marks)

30 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)

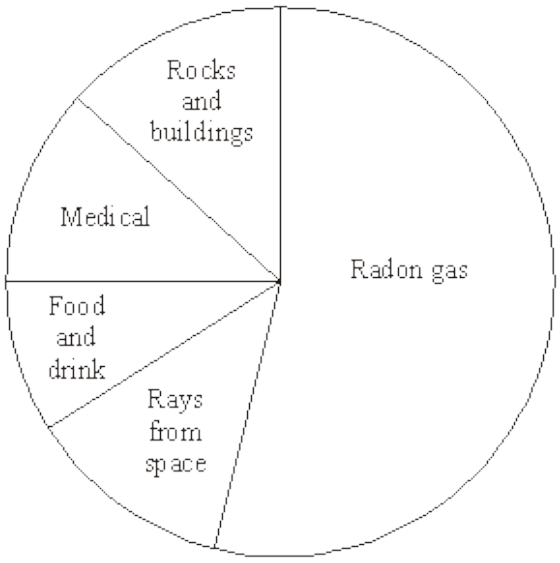
(iii) Why is it important to monitor the amount of radiation the worker has been exposed to?

.....

.....

(1)
(Total 3 marks)

31 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?

.....

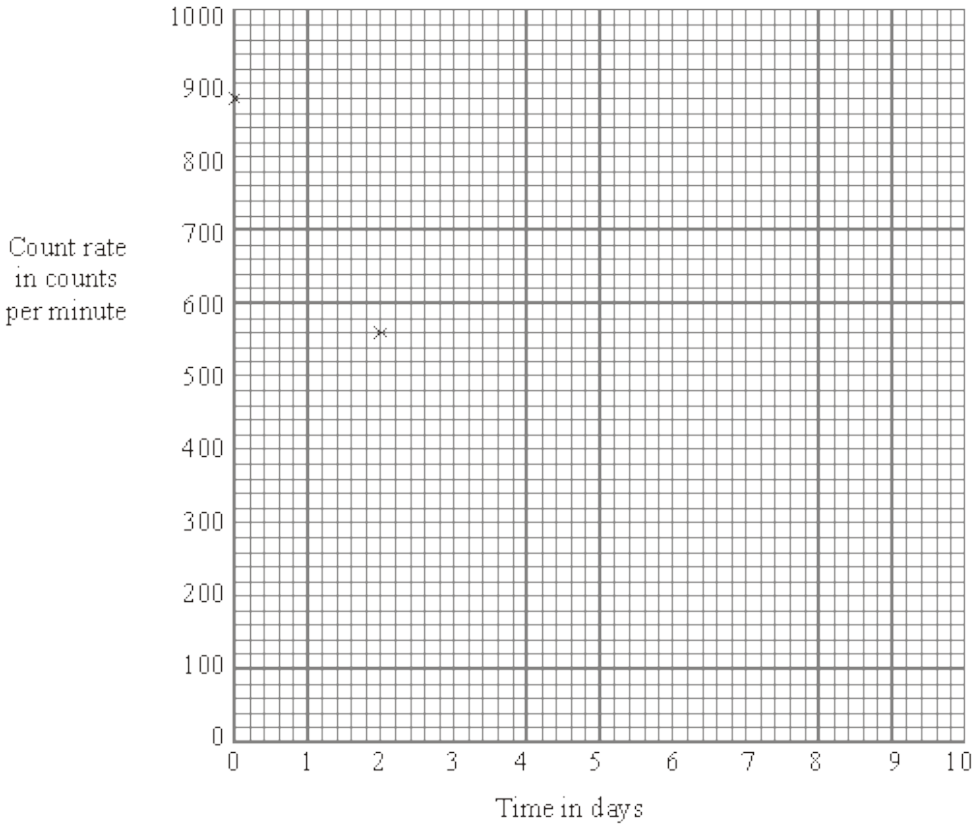
(1)
(Total 2 marks)

32 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?

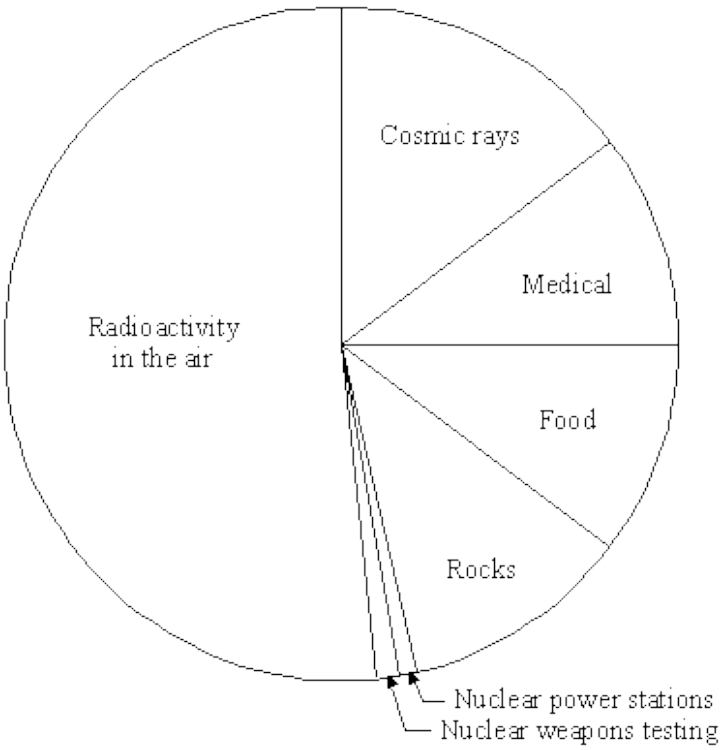
.....

Give a reason for your answer.

.....

(2)
(Total 7 marks)

33 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.

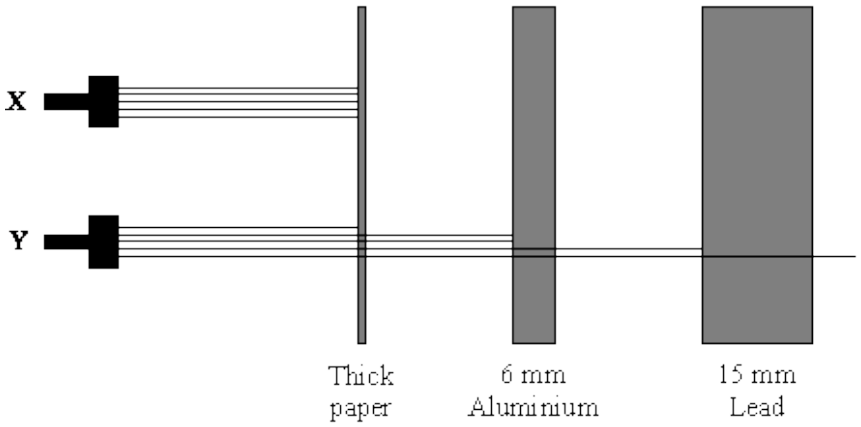
.....

(1)
(Total 2 marks)

34 (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**.



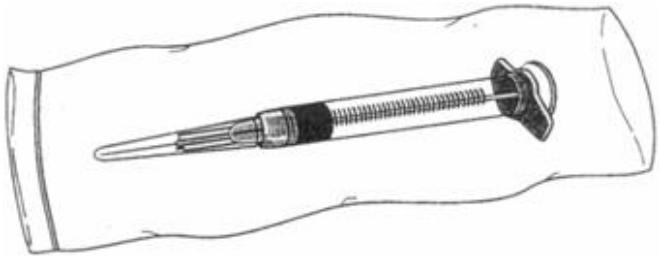
What types of radiation are emitted by each of the sources?

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.

.....

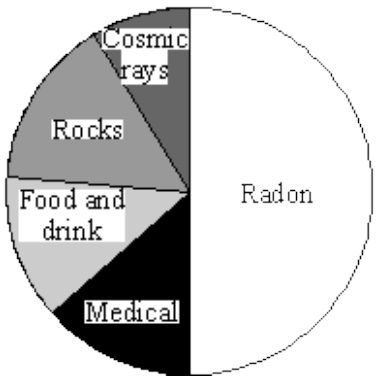
.....

.....

.....

(3)
(Total 5 marks)

35 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.

