For Examiner's Use

1 The radiation from a radioactive source is detected using the apparatus illustrated in Fig. 9.1.

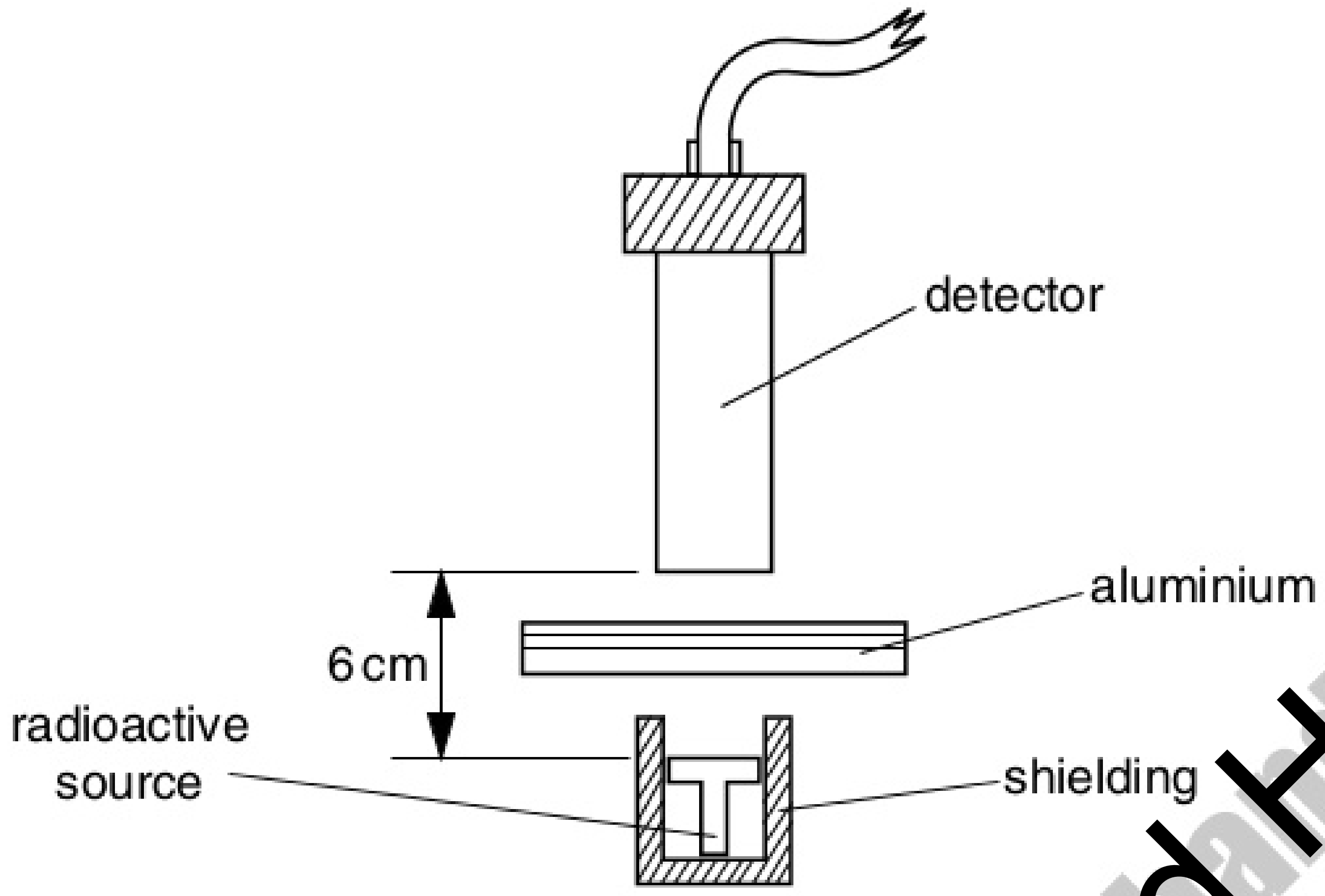

Fig. 9.1

Different thicknesses of aluminium are placed between the source and the detector. The count rate is obtained for each thickness. Fig. 9.2 shows the variation with thickness x of aluminium of the count rate.

