Week 25

IGCSE Physics

Homework bundle for this week

本周作业合集

exercises.lol

Contents 目录

IGCSE Physics Name: ____________ Score: ______

1. Where is almost all of an atom's mass?
   - ☐ in the tiny central nucleus
   - ☐ spread evenly through the atom
   - ☐ in the electrons
   - ☐ in the empty space
2. Nuclear fission is when:
   - ☐ a heavy nucleus splits into two smaller nuclei, releasing neutrons and energy
   - ☐ two light nuclei join together
   - ☐ an atom gains an electron
   - ☐ a nucleus gives out a gamma ray only
3. Radioactive decay is spontaneous and random. This means:
   - ☐ you cannot predict when a particular nucleus will decay, or speed it up
   - ☐ it can be sped up by heating
   - ☐ every nucleus decays at the same instant
   - ☐ it only happens in a laboratory
4. The half-life of a radioactive isotope is the time taken for:
   - ☐ half the unstable nuclei in a sample to decay
   - ☐ all the nuclei to decay
   - ☐ the sample to double
   - ☐ the radiation to travel 1 metre
5. An atom that loses an electron becomes a positive ion.

   ☐ True ☐ False
6. Nuclear fusion is when:
   - ☐ two light nuclei join to make a heavier one, releasing energy
   - ☐ a heavy nucleus splits
   - ☐ a neutron turns into a proton
   - ☐ electrons jump between orbits

7. A source reads 250 counts/min. The background is 30 counts/min. What is the corrected count rate, in counts/min?

________________ counts/min

8. A source reads 800 counts/min and has a half-life of 3 hours. What is the count rate after 6 hours, in counts/min?

________________ counts/min

9. What fraction of the unstable nuclei remain after 3 half-lives? (Give a decimal.)

____

10. In ${}^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \to {}^{141}_{56}\mathrm{Ba} + {}^{92}_{36}\mathrm{Kr} + x\,{}^{1}_{0}\mathrm{n}$, how many neutrons x are released?

____

5. Nuclear physics

Answers · 答案

IGCSE Physics

1. **in the tiny central nucleus**

   Almost all the mass is concentrated in the tiny, dense nucleus; the rest of the atom is mostly empty space.

2. **a heavy nucleus splits into two smaller nuclei, releasing neutrons and energy**

   Fission = splitting a heavy nucleus (after it absorbs a neutron) into two smaller nuclei, plus 2–3 neutrons and energy.

3. **you cannot predict when a particular nucleus will decay, or speed it up**

   Spontaneous = not triggered and not controllable; random = you cannot say which nucleus decays next or exactly when.

4. **half the unstable nuclei in a sample to decay**

   Each half-life, half of the remaining unstable nuclei decay, so the count rate halves.

5. **True**

   Losing a negative electron leaves the atom with more positive charge — a positive ion.

6. **two light nuclei join to make a heavier one, releasing energy**

   Fusion = joining two light nuclei into a heavier one, releasing energy. It powers the Sun.

7. **220 counts/min**

   Corrected = measured − background = $250 - 30 = 220$ counts/min.

8. **200 counts/min**

   6 hours is two half-lives: $800 \to 400 \to 200$ counts/min.

9. **0.125**

   Each half-life halves the number: $\left(\frac{1}{2}\right)^3 = \frac{1}{8} = 0.125$.

10. **3**

   Nucleon numbers must balance: $235 + 1 = 141 + 92 + x$, so $236 = 233 + x$ and $x = 3$.

IGCSE PHYSICS • EXERCISE SHEET

5.1 The nuclear model of the atom

Name: ____________ Class: ________ Date: __________ **Total: 10 marks**

KEY WORDS neutron 中子 • proton 质子 • electron 电子 • nucleus 原子核 • isotope 同位素

Objective

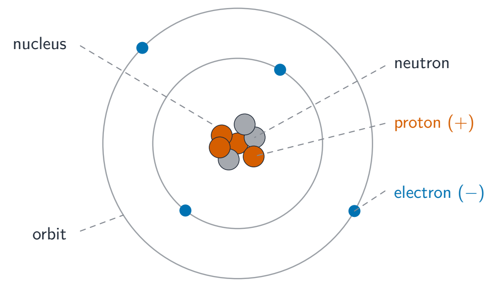
Build the skills to answer exam questions on the **nuclear model of the atom** 原子核模型 — atomic structure, the **alpha-scattering** α 散射 evidence, **nuclide notation** 核素符号, and **isotopes** 同位素.