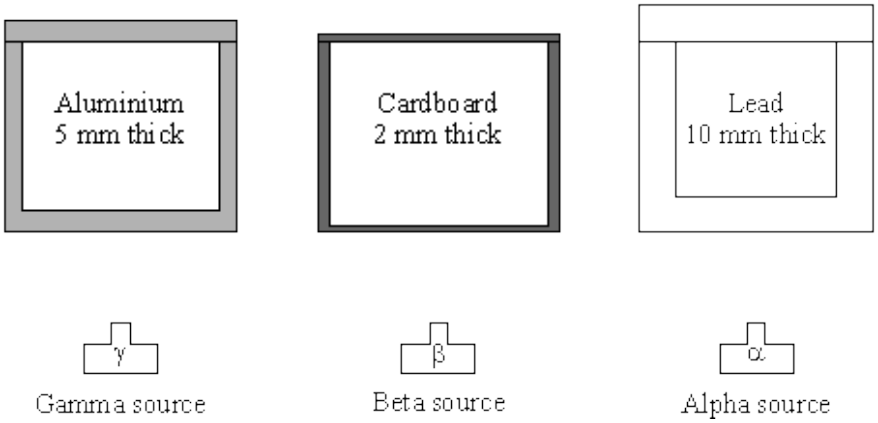
.....

.....

.....

(2)
(Total 3 marks)

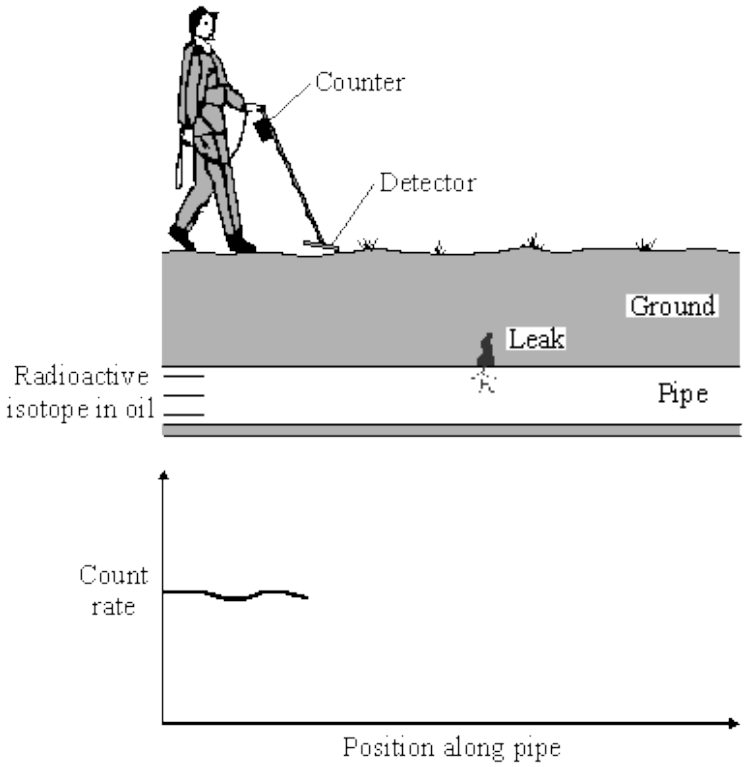
36 (a) The diagram shows three different boxes and three radioactive sources. Each source is stored in a different box.



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.

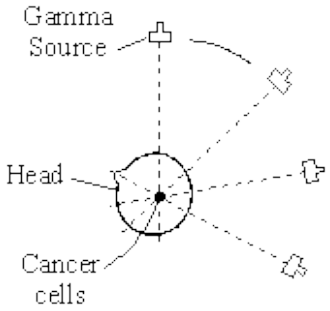
.....

(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)

37 (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.

.....

.....

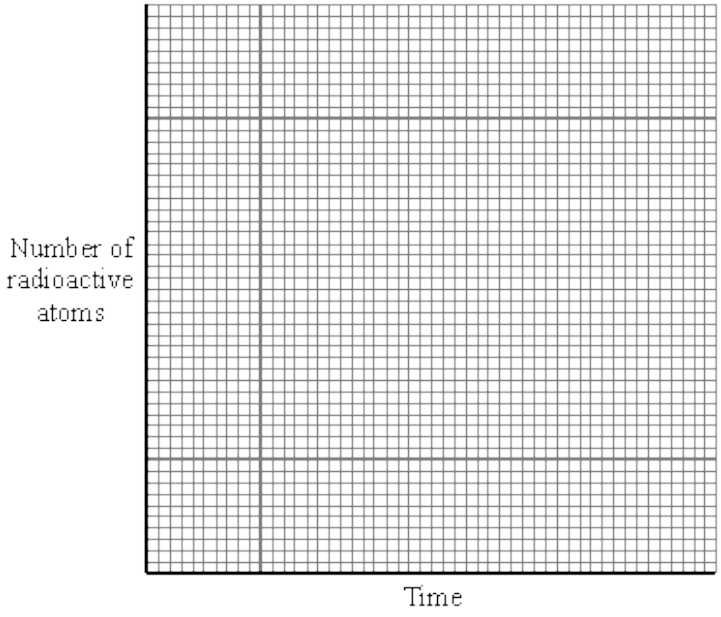
.....

.....

.....

(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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.....

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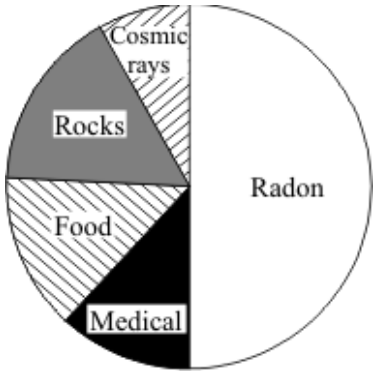
(3)
(Total 10 marks)

38 (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)

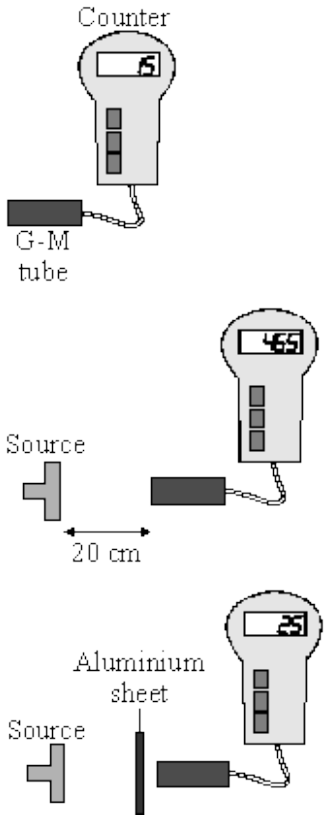
(ii) Name **two** natural sources of background radiation in the pie-chart.

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.

.....

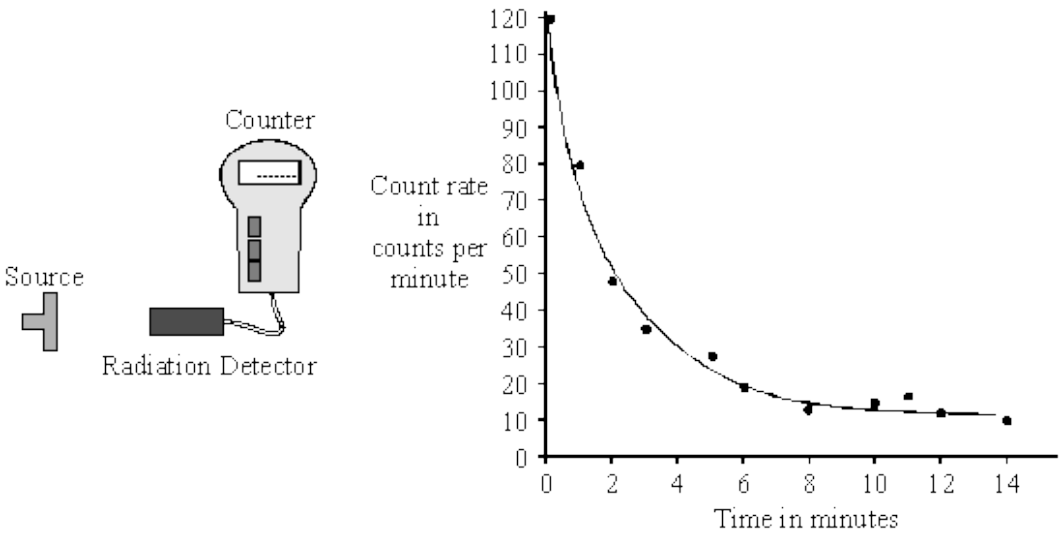
.....

.....

.....

