Hazards and Uses of Radiation

Questions

Name: _____

Class: _____

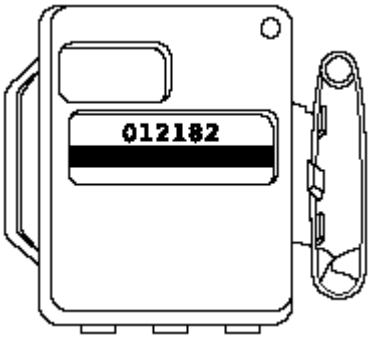
Date: _____

Time: **92 minutes**

Marks: **92 marks**

Comments:

1 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)

2 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)

3 (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?

_____

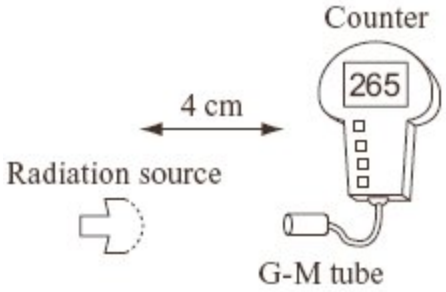
(1)

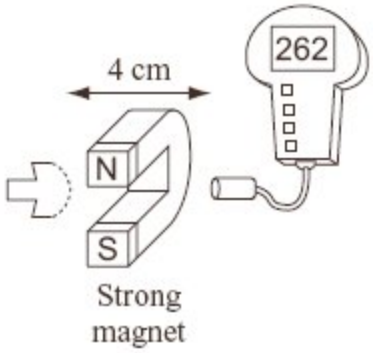
(ii) What effect does nuclear radiation have on living cells?

_____

(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.

_____

_____

_____

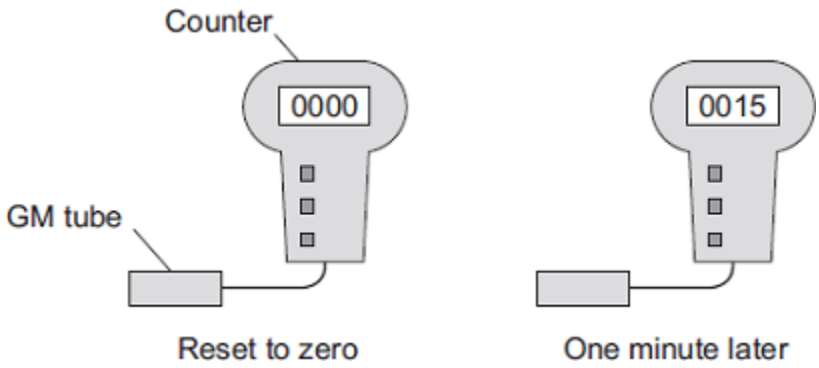
_____

(2)

(Total 7 marks)

4 (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)

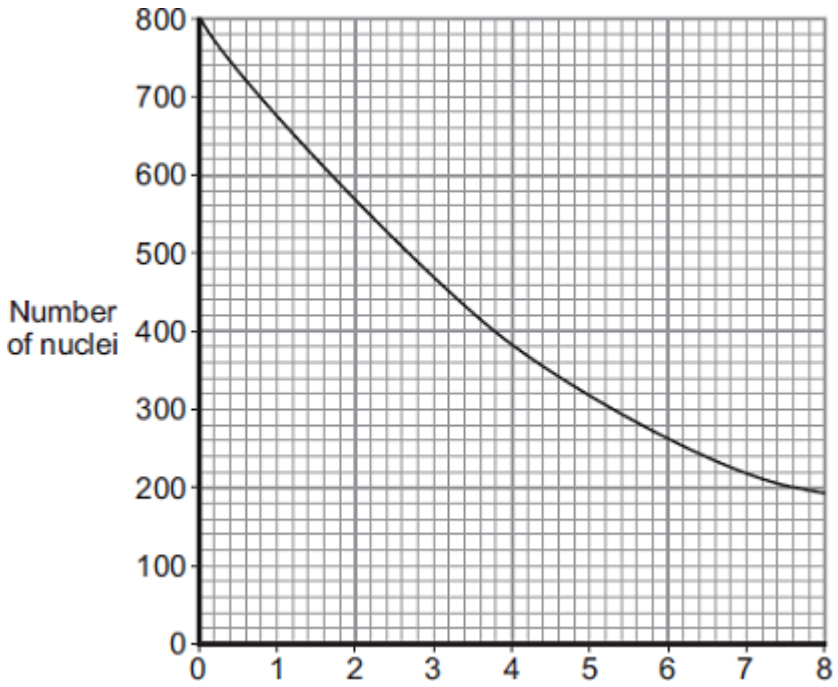
(ii) The decay of radon-222 can be represented by the equation below.