You must be able to:

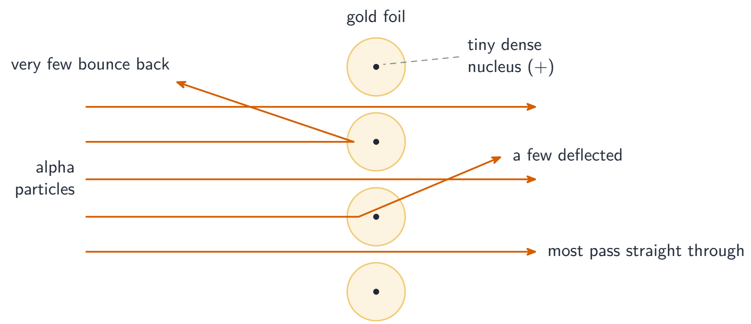
- describe the nuclear atom (tiny dense nucleus, electrons in orbits)
- interpret the alpha-scattering results
- use ${}^{A}_{Z}\mathrm{X}$ to find protons, neutrons and electrons; define isotopes

1 Worked examples

■ Nuclide notation & scattering



Almost all the mass is in the tiny nucleus; the atom is mostly empty space



Most pass straight through (empty space); a few bounce back (small, heavy, positive nucleus)

${}^{197}_{79}$**Au:** 79 protons, $197 - 79 = 118$ neutrons, 79 electrons (neutral atom).

2 Practice

2.1 State what is meant by an isotope. [1]

2.2 For ${}^{23}_{11}\mathrm{Na}$, write down the number of protons and the number of neutrons. [2]

3 Exam-style questions

3.1 In the alpha-scattering experiment, most alpha particles pass straight through the foil. This shows the atom is: [1]

- **A** solid throughout
- **B** mostly empty space
- **C** negatively charged
- **D** very large

3.2 The nuclide ${}^{40}_{19}\mathrm{K}$ is given.

(a) State the number of protons, neutrons and electrons in a neutral atom. [3]

(b) An isotope of potassium is ${}^{39}_{19}\mathrm{K}$. State how its nucleus differs from ${}^{40}_{19}\mathrm{K}$. [1]

3.3 Explain why a very few alpha particles bounce almost straight back off the gold foil. [2]

Solutions

2.1 atoms of the same element (same proton number) with different numbers of neutrons.

2.2 protons $= 11$; neutrons $= 23 - 11 = 12$.

3.1 B. Most passing straight through shows the atom is mostly empty space.

3.2 (a) protons $= 19$; neutrons $= 40 - 19 = 21$; electrons $= 19$.
(b) it has one fewer neutron (20 instead of 21).

3.3 the nucleus is very small, very dense and positively charged; a head-on approach is strongly repelled, so the positive alpha particle bounces back.

30 An isotope of strontium has the nuclide notation $^{84}_{38}Sr$.

How many protons and neutrons are there in a nucleus of this isotope?

	protons	neutrons
A	38	46
B	38	84
C	46	38
D	46	84

32 What occurs during nuclear fusion?

A Two light atomic nuclei join together and emit energy.

B Two light atomic nuclei join together and absorb energy.

C A heavy atomic nucleus splits and emits energy.

D A heavy atomic nucleus splits and absorbs energy.

9 **(a)** An experiment directs alpha particles at a very thin sheet of gold foil.

(i) Most of the alpha particles pass through the thin foil in a straight line.

State the conclusion about atoms from this observation.

....

.... [1]

(ii) Some of the alpha particles are deflected through angles less than 90° and a few are deflected through 180°.

State and explain **two** conclusions about the nuclei of atoms from this observation.

conclusion 1 ....

explanation 1 ....

....

conclusion 2 ....

explanation 2 ....

....

[4]

(b) A source contains a radioactive isotope of strontium. This isotope decays by emission of β-particles. The half-life of this isotope is 29 years.

(i) State the change in the nucleus which occurs when a β-particle is emitted.

.... [1]

(ii) The initial mass of this isotope of strontium in the source is 25 μg.

Calculate the mass of the strontium isotope that decays in 87 years.

mass = ... μg [3]

[Total: 9]

33 The scattering of α-particles by a thin metal foil supports the nuclear model of an atom.

Why are α-particles used rather than neutrons?