(4)
(Total 7 marks)

39 (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)

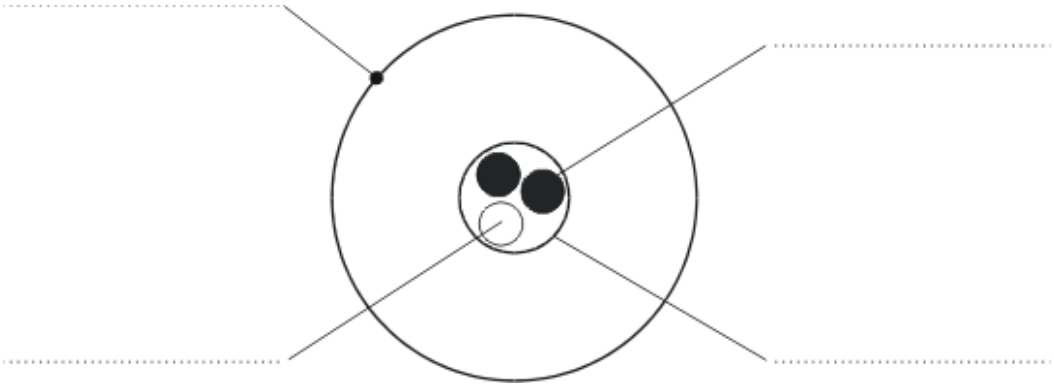
[B] ten seconds. .....

.....

(1)
(Total 10 marks)

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

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



(4)

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

.....

.....

.....

(2)

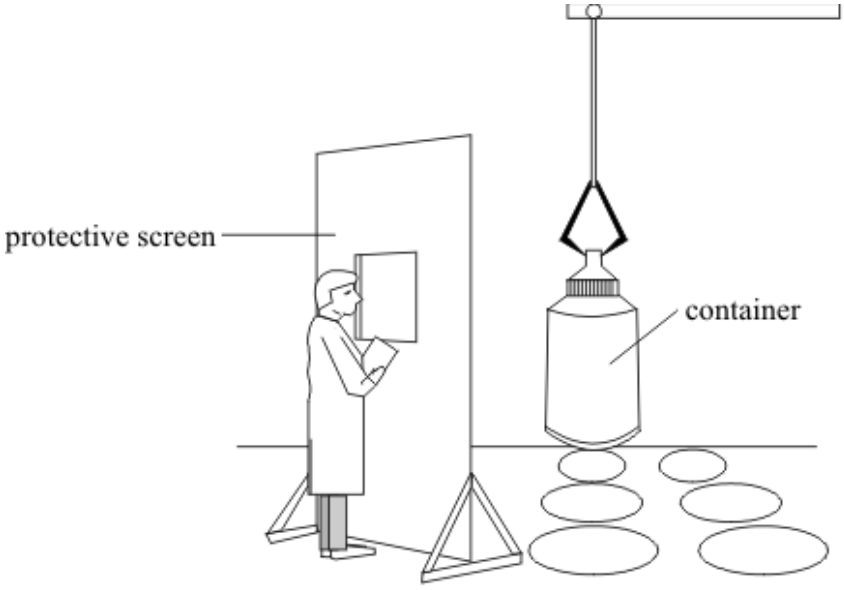
(iii) Tritium is a radioactive substance which emits beta (β) radiation.
Why do the atoms of some substances give out radiation?

.....

.....

(2)

(b) Tritium is one of the elements found in the waste material of the nuclear power industry. The diagram below shows a worker behind a protective screen. The container holds a mixture of different waste materials which emit alpha (α), beta (β) and gamma (γ) radiation.



Suggest a suitable material for the protective screen. The material should prevent radiation from the container reaching the worker. Explain your answer.

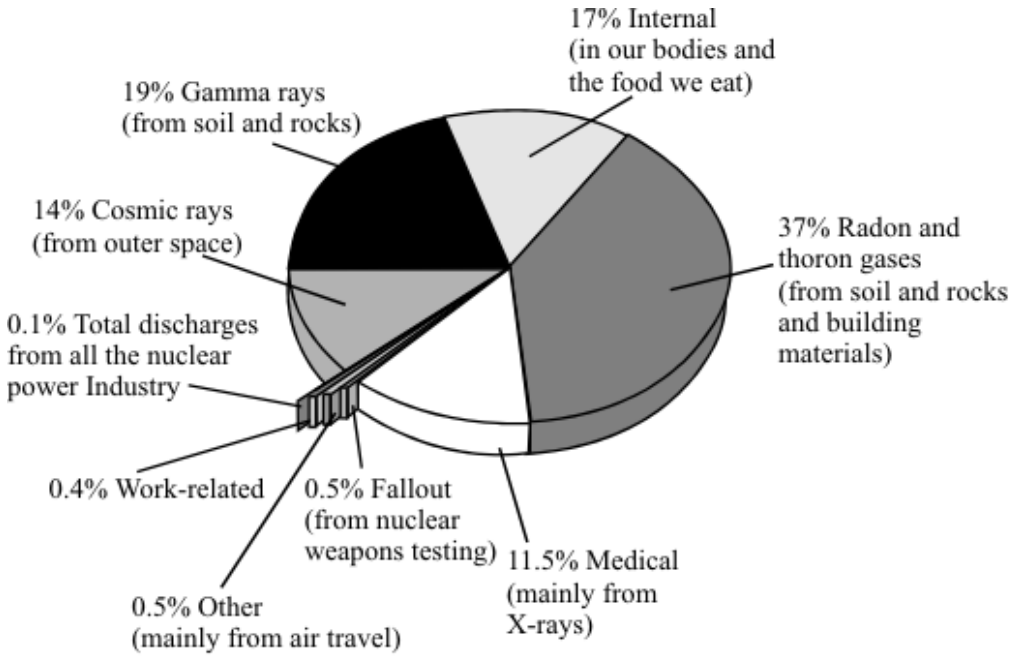
.....

.....

.....

(2)
(Total 10 marks)

41 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?

.....

.....

.....

.....

.....

(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.

.....

.....

(2)

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

.....

.....

.....

.....

(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.

.....

.....

.....

(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.

.....

.....

.....

(3)
(Total 15 marks)

42 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.

.....

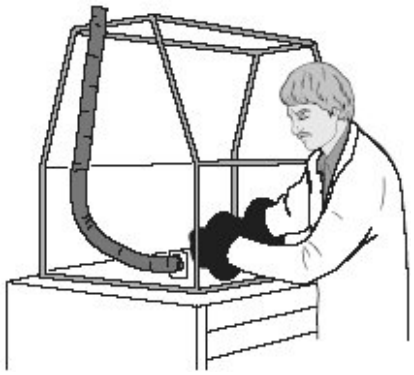
.....

.....

.....

(Total 3 marks)

43 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.

.....

.....

.....

.....

.....

.....

(Total 4 marks)

44 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.

.....

.....

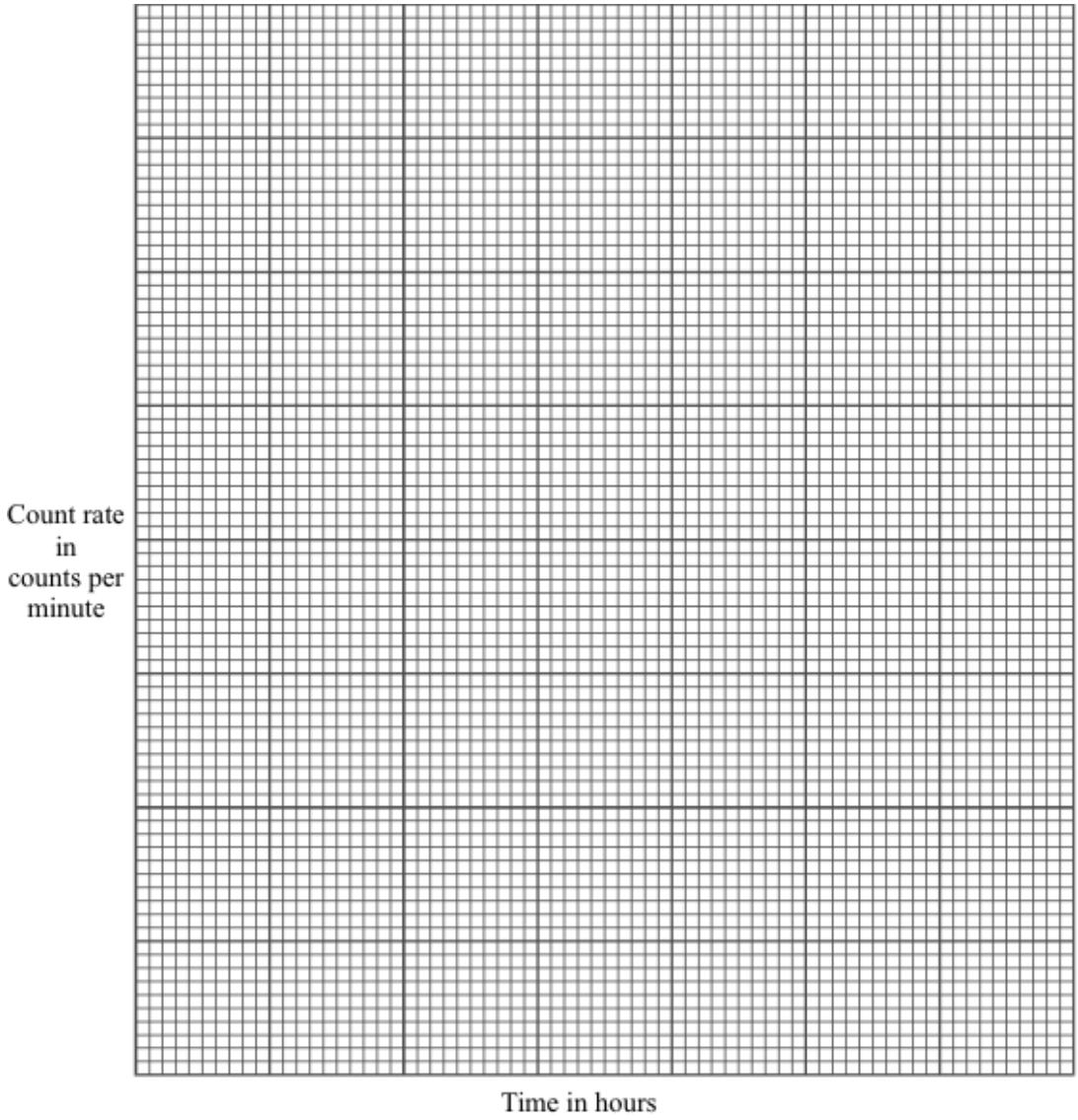
.....

