**Q1.** (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?

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**(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.

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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?

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.....

**(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?

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**(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.

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.....

**(1)**
**(Total 9 marks)**

**Q2.**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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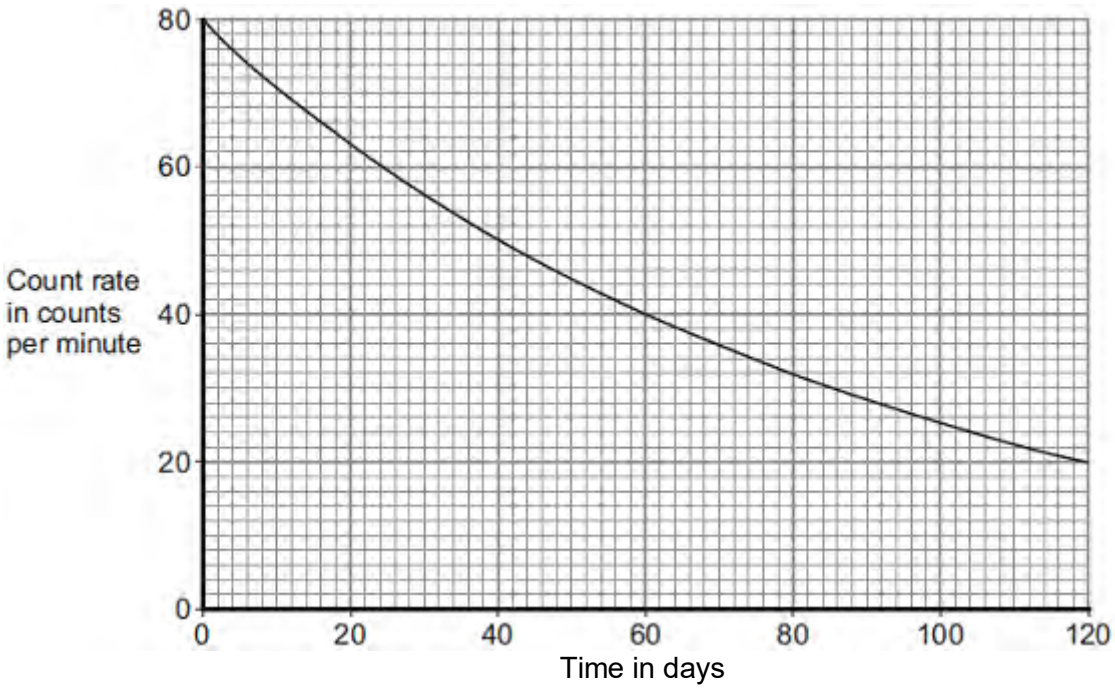
**(1)**

(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 | $1.4 \times 10^{10}$ |

(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.

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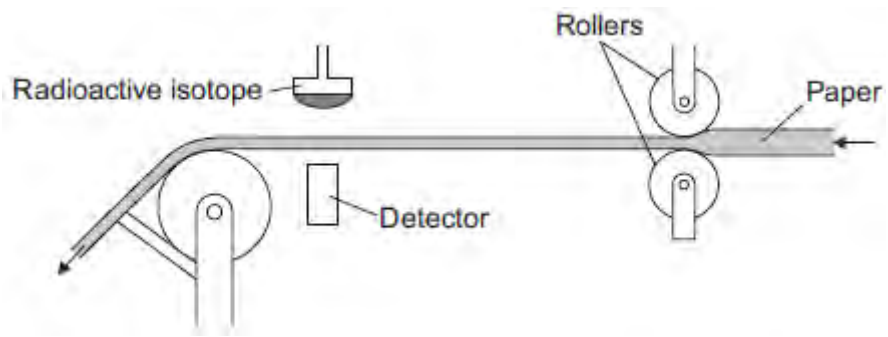
**(2)**

(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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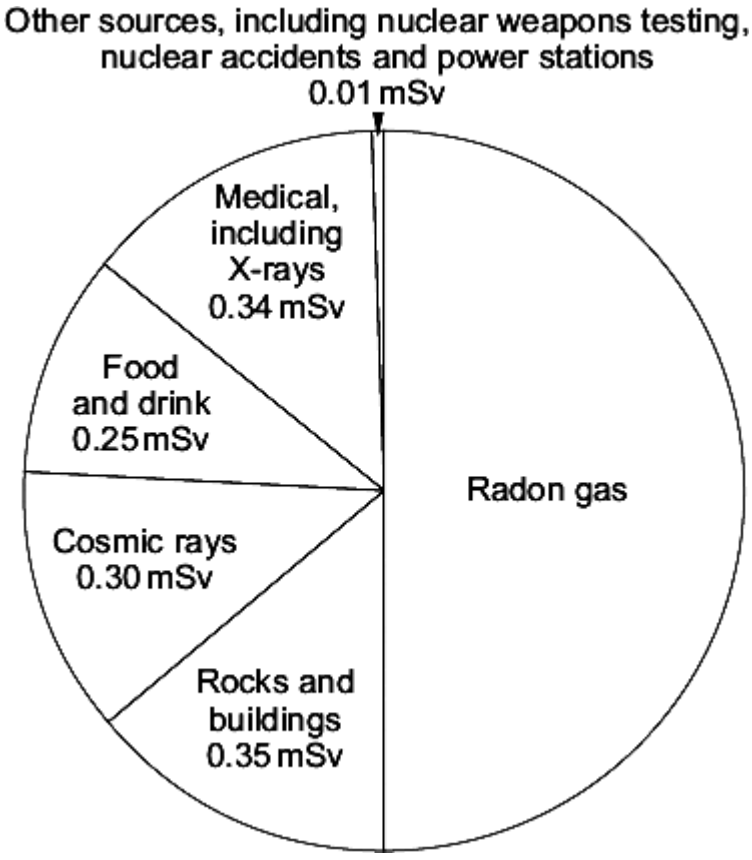
**(3)**
**(Total 14 marks)**

**Q3.** 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?

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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 .....