A because they always travel more slowly

B because they are heavier

C because they are larger in diameter

D because they have a positive charge

9 **(a)** A nuclear power station has a reactor where controlled nuclear fission of uranium-235 takes place.

(i) Explain what is meant by nuclear fission.

....

....

....

....

.... [3]

(ii) State **one** advantage and **one** disadvantage of generating electrical power in nuclear power stations compared with electrical power generated using wind turbines.

advantage ....

disadvantage ....
[2]

(b) Deuterium is an isotope of hydrogen (H) with 1 proton and 1 neutron. Nuclear fusion occurs when two nuclei of deuterium combine. An isotope of helium (He) and a neutron are formed.

Use nuclide notation to write down the nuclide equation for this reaction.

[3]

[Total: 8]

IGCSE PHYSICS • EXERCISE SHEET

5.2 Radioactivity

Name: ____________ Class: __________ Date: ____________ **Total: 48 marks**

KEY WORDS radioactive 放射性 • decay 衰变 • half-life 半衰期 • radiation 辐射 • background radiation 背景辐射 • decay 衰变 • half-life 半衰期 • radiation 辐射 • decay equations 衰变方程 • background radiation 背景辐射

Objective

Build the skills to answer exam questions on **radioactivity 放射性**: **background radiation 背景辐射** and count rates, the three types of radiation, **decay equations 衰变方程**, **half-life 半衰期**, choosing an isotope for a job, and safety.

You must be able to:

- name the sources of background radiation and correct a count rate for it
- compare alpha, beta and gamma by nature, ionising effect and penetration, and explain the ionising order using charge and kinetic energy
- write and balance alpha and beta decay equations
- define half-life and use it in calculations, including a mass or a count rate
- explain how the radiation type and half-life decide which isotope is used for a job
- state the effects of ionising radiation on living things and the safety precautions

1 Worked examples

■ Background radiation and the corrected count rate

Some radiation is always present: **radon 氡** gas in the air (usually the largest source), rocks and buildings, food and drink, and **cosmic rays 宇宙射线** from space. Radiation is measured with a detector joined to a **counter 计数器**, and the **count rate 计数率** is the counts each second or minute.

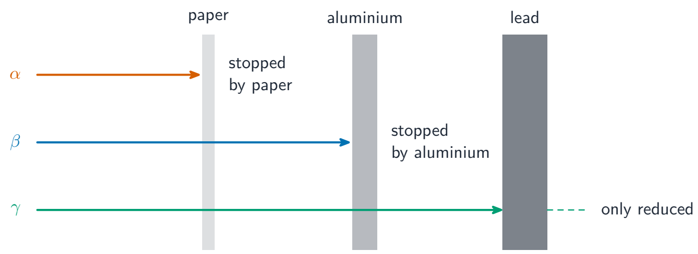
Always measure the background first, with the source removed, and subtract it:

$$\text{corrected count rate} = \text{measured count rate} - \text{background count rate}$$

Worked example 1. A detector next to a source reads 250 counts/min. With the source removed it reads 30 counts/min. Corrected: $250 - 30 = 220$ counts/min.

The three radiations

Type	What it is	Charge	Ionising	Stopped by
alpha (α)	a helium nucleus, 2 protons + 2 neutrons	+2	strongest	a sheet of paper, a few cm of air
beta (β)	a fast electron from the nucleus	−1	medium	a few mm of **aluminium** 铝
gamma (γ)	a high-energy electromagnetic wave	0	weakest	thick **lead** 铅 or concrete (only reduced)



Alpha is the most ionising but the least penetrating; gamma is the opposite

Explain the ionising order from **charge** and **kinetic energy**: an alpha particle carries a charge of +2 and is heavy and slow, so it passes close to many atoms and pulls strongly on their electrons, ionising a great deal and losing its energy in a short distance. A beta particle has a smaller charge (−1) and moves much faster, so it interacts with each atom for less time and ionises less. Gamma has no charge at all, so it ionises least and travels furthest.

Because alpha and beta are charged, an electric or a magnetic field deflects them in **opposite** directions, and the much lighter beta is deflected more. Gamma is not deflected.

Decay equations

In every decay the nucleon numbers balance and the proton numbers balance.