(2)
(Total 4 marks)

45 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

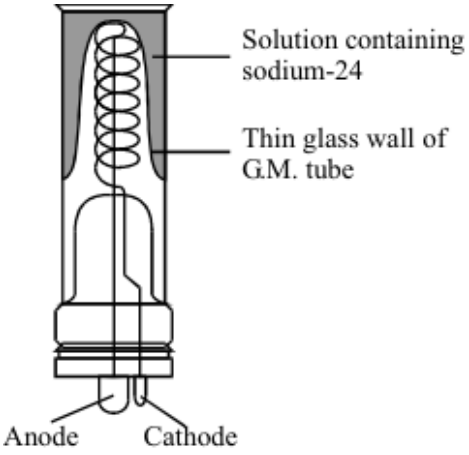
(a) Draw a graph of the results and find the half-life for the isotope. On the graph show how you obtain the half-life.



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. .....

.....

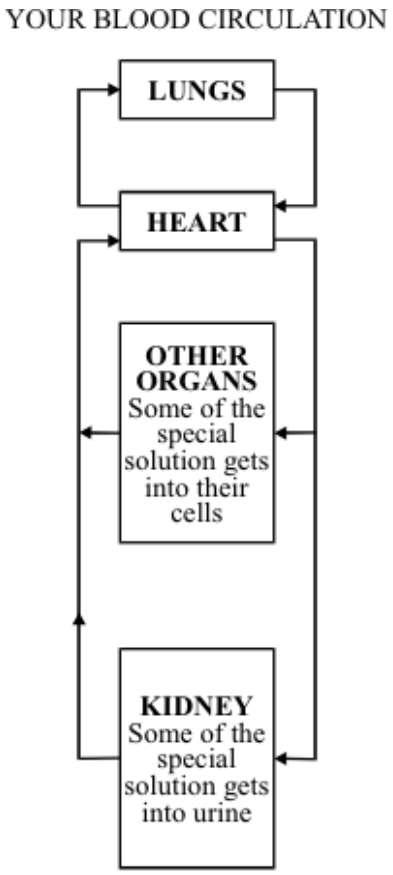
(1)

(Total 8 marks)

46 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.)

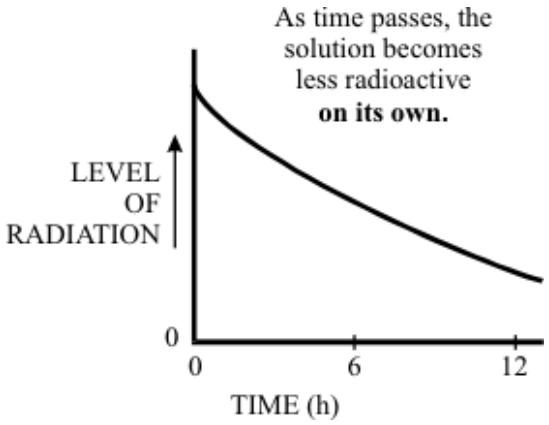
.....

.....

.....

.....

(4)



Radiation from radioactive substances can harm your body cells.

(b) The doctor's method of estimating blood volume will not be completely accurate.
Write down **three** reasons for this.

1 .....

2 .....

3 .....

(3)

(c) The doctors use a radioactive substance which loses half of its radioactivity every six hours. Explain why this is a suitable radioactive substance to use.

.....

.....

(2)
(Total 9 marks)

47 (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.

.....

.....

.....

.....

.....

.....

(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?

.....

.....

(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.)

.....

.....

.....

.....

.....

(2)
(Total 8 marks)

Mark schemes

1

(a) Nucleus splitting into two fragments and releasing two or three neutrons

1

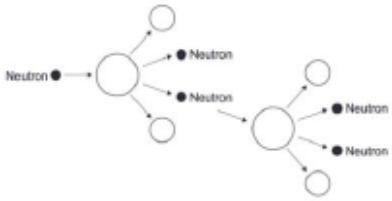
(at least one) fission neutron shown to be absorbed by additional large nucleus and causing fission

1

two or three additional neutrons released from fission reaction

1

*This diagram would gain all **3** marks:*



(b) lowering the control rods increases the number of neutrons absorbed

accept converse description

1

(so) energy released decreases

1

*allow changing the position of the control rods affects the number of neutrons absorbed for **1** mark*

(c) rate of increase between 240 and 276 (MW / min)

2

*allow **1** mark for attempt to calculate gradient of line at 10 minutes*

[7]

2

(a) (average) time taken for the amount / number of nuclei / atoms (of the isotope in a sample) to halve
or
time taken for the count rate (from a sample containing the isotope) to fall to half

accept (radio)activity for count rate

1

(b) *60 ±3* (days)

1

indication on graph how value was obtained

1

(c) (i) cobalt(-60)

1

gamma not deflected by a magnetic field
or
gamma have no charge

dependent on first marking point

accept (only) emits gamma

gamma has no mass is insufficient

*do **not** accept any reference to half-life*

1

(ii) strontium(-90)

1

any **two** from:

- *only* has beta
- alpha would be absorbed
- gamma unaffected
- *beta penetration / absorption depends on thickness of paper*

*if thorium(-232) or radium(-226) given, max **2** marks can be awarded*

2

(iii) cobalt(-60)

1

shortest half-life

accept half-life is 5 years

dependent on first marking point

1

so activity / count rate will decrease quickest

1

(iv) *americium(-241) / cobalt(-60) / radium(-226)*

1

gamma emitter

1

(only gamma) can penetrate lead *(of this box)*

do not allow lead fully absorbs gamma

1

[14]

3 (a) (i) nuclear reactor

1

star

1

(ii) nuclei are joined (not split)

accept converse in reference to nuclear fission

*do **not** accept atoms are joined*

1

(b) (i) any **four** from:

- neutron
- (neutron) absorbed by U (nucleus)

  ignore atom
  *do **not** accept reacts*
  *do **not** accept added to*
- forms a larger nucleus
- (this larger nucleus is) unstable
- (larger nucleus) splits into two (smaller) nuclei / into Ba and Kr
- releasing three neutrons and energy

  accept fast-moving for energy

4

(ii) 56 (Ba)

1

57 (La)

*if proton number of Ba is incorrect allow **1** mark if that of La is 1 greater*

1

$^{0}_{-1}\beta$

accept e for β

$^{139}_{56}Ba \longrightarrow {}^{139}_{57}La + {}^{0}_{-1}\beta$

*scores **3** marks*

1

[10]

4 (a) (i) 18

1

(ii) the count rate for the source

1

(iii) the alpha radiation would not cover such a distance

1

(iv) plots correct to within ½ small square

*allow **1** mark for 4 correct points plotted*

2

correct curve through points as judged by eye

1

(v) two attempts at finding 'half-distance' using the table

20 to 10 cpm d = 0.4 m
125 to 56 cpm d = 0.2 m
31 to 14 cpm d = 0.4 m

*allow **1** mark for one attempted comparison*

2

obeyed or not obeyed

dependent on previous two marks

1

(b) (i) there is no effect on the count rate in experiment 1 because the field is parallel **or** beta particles are not deflected **or** there is no force