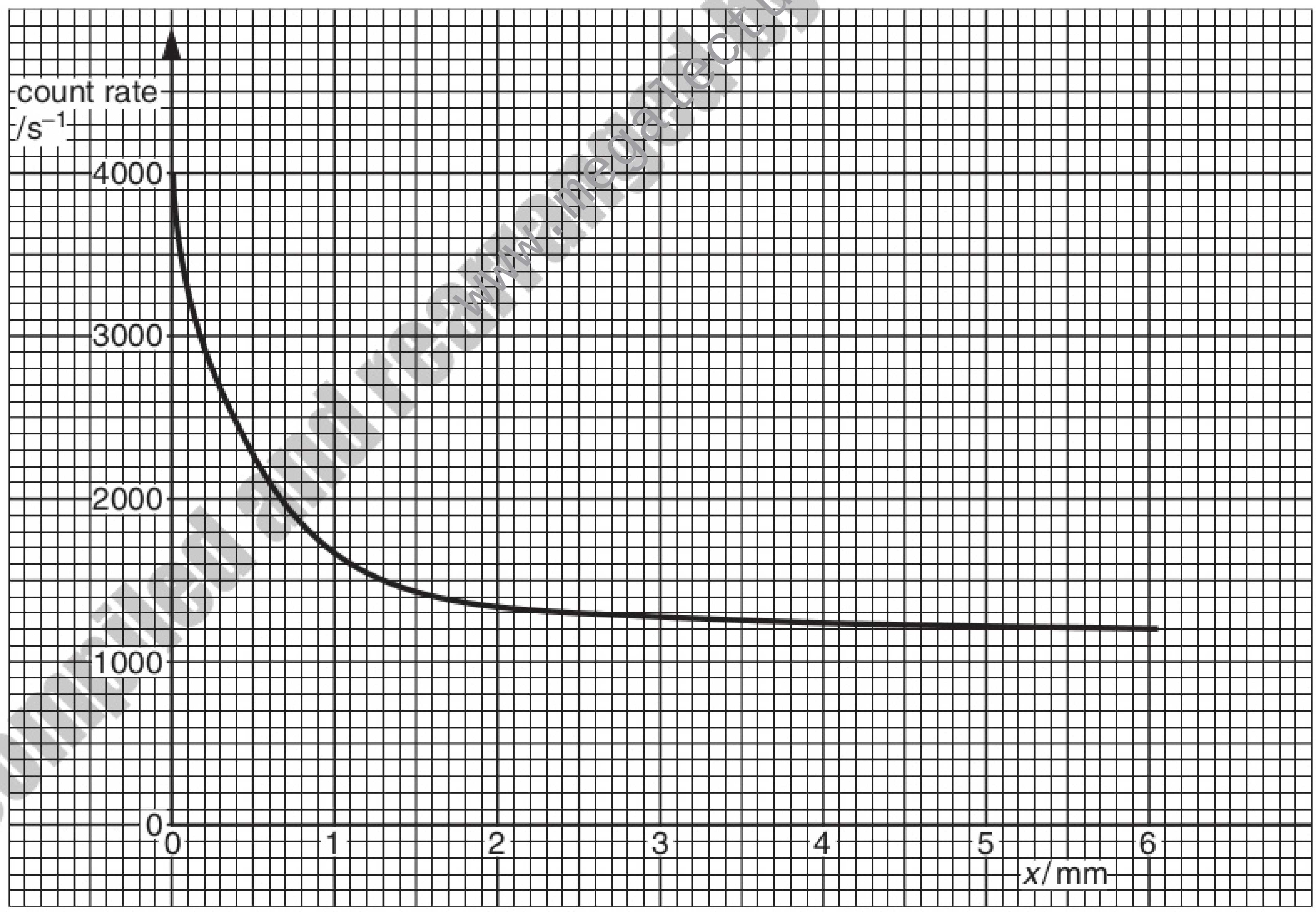

Fig. 9.2

For Examiner's Use

(a) Suggest why it is not possible to detect the presence of the emission of α-particles from the source.