Alpha decay loses 2 protons and 2 neutrons, so A falls by 4 and Z by 2:

$$^{226}_{88}\mathrm{Ra} \rightarrow \ ^{222}_{86}\mathrm{Rn} + ^{4}_{2}\alpha$$

Beta decay: inside the nucleus a neutron changes into a proton and an electron, and the electron leaves as the beta particle. So A is unchanged and Z rises by 1:

$$^{24}_{11}\mathrm{Na} \rightarrow \ ^{24}_{12}\mathrm{Mg} + ^{0}_{-1}\beta$$

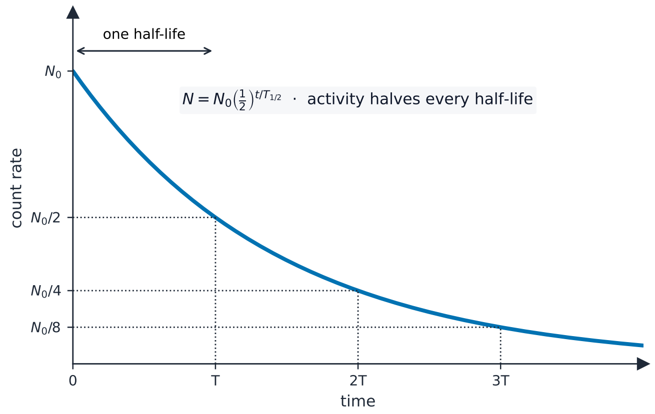
Gamma emission changes neither number: the nucleus only loses energy.

Worked example 2. $^{241}_{95}$Am decays by alpha emission to an isotope of neptunium. Nucleon number: 241 − 4 = 237. Proton number: 95 − 2 = 93. So

$$^{241}_{95}\mathrm{Am} \rightarrow \ ^{237}_{93}\mathrm{Np} + ^{4}_{2}\alpha$$

Half-life

The **half-life** is the time for half the unstable nuclei in a sample to decay. After each half-life the number left, and the corrected count rate, falls to half. Count the halvings rather than dividing the total time.



Each half-life the count rate halves: $N_0 \rightarrow N_0/2 \rightarrow N_0/4 \rightarrow N_0/8$

Worked example 3. A source falls from 800 to 100 counts/min and its half-life is 5 days. The halvings are 800 → 400 → 200 → 100, which is 3 half-lives, so the time is 3 × 5 = 15 days.

Worked example 4 (mass decayed). A source contains 25 μg of an isotope whose half-life is 29 years. Find the mass that decays in 87 years.

1. Number of half-lives: 87 ÷ 29 = 3.
2. Fraction left: $(\frac{1}{2})^3 = \frac{1}{8}$, so the mass left is 25 ÷ 8 = 3.1 μg.
3. The question asks for the mass that **decayed**: 25 − 3.1 = 22 μg.

Read a half-life off a graph by taking any starting value, finding half of it, and reading the time between them. Subtract the background from every reading first.

Choosing an isotope, and safety

The job decides the radiation and the half-life:

- **smoke alarm**: an alpha source with a long half-life. Alpha ionises the air between two plates so a small current flows; smoke particles absorb the alpha and the current drops. Alpha is safe outside the alarm because paper (or a few centimetres of air) stops it, and the long half-life means the alarm lasts for years.

- **thickness gauge** for paper or foil: a beta source, because the amount getting through changes with the thickness (alpha would all be stopped, gamma would all pass).
- **medical tracer**: a gamma emitter with a short half-life, so the radiation escapes the body to a detector and the activity soon falls to a safe level.
- **sterilising** equipment or food, and treating tumours: gamma, because it penetrates the sealed package or the body.

Ionising radiation damages **living cells** 细胞: it can kill cells, cause **mutations** 突变 in the genes, and cause cancer. To keep the **dose** 剂量 low: reduce the **exposure** 照射 time, increase the distance from the source, and use **shielding** 屏蔽 such as lead. Handle sources with tongs, never with bare hands; point them away from people; store them in a lead-lined box.