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

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

(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

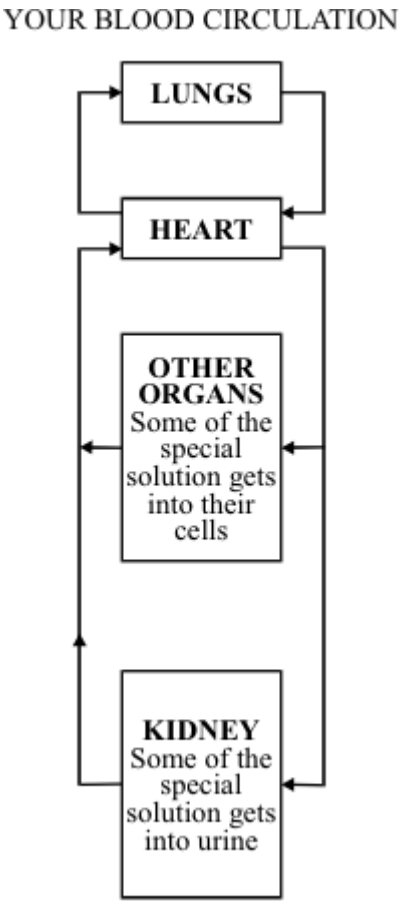
(2)

(Total 9 marks)

5 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.)

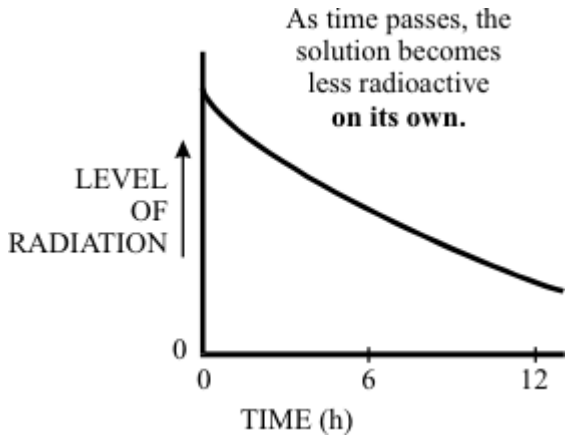
_____

_____

_____

_____

(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)

6 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.

_____

_____

_____

_____

_____

(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.

_____

_____

_____

_____

_____

(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)

7 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.