1

count rate is reduced in experiment 2 because field is perpendicular **or** beta particles are deflected **or** there is a force

1

(ii) only background radiation (as beta do not travel as far)

1

slightly different values show the random nature of radioactive decay

1

[13]

5 (a) cosmic rays

1

radon gas

1

(b) (i) Radioactive decay is a random process

1

(ii) 19

1

(iii) 140

accept 159 – their (b)(i) correctly calculated

1

(iv) gamma

1

the count stayed the same

1

or

gamma does not have a charge

accept gamma is an electromagnetic wave

(so) gamma is not deflected / affected by the magnetic field

accept magnet for magnetic field

*do **not** accept is not attracted to the magnet*

last two marks may be scored for an answer in terms of why it cannot be alpha or beta

only answer simply in terms of general properties of gamma are insufficient

1

(c) lead absorbs (some of the) radiation

accept radiation cannot pass through (the lead)

or

less radiation emitted into the (storage) room

1

(d) Should radioactive waste be dumped in the oceans

1

[10]

6

(a) (i) any **one** from:

- nuclear power (stations)

  accept nuclear waste
  accept coal power stations

- nuclear weapons (testing)

  accept nuclear bombs / fallout

- nuclear accidents

  accept named accident, eg Chernobyl or Fukushima

  accept named medical procedure which involves a radioactive source
  accept radiotherapy
  accept X-rays
  accept specific industrial examples that involve a radioactive source

  nuclear activity / radiation is insufficient

  smoke detectors is insufficient

1

(ii) (radioactive decay) is a random process

accept an answer in terms of background / radiation varies (from one point in time to another)

1

(b) any **one** from:

- (maybe) other factors involved

  accept a named 'sensible' factor, eg smoking

- evidence may not be valid

  accept not enough data

- may not have (a complete) understanding of the process (involved)

1

(c) (i) 2

1

2

1

(ii) 218

correct order only

1

84

1

(d) 3.8 (days)

*allow **1** mark for showing correct method using the graph provided no subsequent steps*

*correct answers obtained using numbers other than 800 and 400 gain **2** marks provided the method is shown*

2

[9]

7 (a) (both graphs show an initial) increase in count rate

accept both show an increase

1

(b) only the right kidney is working correctly

1

any **two** from:

*if incorrect box chosen maximum of **1** mark can be awarded*

reference to named kidney can be inferred from the tick box

- count-rate / level / line for right kidney decreases (rapidly)

  it decreases is insufficient

- count-rate / level / line for left kidney does not change

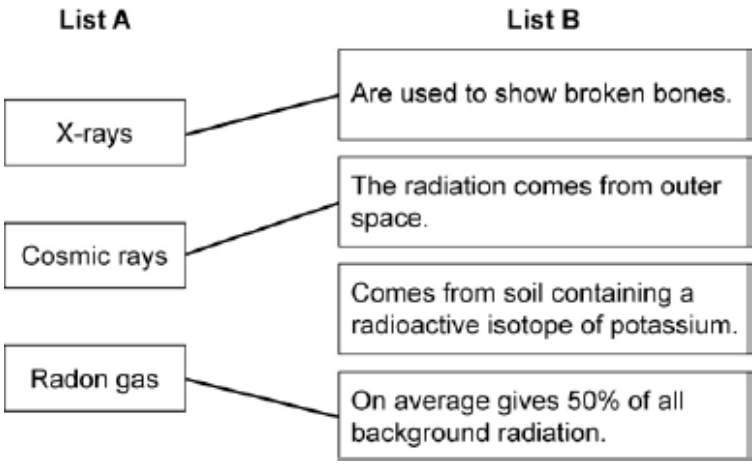
  it does not change is insufficient

- radiation is being passed out into urine – if referring to right kidney
- radiation is not being passed out – if referring to the left kidney
- left kidney does not initially absorb as much technetium-99

2

[4]

8 (a) 1 mark for each correct line



*if more than 1 line has been drawn from a box in **List A** then all those lines are marked incorrect*

3

(b) higher in village B

1

by 6 units

*allow **1** mark for correctly obtaining a height difference of 180 (m) / 4 times higher – this refers to height not radiation levels*

*accept for **3** marks in village A it is 2 units (extra) and in village B it is 8 units (extra) allow **1** mark for a correct radiation calculation based on incorrect height readings*

2

[6]

9 (a) (i) 2.5

1

(ii) The radiation dose from natural sources is much greater than from artificial sources

1

(b) (i) any **one** from:

- different concentrations in different rooms
- to average out daily fluctuations

accept to find an average

accept to make the result (more) reliable / valid

*do **not** accept to make more accurate on its own*

1

(ii) average level (much) higher (in **C** and **D**)

accept converse

1

some homes have very high level (in **C** and **D**)

*accept maximum level in **A** and **B** is low*

1

or

maximum level in some homes (in **C** and **D**) is very high

*accept higher radiation levels (in **C** and **D**) for **1** mark*

[5]

10 (a) (i) on average, cosmic rays produce less background radiation than rocks.

1

having no X-rays reduces a person's radiation dose.

1

(ii) 4

*allow **1** mark for 350 / 4*

*allow **1** mark for an answer 3.5*

2

(b) (i) (risk) increases

1

(ii) C

*reason only scores if **C** chosen*

1

shows a lower risk for low doses (than for zero exposure)

accept risk reduces when you go from low to moderate (doses)

1

(c) (i) *no mark for YES or NO, marks are for the explanation*

YES

fewer mice exposed first to a low dose

1

get cancer (than those only exposed to a high dose)

only scores if first marking point scores

NO

the results are for mice (1)

and may not be applicable to people (1)

1

(ii) ethical

1

[10]

11 (a) (i) 1.25 (mSv)

1

(ii) any **two** from:

- (frequent) flying
  accept stated occupation that involves flying
- living at altitude
- living in areas with high radon concentrations
  accept a specific area, eg Cornwall
- living in a building made from granite (blocks)
- having more than the average number of X-rays
  or
  having a CT scan
  accept more medical treatments
- working in a nuclear power station
  accept any suggestion that could reasonably increase the level from a specific source

2

(b) (i) to be able to see the effect of exposure (to radon gas)
or
as a control
accept to compare (the effect of) exposure (with no exposure)

1

(ii) increased levels of exposure increases the risk (of developing cancer)
accept exposure (to radon gas) increases the risk

1

smoking increases the (harmful) effect of radon
answers that simply reproduce statistics are insufficient

1

(c) LNT model – risk increases with increasing radiation (dose) level
accept in (direct) proportion
accept low doses increase the risk

1

Radiation hormesis - low radiation (dose) levels reduce the risk

1

(d) two valid points made – examples:

- animals have no choice and so should not be used
- should not make animals suffer
- better to experiment on animals than humans
- experiments lead to a better understanding / new knowledge
- experiments may lead to health improvement / cures for humans

results for animals may not apply to humans is insufficient

2

[10]

12 (a) cobalt-(60)

1

gamma (radiation) will pass through food / packaging

this can score if technetium chosen

1

long half-life so level of radiation (fairly) constant for (a number) of years

this can score if strontium / caesium is chosen
accept long half-life so source does not need frequent replacement
accept answers in terms of why alpha and beta cannot be used
gamma kills bacteria is insufficient

1

(b) (i) people may link the use of radiation with illness / cancer

accept (they think) food becomes radioactive
accept (they think) it is harmful to them
'it' refers to irradiated food

1

(ii) not biased / influenced (by government views)

1

(iii) any **two** from:

- data refers only to (cooked) chicken
- data may not generalise to other foods
- the content of some vitamins increases when food / chicken is irradiated
- no vitamins are (completely) destroyed
- (only) two vitamins decrease (but not significantly)

accept irradiated chicken / food contains a higher level of vitamins
marks are for the explanation only

2

(iv) so can choose to eat / not eat that (particular) food

accept irradiated food may cause health problems (for some people)

accept people may have ethical issues (over eating irradiated food)

1

(c) (i) electron
from nucleus / neutron

***both** parts required*

1

(ii) 90 years

*allow **1** mark for showing 3 half-lives*

2

[11]

13 (a) (i) half / 50 %

1

(ii) Measure the radon gas level in more homes in this area

1

(b) (i) 86

1

(ii) 222

1

[4]

14 (a) (i) any **one** from:

- food / drink
- rocks / building materials
- cosmic rays / rays from space

accept correctly named example

1

(ii) any **one** from:

- nuclear power / coal power (stations)
  accept nuclear waste
- nuclear accidents
  accept named accident eg Chernobyl
- nuclear weapons testing
  accept named medical procedure which involves a radioactive source
  accept radiotherapy
  nuclear activity / radiation is insufficient
  *do **not** accept CT scans*