2 Practice

2.1 State what material stops beta radiation. [1]

2.2 Name two sources of background radiation. [2]

2.3 A detector reads 250 counts/min; the background is 30 counts/min. Find the corrected count rate. [2]

2.4 State the nature and the charge of an alpha particle and of a beta particle. [2]

2.5 Complete this decay equation, giving both numbers for the new nucleus: ${}^{210}_{84}\text{Po} \rightarrow {}^{?}_{?}\text{Pb} + {}^{4}_{2}\,\alpha$. [2]

2.6 A source has a half-life of 6 hours. Its corrected count rate is now 960 counts/min. Find the count rate after 18 hours. [3]

2.7 State two precautions a scientist should take when working with a radioactive source, and explain why each one lowers the dose. [4]

3 Exam-style questions

3.1 A source of radiation is placed near a detector. A sheet of paper between them makes no difference to the count rate, but a 5 mm sheet of aluminium reduces it almost to the background level. Which radiation is the source emitting? [1]

- **A** alpha only
- **B** beta only
- **C** gamma only
- **D** alpha and gamma

3.2 A nucleus emits a beta particle. Which row is correct? [1]

- **A** nucleon number unchanged, proton number +1
- **B** nucleon number unchanged, proton number −1
- **C** nucleon number −4, proton number −2
- **D** nucleon number −1, proton number unchanged

3.3 A student investigates a radioactive source. Before using it she records a count rate of 24 counts/min with the source in its lead box. With the source in place the detector reads 824 counts/min.

(a) Explain why she measured the count rate before bringing out the source, and calculate the corrected count rate. [3]

(b) The corrected count rate falls to 100 counts/min after 12 hours. Determine the half-life of the source. [3]

(c) The source emits beta particles. Describe what happens inside a nucleus when a beta particle is emitted. [2]

(d) Suggest, with a reason, whether this source would be suitable for a smoke alarm. [2]

3.4 A smoke alarm contains a small americium-241 source, which decays by alpha emission to an isotope of neptunium (Np).

(a) Complete the nuclide equation: ${}^{241}_{95}\mathrm{Am} \rightarrow \;\ldots\ldots\mathrm{Np} + \ldots\ldots\alpha.$ [3]

(b) Describe how the alpha particles ionise the air inside the alarm. [3]

(c) Suggest and explain two reasons why the alarm uses an alpha emitter rather than a gamma emitter. [4]

(d) The half-life of americium-241 is 432 years. Explain why this long half-life is an advantage for a smoke alarm. [1]

3.5 A hospital uses a gamma-emitting isotope with a half-life of 6 hours as a medical tracer.

(a) Explain why a gamma emitter, and not an alpha emitter, is used inside the body. [2]

(b) Explain why a half-life of 6 hours is more suitable than one of 6 years. [2]

(c) A sample contains 80 μg of the isotope. Calculate the mass that has decayed after 24 hours. [3]

(d) State two effects that ionising radiation can have on living cells. [2]

Solutions

2.1 A few millimetres of aluminium.

2.2 Any two of: radon gas in the air; rocks and buildings; food and drink; cosmic rays from space.

2.3 Corrected $= 250 - 30 = 220$ counts/min.

2.4 Alpha: a helium nucleus (2 protons and 2 neutrons), charge $+2$. Beta: a fast-moving electron, charge -1.

2.5 $^{206}_{82}$Pb: nucleon number $210 - 4 = 206$, proton number $84 - 2 = 82$.

2.6 $18 \div 6 = 3$ half-lives; $960 \to 480 \to 240 \to 120$; 120 counts/min.

2.7 Any two, each with its reason: reduce the time spent near the source, because the dose received rises with the exposure time; stand further away (use tongs), because the radiation spreads out so the intensity falls with distance; work behind lead shielding, because the lead absorbs the radiation before it reaches the body.

3.1 B. Paper stops alpha, so there is no alpha; aluminium stops beta and would not stop gamma, so the source emits beta only. A and D would have been blocked by the paper, and C would still pass through the aluminium.

3.2 A. A neutron becomes a proton, so the proton number rises by one while the total number of nucleons is unchanged. C describes alpha decay.

3.3 (a) The reading with the source shut away is the background radiation, which is always present and must be subtracted so the count rate is due to the source alone; corrected $= 824 - 24 = 800$ counts/min.
(b) $800 \to 400 \to 200 \to 100$ is 3 half-lives; half-life $= 12 \div 3 = 4$ hours.
(c) A neutron in the nucleus changes into a proton and an electron, which is emitted as the beta particle.
(d) No: beta passes through smoke without being absorbed, so the current would not change when smoke entered — an alarm needs an alpha source.