_____

_____

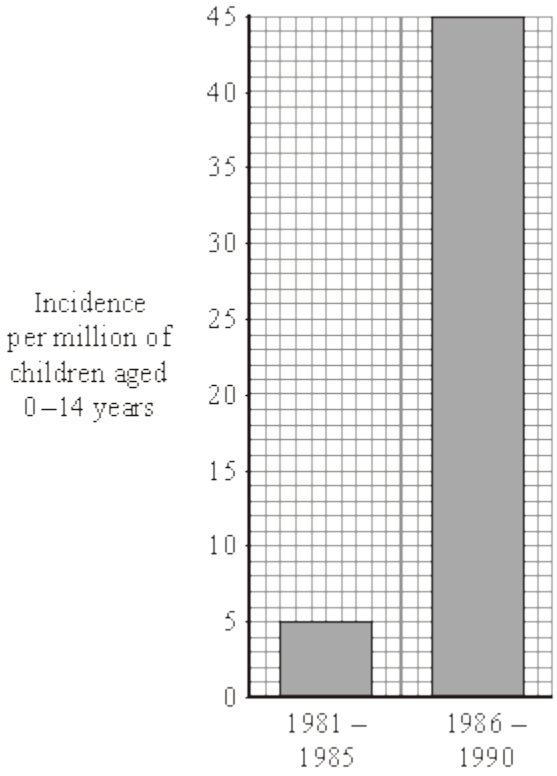
_____

_____

_____

(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. _____

_____

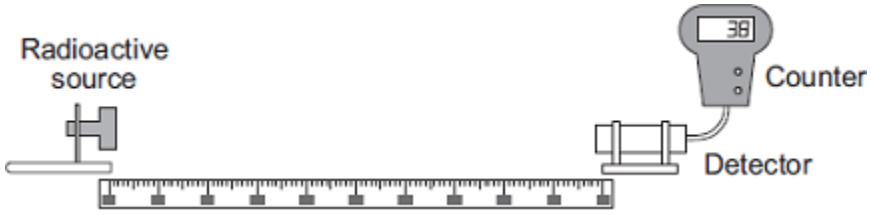
2. _____

_____

(2)

(Total 11 marks)

8 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?