....

....[1]

(b) State the evidence provided on Fig. 9.2 for the emission from the source of

(i) β-particles,

....

....

....

(ii) γ-radiation.

....

....

....

[4]

For Examiner's Use

2 Fig. 8.1 shows the position of Neptunium-231 ($^{231}_{93}$Np) on a diagram in which nucleon number (mass number) *A* is plotted against proton number (atomic number) *Z*.

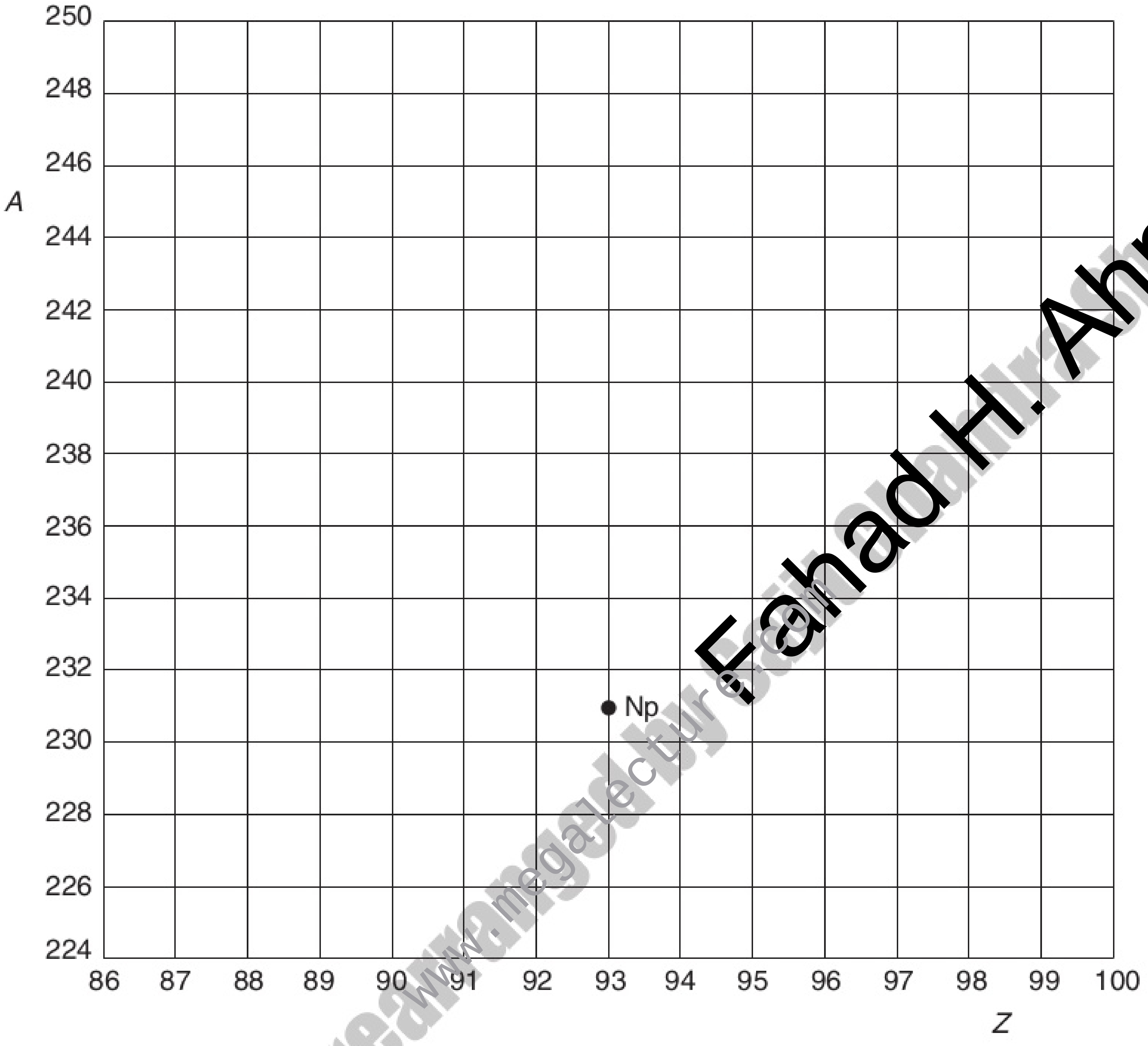

Fig. 8.1

(a) Neptunium-231 decays by the emission of an α-particle to form protactinium. On Fig. 8.1, mark with the symbol Pa the position of the isotope of protactinium produced in this decay. [1]