1

(iii) different number of / fewer protons
accept does not have 86 protons
accept only has 84 protons
or
different atomic number
*do **not** accept bottom number different*
reference to mass number negates this mark

1

(b) 168

accept 169 if clear, correct method is shown
*allow **1** mark for a correct dose ratio involving the spine*
eg 2:140 etc
***or** ratio of days to dose is 1.2*
***or** ratio of dose to days is 0.83*

2

(c) (i)

Group A	**Group B**
J M O	**K L N**

all correct
any order within each group

1

(ii) similar (number) / same (number) / large (number)
accept the same specific number in each group eg three
reference to other factors such as age is neutral

1

(iii) how many people in each group developed cancer
a clear comparison is required

1

(iv) *there are no marks for **Yes** or **No** the mark is for the reason*

Yes
the benefit of having the scan is greater than the risk
or
the risk is (very) small (compared to the chance from natural causes)
accept the risk is much greater from natural causes

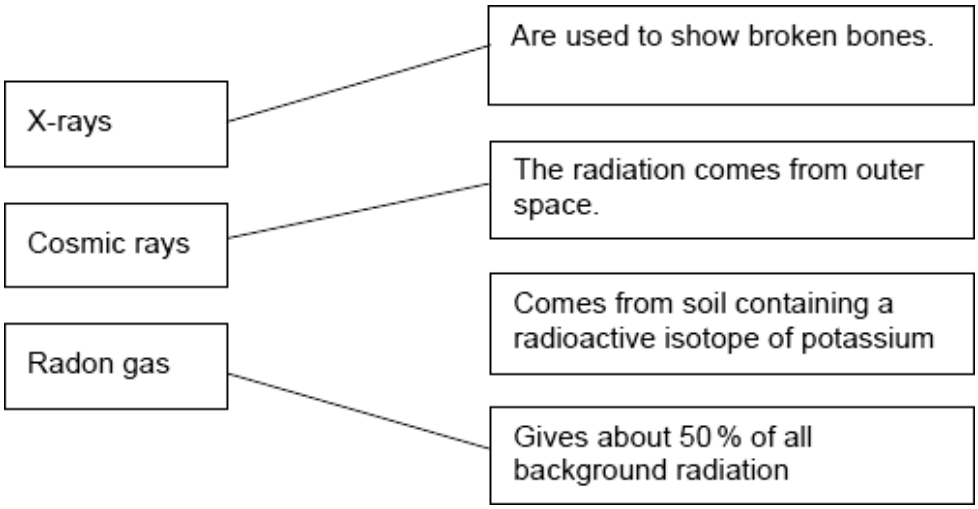
No
no additional risk is acceptable

1

[9]

15 **1** mark for each correct line

*If more than 1 line has been drawn from a box in **List A** then all those lines are marked incorrect.*



[3]

16 (a) gamma will pass through the body

it refers to gamma

or
alpha will not pass through the body

answers must relate to the body
accept skin for body

1

gamma is only slightly ionising

accept gamma causes less damage to cells / tissue

or

alpha is heavily ionising

*do **not** accept gamma causes no damage to cells*

less harmful is insufficient

1

(b) (i) (both graphs show an initial) increase in count-rate

accept both show an increase

1

(ii) only the right kidney is working correctly

1

any **two** from:

*if incorrect box chosen maximum of **1** mark can be awarded*

reference to named kidney can be inferred from the tick box

- count-rate / level / line for right kidney decreases (rapidly)

  it decreases is insufficient

- count-rate / level / line for left kidney does not change

  it does not change is insufficient

- radiation is being passed out / into urine - if referring to right kidney
- radiation is not being passed out - if referring to the left kidney

2

(c) (i) time taken for number of nuclei to halve

or

time taken for the count-rate to halve

1

(ii) short half-life – the level of radiation (in the body) decreases rapidly

it refers to short life isotope

1

to a safe / very small level

or

a long half-life – the radiation remains in the body / for a long time

level of radiation remains high

answers in terms of damage eg cancer are insufficient

1

[9]

17 (a) (i) 2.5

1

(ii) The radiation dose from natural sources is much greater than from artificial sources.

1

(b) (i) other factors may be involved

accept a specific suggestion

eg they may be exposed to other types of radiation

accept cannot be sure (in many cases) that the cause of death is radon (poisoning)

1

(ii) any **one** from:

- different concentrations in different rooms
- to average out daily fluctuations

accept to find an average

accept to make the result (more) reliable / valid

*do **not** accept to make more accurate on its own*

1

(iii) average level (much) higher (in **C** and **D**)

accept converse

1

some homes have very high level (in **C** and **D**)

*accept maximum level in **A** and **B** is low*

or

maximum level in some homes (in **C** and **D**) is very high

*accept higher radiation levels (in **C** and **D**) for **1** mark*

1

[6]

18 (a) (i) half / ½ / 50%

accept 1 (part) in 2 (parts) 1

1

(ii) (the) food (we eat) is radioactive

accept because of the food (we eat)

accept we breathe in radon

radon in the air is neutral

1

(b) higher in village B

1

by 6 units

allow 1 mark for correctly obtaining a height difference of 180(m)/ 4 times higher – this refers to height and not radiation levels

accept for 3 marks in village A it is 2 units (extra) and in village be it is 8 units (extra)

allow 1 mark for a correct radiation calculation based on incorrect height readings

2

[5]

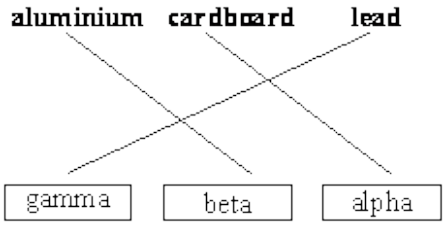
19 (a) (i) **P**

1

(ii) **Q**

1

(b) 3 lines correct



*allow **1** mark for 1 correct line*

two lines drawn from any source or box – both incorrect

2

(c) (i) **K**

1

(ii) 56

accept 50 – 60 inclusive

1

(iii) **K**

1

(iv) to inject... tracer

1

[8]

20 (a) (i) beta and gamma

both answers required

accept correct symbols

1

(ii) alpha and beta

both answers required

accept correct symbols

1

(iii) gamma

accept correct symbol

1

(b) nothing *(*you do to a radioactive substance / source*)* changes the count rate / activity / rate of decay / radiation (emitted)

accept it = radiation emitted

or *(*reducing*)* the temperature does not change the activity / count rate / rate of decay / radiation (emitted)

1

(c) (i) has <u>one</u> more neutron

correct answer only

1

(ii) 14 days

no tolerance

*allow **1** mark for showing a correct method on the graph*

2

(iii) any **two** from:

- beta particles / radiation can be detected externally
- beta particles / radiation can pass out of / through the plant
- long half-life gives time for phosphorus to move through the plant / be detected / get results
- phosphorus-32 is chemically identical to phosphorus-31
- phosphorus-32 is used in the same way by a plant as phosphorus-31

2

[9]

21 (a) top and bottom boxes identified

1

(b) Medical (treatment)

or X-rays

answer must be in table
accept treatment for medical treatment

1

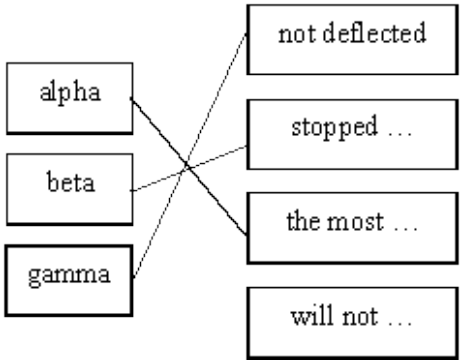
(c) 15

*allow **1** mark for correctly identifying 300 as the average dose*

2

[4]

22 (a) 3 lines correctly drawn



***1** mark for each correct line if more than one line is drawn from a box in List **A** all lines from that box are wrong*

3

(b) nucleus

accept nuclei
*do **not** accept nuclear*

1

(c) **Y**

*do **not** accept gamma*

any **two** from:

*do **not** accept other properties of gamma*

- least dangerous (inside the body)

  *do **not** accept not dangerous*

  accept not as harmful as alpha

  (inside the body)

- least ionising

- penetrates through the body

  *do **not** accept can be detected externally*

1

- is a gas / can be breathed in

  accept it is not a solid

  *(cannot score if **Z** chosen)*

  *if **X** chosen can score this gas mark*

  *if **Z** chosen can score **both** gamma marks*

2

(d) any **one** from:

*do **not** accept kills bacteria*

- longer shelf life

  accept stays fresh longer / stops it going bad / mouldy

- food can be supplied from around the world

- wider market for farmers

- cost to consumers (may be) lower

- less likely to / will not get food poisoning

  accept infection / disease / ill for food poisoning

1

[8]

23 (a) (i) 3 fewer neutrons

accept fewer neutrons

accept different number of neutrons

*do **not** accept different number of electrons*

1

(ii) electron from the nucleus

both points needed

1

(iii) 32 (days)

*allow **1** mark for clearly obtaining 4 half-lives*

2

(iv) has a **<u>much</u>** longer half-life

accept converse answers in terms of iodine-131

accept it has not reached one half-life yet

1

little decay happened / still in the atmosphere

accept it is still decaying

1

(b) any **two** from:

marks are for reasons

- some children developed TC before 1986
- some children (after 1986) that developed TC did not live in highly contaminated areas
- the (large) increase can (only) be explained by (a large increase in) radiation as caused by Chernobyl
- all areas would be contaminated (and raise the risk of TC)
- no evidence (of effect) of other variables

2

(c) People not exposed (to the radiation but who were otherwise similar)

accept people not affected (by the radiation)

1

(d) any **two** from:

*answers should be in terms of nuclear power and **not** why we should not use other fuels*

- produce no pollutant / harmful gases

  accept named gas or greenhouse gases
  *do **not** accept no pollution*

- produces a lot of energy for a small mass (of fuel) **or**
  is a concentrated energy source

  accept amount for mass

  accept high energy density

- it is reliable **or**
  it can generate all of the time

- produces only a small volume of (solid) waste

  accept amount for volume

2

[11]

24 (a) (i) protons

1

neutrons

answers may be in either order

1

(ii) 86

1

(iii) two **fewer** protons and two **fewer** neutrons

*do **not** accept two fewer protons and neutrons*

or 84 protons 134 neutrons

*do **not** accept 218 protons and neutrons*

1

(b) (i) 0.4

accept $\frac{2}{5}$ */ accept 40 % for 2 marks*

*allow **1** mark for correct totalling = 1.8*

*allow **1** mark for a clearly correct method with a clearly incorrect total*

2

(ii) any **one** from:

- nuclear weapon testing
  *do **not** accept nuclear*
- nuclear power (stations)
  accept nuclear/ radioactive waste
- nuclear accidents
- medical
  accept X-rays

1

(c) (i) 2

accept 2:1
accept twice as big
ignore units

1

(ii) No with a reasonable reason explained

only going for two weeks so

or even staying for a year

total exposure well under lowest limit for causing cancer

***1** mark is for a time frame*
***1** mark is for correctly relating to a dose*

1

or Yes with a reasonable reason explained

all levels of radiation are (potentially) hazardous (1)

accept low doses could still cause cancer
accept all levels affect you
*do **not** accept radiation dose is high(er)*
*do **not** accept level of background radiation is higher in Germany*

harm caused by lower doses may not have been recorded (1)

or evidence may not be complete

or insufficient research into effect of small doses

1

[10]

26 (a) (i) alpha

1

(ii) damages them / changes DNA

accept kills them / destroys

accept causes cancer

accept causes cell mutations

*do **not** accept they ionise cells on its own*

1

(b) count is (roughly) the same

1

gamma is not affected by magnetic field

accept magnet for magnetic field

1

or

alpha and beta are deflected by a magnetic field (1)
count would go down significantly (1)

(c) time taken for number of nuclei to halve

*do **not** accept time for radioactivity to halve*

or

time taken for count rate to fall to half
(its initial value)

*do **not** accept time for nuclei to halve*

1

(d) not enough time to take measurements / make observations

1

before level of radiation became insignificant

1

[7]

27 (a) (i) electromagnetic (wave / radiation)

accept em (wave / radiation)

ignore reference to frequency

1

(ii) gamma can penetrate the crate / box / packaging

accept converse (but must relate to both alpha and beta)

ignore just gamma radiation kills bacteria

accept can get through to food

1

(iii) neutrons

1

(b) (i) absorb gamma / radiation

accept it stops / reduces the radiation

1

(ii) any **one** from:

- slow down the conveyor belt
- food does more than one circuit
- stay on the conveyor belt longer
- food closer to the source / radiation

ignore larger doses / use more of the source

ignore thinner packaging

1

(c) (i) idea of testing food on humans / animals

1

no (measured) ill effects **or** monitor their health

accept monitor people that have eaten the food

*accept a measurement / comparison for **1** mark*

eg measure the amount of radiation in treated food

*comparison plus a reason for the comparison would get **2** marks*

*eg idea of measuring level of radiation in treated food **with** no measurable increase in level = **2** marks **or** comparing it to untreated food = **2** marks*

1

(ii) so can make own decision about eating or not eating treated food

accept may be against their religious / moral views

accept some people prefer food that hasn't been tampered with

ignore in case they don't like the idea of eating treated food

accept don't want to eat treated food

ignore might be allergic to the food

*eg think it will give them cancer = **0** marks*

*think it will give you cancer so I need to know so that I can choose = **1** mark1*

1

[8]

28 (i) any **one** from:

the ground
the air
radon (gas)
building materials
buildings
rocks / granite
food
cosmic rays or solar rays

*do **not** accept mobile phones*

X-rays
nuclear weapons testing
nuclear power stations / accidents

accept from outer space

*accept sun but **not** sunlight*

accept medical uses

1

(ii) 2

allow $\frac{1200}{60 \times 10}$ **or** $\frac{120}{600}$ **or** 120

2

[3]

29 (a) (i) two protons and two neutrons **or** the nucleus of a helium atom

1

(ii) <u>different</u> numbers of neutrons **or** one has (3) more or less neutrons than the other

accept different mass (numbers)

if give a number as a difference it must be 3

1

(iii)

*if polonium or hydrogen chosen gets **0** marks*

technetium (99) or none

1

any **two** from:

*do **not** accept gamma rays are less dangerous*

gamma rays less dangerous inside the body

gamma radiation less likely to be absorbed by cells **or** gamma rays do not ionise cells

gamma rays can penetrate the body (to be detected externally)

first 3 points valid if either technetium or iridium or none is given

2

short half-life so safe levels inside body soon reached

half-life long enough to obtain measurements

half-life short enough not to cause long term damage

last 3 points valid if either technetium or uranium or none is given

(b) 2200 ± 200

*allow **1** mark for attempted use of 70% on the graph*

2

[7]

30 (i) photographic film / paper

accept X-ray film

1

(ii) (when developed) the film is darker

must have a comparison

1

(iii) to prevent them receiving / being exposed to too much radiation **or**
so they know how much radiation they have been exposed to

accept if he gets too much radiation there may be something wrong with the plant

*any statement making reference to a need for preventive or corrective action gains **1** mark*

*an isolated statement of fact of the effect of radiation gains **0** marks*

1

[3]

31 (i) radon (gas)

*do **not** accept gas*

1

(ii) background

1

[2]

32 (a) all points correctly plotted

tolerance ± $\frac{1}{2}$ square on y axis only

*allow **1** mark for 3 correctly plotted points*

2

attempt made to draw a smooth curve

*do **not** accept dot-to-dot line*

1

(b) (i) 3 days ± 0.2
or any value correctly obtained using their graph line

if no line drawn in (a), answer must be exactly 3

1

(ii) 3 days or their (b)(i)

1

(c) radon-222

*accept radon **or** 222*
accept alpha or 3.8
correct isotope required for reason to score

1

has the shortest half-life

accept the others have longer half-lives

1

[7]

33 (i) any **one** from

cosmic rays

rocks

food

air

1

(ii) any **one** from

medical

nuclear power stations

nuclear weapons testing

food

***but** do **not** accept food in both (1) and (ii)*

1

[2]

34 (a) X emits beta

accept β

1

Y emits alpha, beta, gamma

must have all three accept α, β, γ

1

(b) gamma

accept beta and gamma
any mention of alpha loses first mark

1

radiation can penetrate (the plastic)

1

kills bacteria **or** microbes **or** micro-organisms **or** viruses

***not** germs*

1

[5]

35 (i) radiation (received by the body) due to our environment

***not** naturally occurring radiation*
accept radiation all around us
accept radiation that is always there

1

(ii) larger than average dose of <u>cosmic rays</u>

must have idea of comparison

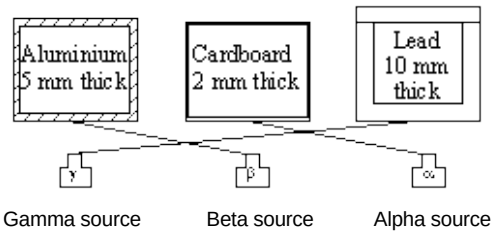
1

when flying less air to absorb **or** shield from radiation

1

[3]