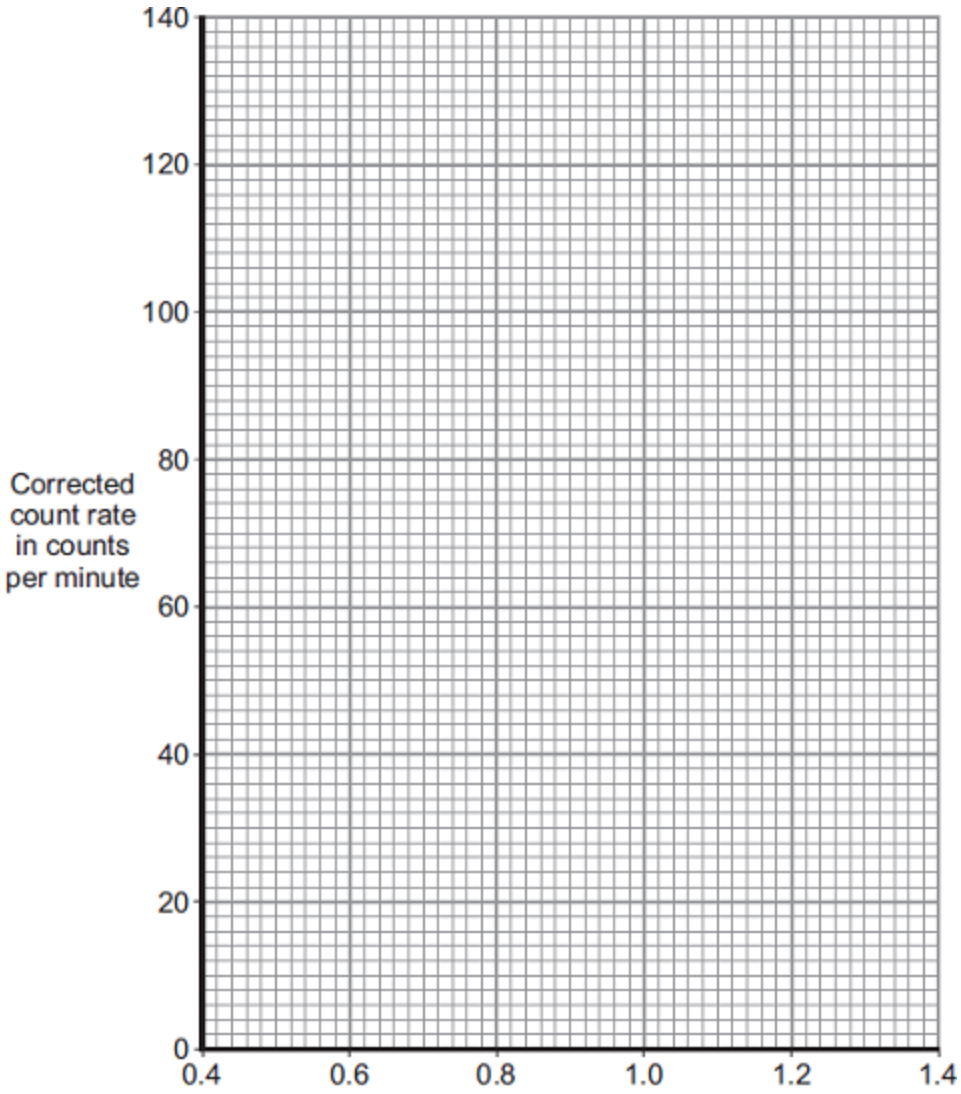
_____

_____

(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

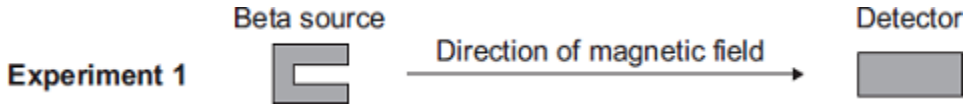
Use **Table 1** to determine if the hypothesis is correct for this radioactive source.

You should use calculations in your answer.

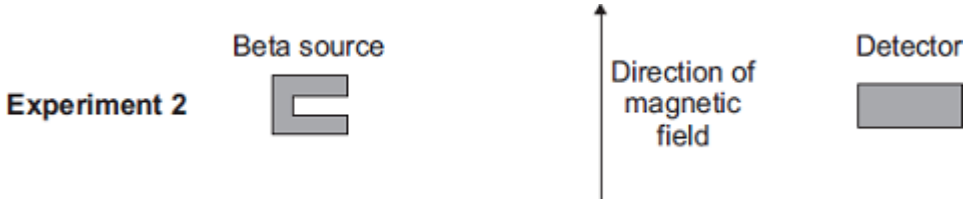
(3)

(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.

_____

_____

_____

_____

_____

_____

(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

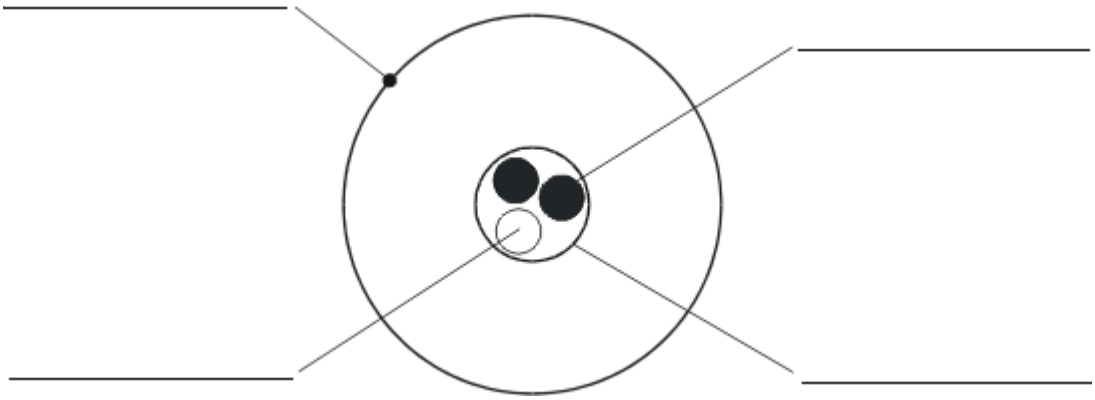
Explain these results.