(b) Plutonium-243 ($^{243}_{94}$Pu) decays by the emission of a β-particle (an electron). On Fig. 8.1, show this decay by labelling the position of Plutonium-243 as Pu and the position of the daughter product as D. [2]

For Examiner's Use

3 The radioactive decay of nuclei is both spontaneous and random.

Explain what is meant by

(a) *radioactive decay* of a nucleus,

....

....

.... [2]

(b) *spontaneous* decay,

....

....

.... [2]

(c) *random* decay.

....

....

.... [2]

For Examiner's Use

4 The radioactive decay of a strontium (Sr) nucleus is represented in Fig. 7.1.

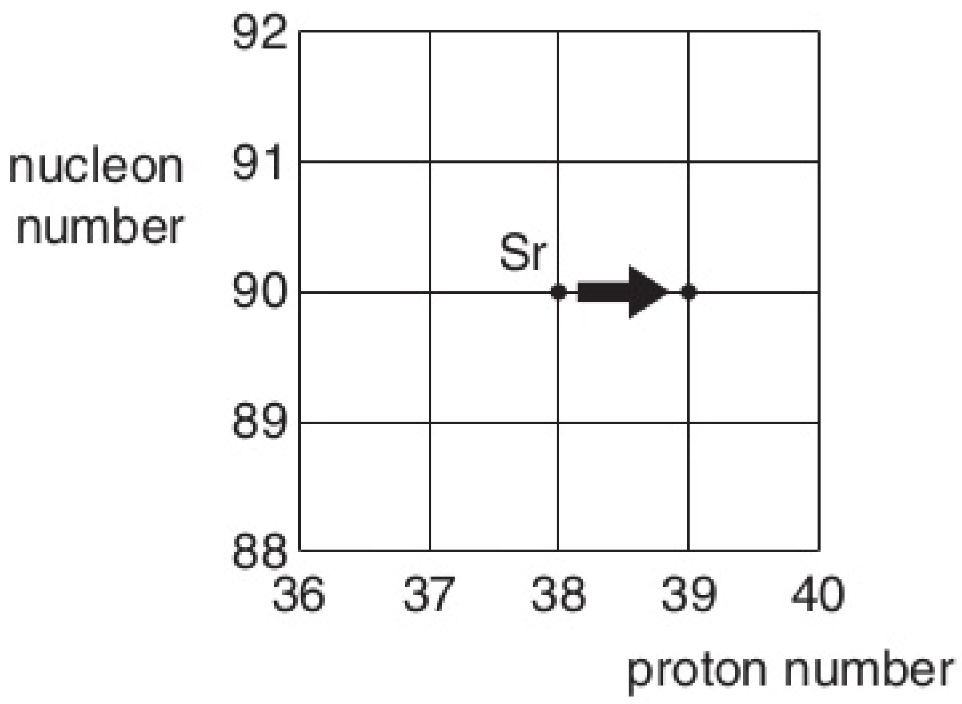

Fig. 7.1

(a) State whether Fig. 7.1 represents α-decay, β-decay or γ-decay.