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2 .....

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**(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?

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**(1)**

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

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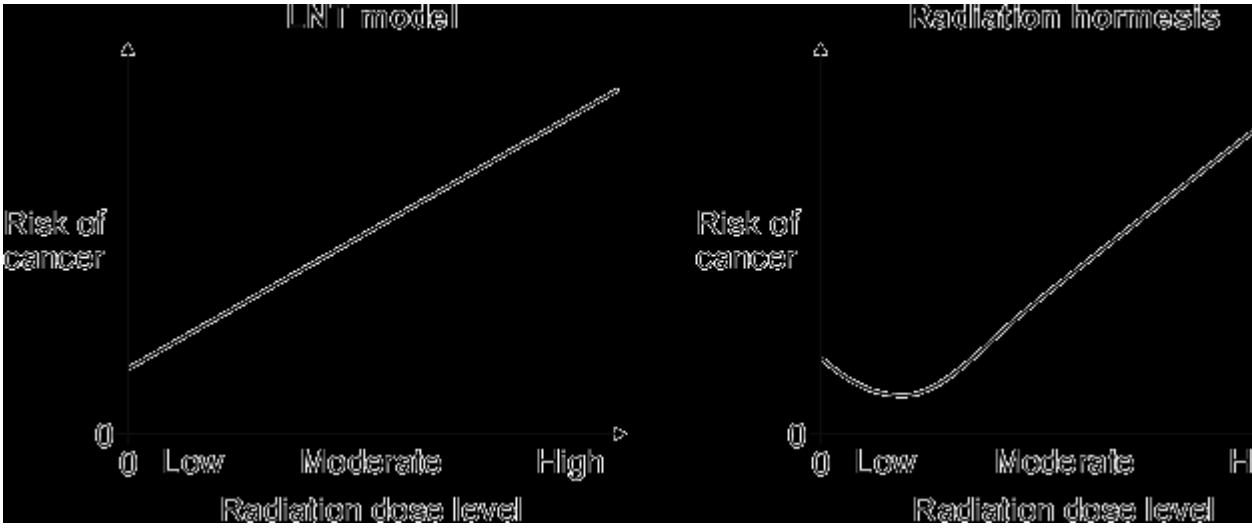
**(2)**

(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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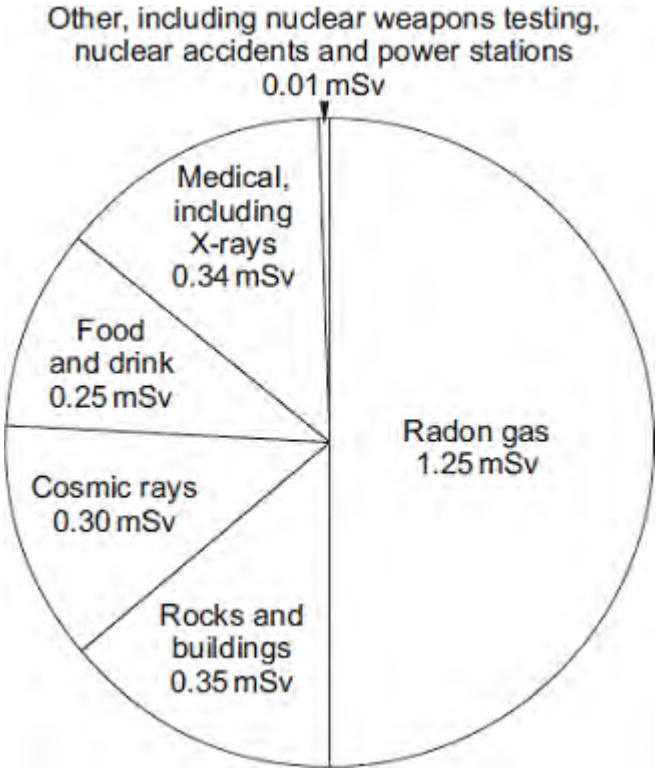
**(2)**
**(Total 10 marks)**

**Q4.** 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?

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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.

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**(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**.

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**(2)**

**(Total 5 marks**

**Q5.** 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.

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

.....  .....  .....

**(3)**
**(Total 10 marks)**

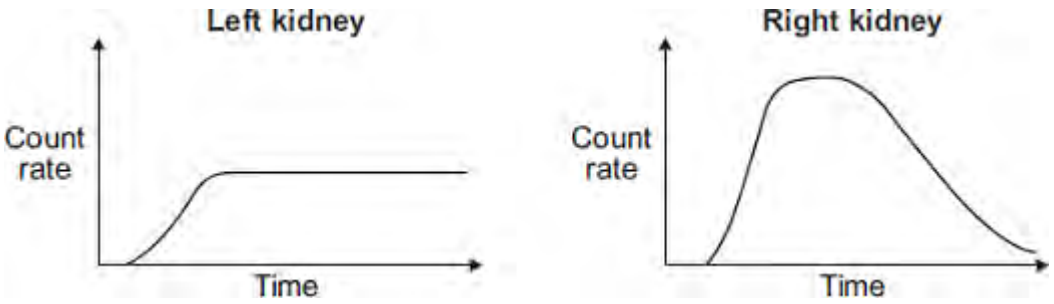
**Q6.** A doctor uses the radioactive isotope technetium-99 to find out if a patient's kidneys are working correctly.


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?

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**(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)**