(2)

(Total 13 marks)

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

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



(4)

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

_____

_____

_____

(2)

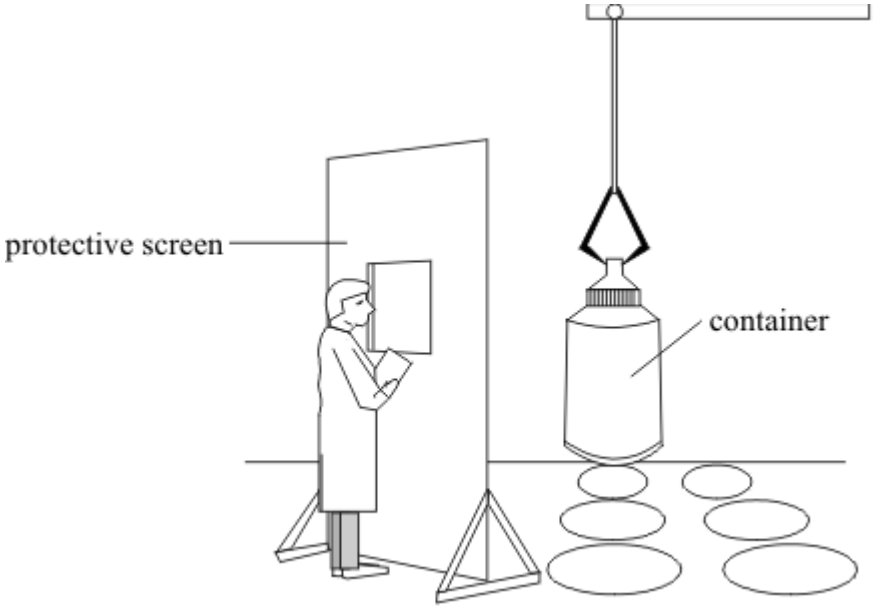
(iii) Tritium is a radioactive substance which emits beta (β) radiation.
Why do the atoms of some substances give out radiation?

_____

_____

(2)

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



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

_____

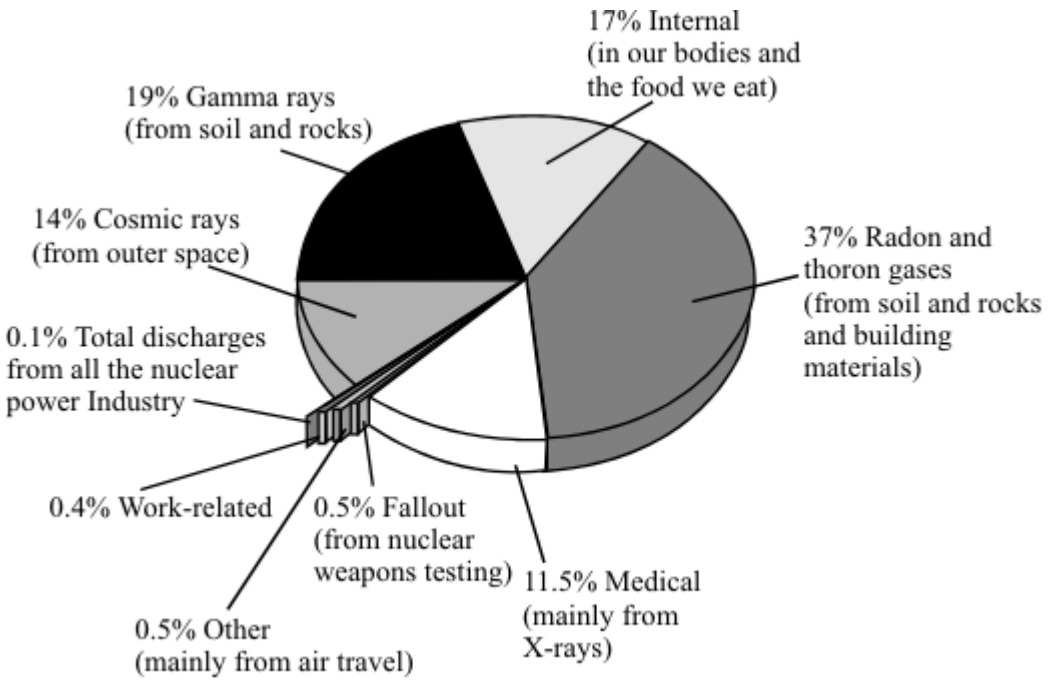
_____

_____

(2)

(Total 10 marks)

10 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)