.... [1]

(b) One type of radioactive decay cannot be represented on Fig. 7.1. Identify this decay and explain why it cannot be represented.

....

....

.... [2]

5 Uranium-236 ($^{236}_{92}U$) and Uranium-237 ($^{237}_{92}U$) are both radioactive.
Uranium-236 is an α-emitter and Uranium-237 is a β-emitter.

(a) Distinguish between an α-particle and a β-particle.

....

....

....

....

....

.... [4]

(b) The grid of Fig. 7.1 shows some proton numbers *Z* on the *x*-axis and the number *N* of neutrons in the nucleus on the *y*-axis.

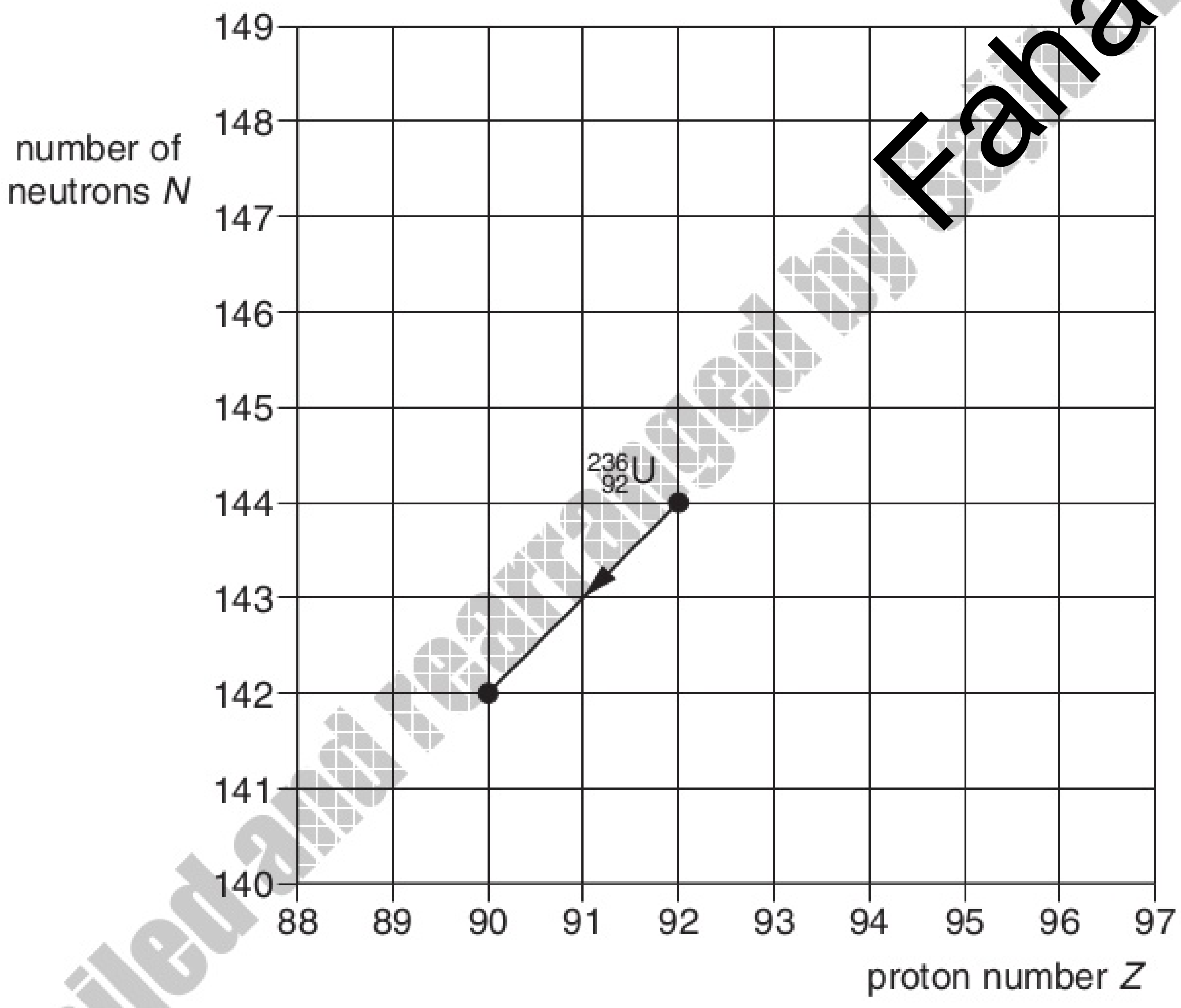

Fig. 7.1

The α-decay of Uranium-236 ($^{236}_{92}U$) is represented on the grid. This decay produces a nucleus of thorium (Th).

For Examiner's Use

(i) Write down the nuclear equation for this α-decay.

.... [2]

(ii) On Fig. 7.1, mark the position for a nucleus of

1. Uranium-237 (mark this position with the letter U),

2. Neptunium, the nucleus produced by the β-decay of Uranium-237 (mark this position with the letters Np). [2]

6 The spontaneous and random decay of a radioactive substance involves the emission of either α-radiation or β-radiation and/or γ-radiation.

(a) Explain what is meant by *spontaneous* decay.

....

....

.... [2]

(b) State the type of emission, one in each case, that

(i) is not affected by electric and magnetic fields,

.... [1]

(ii) produces the greatest density of ionisation in a medium,

.... [1]

(iii) does not directly result in a change in the proton number of the nucleus,