36 (a) all **3** correct



*allow **1** mark for **one or two** possible links*
no marks for more than one line from a source or to a box

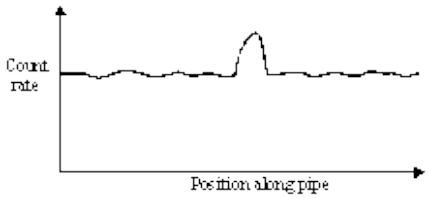
2

(b) (i) geiger-müller (tube)

accept G-M (tube)
accept geiger tube or geiger counter

1

(ii) steady line rising then falling at leak



must be one peak only

1

(c) (i) can penetrate (skull **or** head)

accept goes through body
accept most penetrating
*do **not** accept strongest*
*do **not** accept can penetrate skin*

1

(ii) cancer cells receive full dose **or** more radiation

accept healthy cells not damaged

1

healthy **or** other cells receive low dose only

*do **not** accept it is safer*

1

(iii) any **two** properties from:

- travel through a vacuum
  *do **not** accept they are an energy form*
- travel at same speed in air **or** vacuum
- can be diffracted
  treat as a list ignoring 1 and 2
- can be reflected
- can be refracted
- travel in straight lines
- all transverse
- can be polarised
- transfer energy

2

[9]

37 (a) (i) an unstable nucleus **or** atom **or** isotope

accept nucleus has too much energy

an atom **or** nucleus **or** isotope which decays

1

(ii) sodium – 24

if Mg-27 chosen can get third mark if explained

sufficiently long to allow circulation and take readings

short enough that levels of radiation in the body will become insignificant quickly

3

(iii) each axis is given a linear scale

1

curve concave to axes drawn

1

(curve) shows correct half-life of five years

must show two half lives check first two plotted points correct to ± half square

1

(b) any **three** points from the following:

- waste remains radioactive for a long time **or** waste has to be disposed of
- waste may leak from its storage point
- possibility of accident at power station **or** in transport of fuel
- contamination of the local environment
- people living close to a power station may have a greater risk of developing cancer **or** leukaemia

  accept harmful to people
- high cost to decommission power station

  *do **not** accept expensive*

3

[10]

38 (a) (i) cosmic rays

1

(ii) any **two from:**
rocks
cosmic rays
food
radon

2

(b) (i) 15

1

(ii) 450

e.c.f. 465 – (d)(i)

*do **not** accept negative number*

1

(iii) beta

count (greatly) reduced by aluminium
***or** alpha not reach GM tube and gamma would pass (unaffected) through the aluminium*

accept aluminium stops beta

2

[7]

39 (a) (i) it is random

*do **not** accept unpredictable*

*do **not** accept irregular*

1

(ii) source adds nothing **or** little to the count

1

continues to record background level

accept a clear explanation of background

1

(b) (i) an electron

accept $\frac{0}{-1}e$

1

(ii) <u>electromagnetic</u> wave with **high frequency** or short wavelength

*must have high frequency **or** short wavelength*

1

(iii) 15

*allow **1** mark for **3** iterative steps 584/2 292/2 146/2*

allow I mark for 45/3

3

(iv) [A] a safe level of radiation reached much quicker

could answer in terms of isotope but answer must be clear whether it refers to isotope or sodium-24

1

[B] long enough to obtain measurements

1

[10]

40 (a) (i) electron
neutron
proton
nucleus

1 mark for each correct label

4

(ii) H-1 has no neutrons
H-3 has 2 neutrons

more neutrons gets 1 mark

2

(iii) nucleus unstable

2

(b) lead/concrete
lead/concrete needed to stop gamma rays

2

[10]

41 (a) two from:
internal/bodies
thoron
building materials
soil
food
rocks
radon
gamma rays
cosmic rays/outer space

any 2 for 1 mark each

2

(b) only a very small amount of the background radioactivity comes from nuclear power owtte.

accept any sensible response for 1 mark

1

(c) use G.M. tube/meter/counter or film
'count' higher than or compare with background/normal/control or film is blacker

for 1 mark each

2

(d) more neutrons/different number

gains 1 mark

but I-131 has 4 extra neutrons = 2
or I-131 has 78 neutrons I-127 has 74 (2)

gains 2 marks

2

(e) (i) emits radiation
ionises
molecules
in cells
radiation damages cells/mutation/kills cells
may cause cancer
β /☌/radiation is penetrating
half-life is long enough for damage to be caused

any 4 for 1 mark each (4 from above)

4

(ii) e.g. replace I-127 in body/body cannot tell the difference/causes thyroid cancer/causes cancer (but not if already given in (i))

for 1 mark

1

(iii) **Either** No
half-life = 8 days many half lives have passed/attempts to calculate number of half-lives **or** explains meaning of half-life so very little left/become harmless

for 1 mark each

or Yes half-life = 8 days such a large quantity was released although little left it is still harmful

for 1 mark each

3

[15]

42 **Quality of written communication**

The answer to this question requires ideas in good English in a sensible order with correct use of scientific terms. Quality of written communication should be considered in crediting points in the mark scheme

Any **three** from

radon releases (alpha) radiation

accept radon is radioactive

1

(radon **or** radiation causes) harm **or** damage to body **or** cells

accept cause cancer / mutations /
radiation sickness

1

idea that living near radiation over long period will lead to large 'dose' of radiation

radon (is a gas) that can be breathed in

1

[3]

43 Quality of written communication

correct use of **three** scientific terms e.g. radiation / α **or** β **or** γ / cells / ionisation / mutation (not cells or body) / chromosomes / DNA / genes / cancer

1

any **three** from:

(materials emit) radiation

named type of radiation (α **or** β **or** γ)

damage / harm / kill

dangerous is neutral

cells / chromosomes / DNA / genes

cancer

mutations

ionisation

gloves or glass absorb radiation / prevent radiation reaching body or cells

3

[4]

44 (i) (strontium-90)
beta rays <u>partly</u> absorbed by aluminium

*accept gamma rays not absorbed **and** alpha all absorbed*

if phosphorus -32 then one mark max for beta ray explanation

1

long half life means it can be <u>used for a long time</u>

1

(ii) (technetium-99)
(gamma) rays will <u>pass out</u> of body / less likely to be absorbed

accept (gamma) less damaging or alpha / beta will damage cells if cobalt -60 then one mark max for gamma ray explanation

1

short half life means it will <u>not affect body over a long period</u>

1

[4]

45 (a) sensible scales

full use of y axis

1

completely accurate plotting

1

a smooth curve going through all bar one of the points

do not accept a dot-to-dot graph if two parts shown for curves
accept the more correct

1

at least one line or a clear mark showing how to obtain the half life
from the graph and obtaining between 13 and 15

at the bottom of the page cross or ticks in the order of the mark scheme

1

(b) (i) to let the beta particles get through

*accept must be there to let the radiation through **or** if thick they may be stopped*

1

(ii) alpha particles would be stopped by the glass **or** cannot penetrate glass

do not accept alphas are weak

1

(c) (i) it will give more counts per minute for a small quantity **or** it does not last so long so may not be as dangerous

accept answers in terms of 5 years assume it refers appropriately

1

(ii) it will not be there long enough to act as a tracer **or** it could cause radiation damage as all its activity will be in the first place it enters the system

accept answer in terms of 5 seconds

accept not there long enough to work assume it refers appropriately

1

[8]

46

(a) evidence of $\frac{7350}{15}$

gains 1 mark

but

490

gains 2 marks

but

4900

gains 3 marks

units cm^3

for 1 further mark

4

(b) some of radioactive solution gets into cells/body organs
some of radioactive solution gets into urine (in the kidney)
the radioactive solution becomes less radioactive during the test
variability in readings

in any order for 1 mark each

3

(c) *ideas that*

- won't lose (too) much radioactivity during the test
- won't stay radioactive/harm cells for too long after test is over

for 1 mark each

2

[9]

47 (a) c/gamma

- because more penetrating
- so can reach/damage cells from outside body/through skin

but

a/alpha

- does more damage/more likely to cause cancer
- can only do this if <u>inside</u> the body/cells

each • for 1 mark
[credit same ideas expressed conversely]

4

(b)
- must emit alpha / a radiation
- *idea that* half-life must be just long enough to kill cancer cells

each for 1 mark
[do not credit simply short half-life]
(allow 'must be liquid / in solution)

2

(c) *evidence of repeated halving* ***then***

$\underline{\boldsymbol{n}}$ ´ 3.6

gains 1 mark

but

answer in range
22 – 25.2 days
(ie >6 and up to 7 half lives)

gains 2 marks

2

[8]