3.4 (a) $^{237}_{93}$Np and $^{4}_{2}\alpha$.
(b) The alpha particles are emitted from the americium and collide with (or pass close to) molecules in the air between the plates, knocking electrons out of them so the air contains ions and conducts.
(c) Any two, each with its explanation: alpha is easily absorbed by smoke particles, so the current drops as soon as smoke enters, while gamma would pass straight through and the alarm would not respond; alpha is much more ionising, so it makes the air conduct well enough to give a steady current; alpha has a very short range and is stopped by the plastic case, so it is far less harmful to people in the house than gamma would be.
(d) The activity stays almost constant for the whole life of the alarm, so it does not need replacing.

3.5 (a) Gamma is the most penetrating, so it passes out of the body to the detector outside; alpha would be absorbed within a few centimetres of tissue, giving a large dose to the patient and no signal outside.
(b) A 6-hour half-life means the activity falls to a safe level within a day, so the patient's dose is small; a 6-year half-life would keep irradiating the patient long after the scan.

(c) $24 \div 6 = 4$ half-lives; mass left $= 80 \div 2^4 = 80 \div 16 = 5.0\ \mu$g; mass decayed $= 80 - 5.0 = 75\ \mu$g.
(d) Any two of: cell death; mutation of the genes; cancer.

31 A student is investigating the count rate of a radioactive substance.

How must he adjust his reading for the background count?

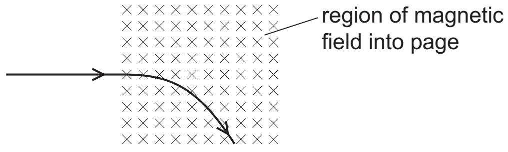
A Add the background count to his reading.

B Ignore the background count as it will not affect his reading.

C Subtract the background count from his reading.

D Take repeat readings to eliminate the background count.

33 A beta-particle enters a uniform magnetic field directed into the page and deflects downwards, as shown.



Which direction of electric field would also deflect an electron downwards?

A into the page

B out of the page

C down the page

D up the page

34 The radioactive isotope radon, $^{222}_{86}$Rn, is an alpha (α) emitter.

During this radioactive decay, an isotope of polonium, Po, is produced.

How many neutrons does a nucleus of this isotope of polonium contain?

A 130 **B** 132 **C** 134 **D** 136

9 **(a)** An experiment directs alpha particles at a very thin sheet of gold foil.

(i) Most of the alpha particles pass through the thin foil in a straight line.

State the conclusion about atoms from this observation.

....

.... [1]

(ii) Some of the alpha particles are deflected through angles less than 90° and a few are deflected through 180°.

State and explain **two** conclusions about the nuclei of atoms from this observation.

conclusion 1 ....

explanation 1 ....

....

conclusion 2 ....

explanation 2 ....

....

[4]

(b) A source contains a radioactive isotope of strontium. This isotope decays by emission of β-particles. The half-life of this isotope is 29 years.

(i) State the change in the nucleus which occurs when a β-particle is emitted.

.... [1]

(ii) The initial mass of this isotope of strontium in the source is 25 μg.

Calculate the mass of the strontium isotope that decays in 87 years.

mass = ... μg [3]

[Total: 9]

10 The isotope americium-241 is represented by

$${}^{241}_{95}\text{Am}.$$

This isotope decays by an α-emission to an isotope of neptunium (Np).

(a) Complete the nuclide equation for this decay.

$${}^{241}_{95}\text{Am} \rightarrow {}^{\dots\dots}_{\dots\dots}\text{Np} + {}^{\dots\dots}_{\dots\dots}\alpha$$

[3]

(b) Fig. 10.1 shows a simple diagram of a smoke detector. The smoke detector contains a small sample of americium-241. This isotope ionises the air between the metal plates in the detector.

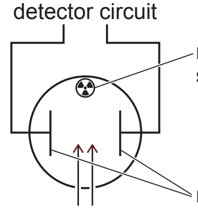


Fig. 10.1

(i) Describe how the americium-241 ionises air.

....

....

....

.... [3]

(ii) Suggest and explain **two** reasons why smoke detectors use an isotope that emits α-particles rather than an isotope that emits γ-radiation.

1. ....

....

....

2. ....

....

....

[2]

[Total: 8]