.... [1]

(iv) has a range of energies, rather than discrete values.

.... [1]

7 **(a)** One isotope of gold is represented as

$$^{197}_{79}Au.$$

State the number of neutrons in one nucleus of this isotope.

number = ... [1]

(b) In an α-particle scattering experiment, an α-particle approaches an isolated gold nucleus, as illustrated in Fig. 8.1.

Fig. 8.1

Complete Fig. 8.1 to show the path of the α-particle as it passes by, and moves away from, the gold nucleus. [2]

(c) The α-particle in **(b)** is replaced by one having greater initial kinetic energy.

State what change, if any, will occur in the final deviation of the α-particle.

....[1]

8 A nucleus of an atom of francium (Fr) contains 87 protons and 133 neutrons.

(a) Write down the notation for this nuclide.

....
Fr
....

[2]

(b) The nucleus decays by the emission of an α-particle to become a nucleus of astatine (At).

Write down a nuclear equation to represent this decay. [2]

For Examiner's Use

9 The α-particle scattering experiment provided evidence for the existence of a nuclear atom.

(a) State what could be deduced from the fact that

(i) most α-particles were deviated through angles of less than 10°,

....

....

.... [2]

(ii) a very small proportion of the α-particles was deviated through angles greater than 90°.

....

....

.... [2]

(b) Fig. 7.1 shows the path AB of an α-particle as it approaches and passes by a stationary gold nucleus.

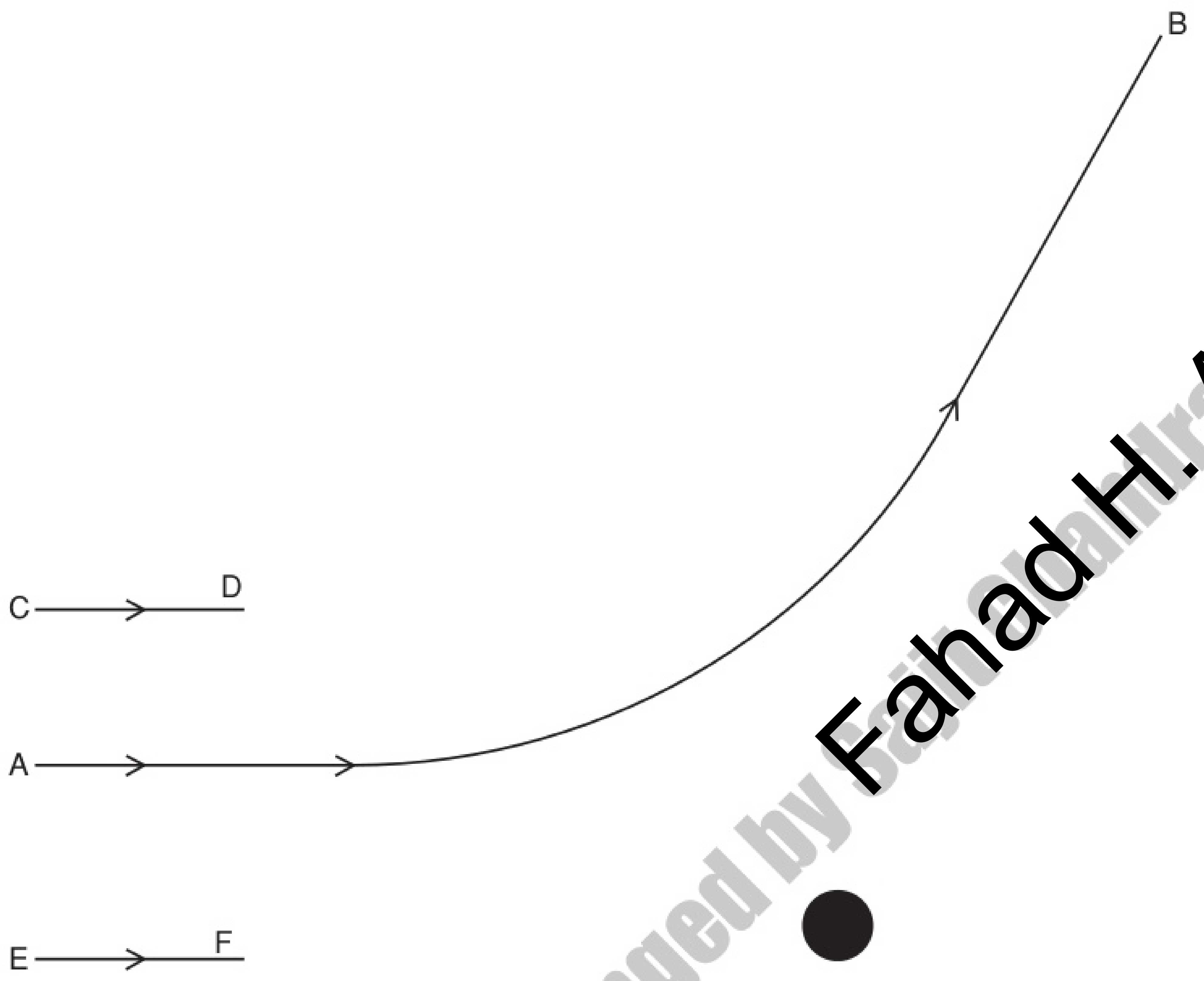

Fig. 7.1

On Fig. 7.1, draw lines (one in each case) to complete the paths of the α-particles passing by the gold nucleus when the initial direction of approach is

(i) along line CD,

(ii) along line EF.

[3]

For Examiner's Use

10 **(a)** Evidence for the nuclear atom was provided by the α-particle scattering experiment. State the results of this experiment.

....

....

....

.... [2]

(b) Give estimates for the diameter of

(i) an atom,

....[1]

(ii) a nucleus.

....[1]

For Examiner's Use

11 Thoron is a radioactive gas. The variation with time *t* of the detected count rate *C* from a sample of the gas is shown in Fig. 8.1.

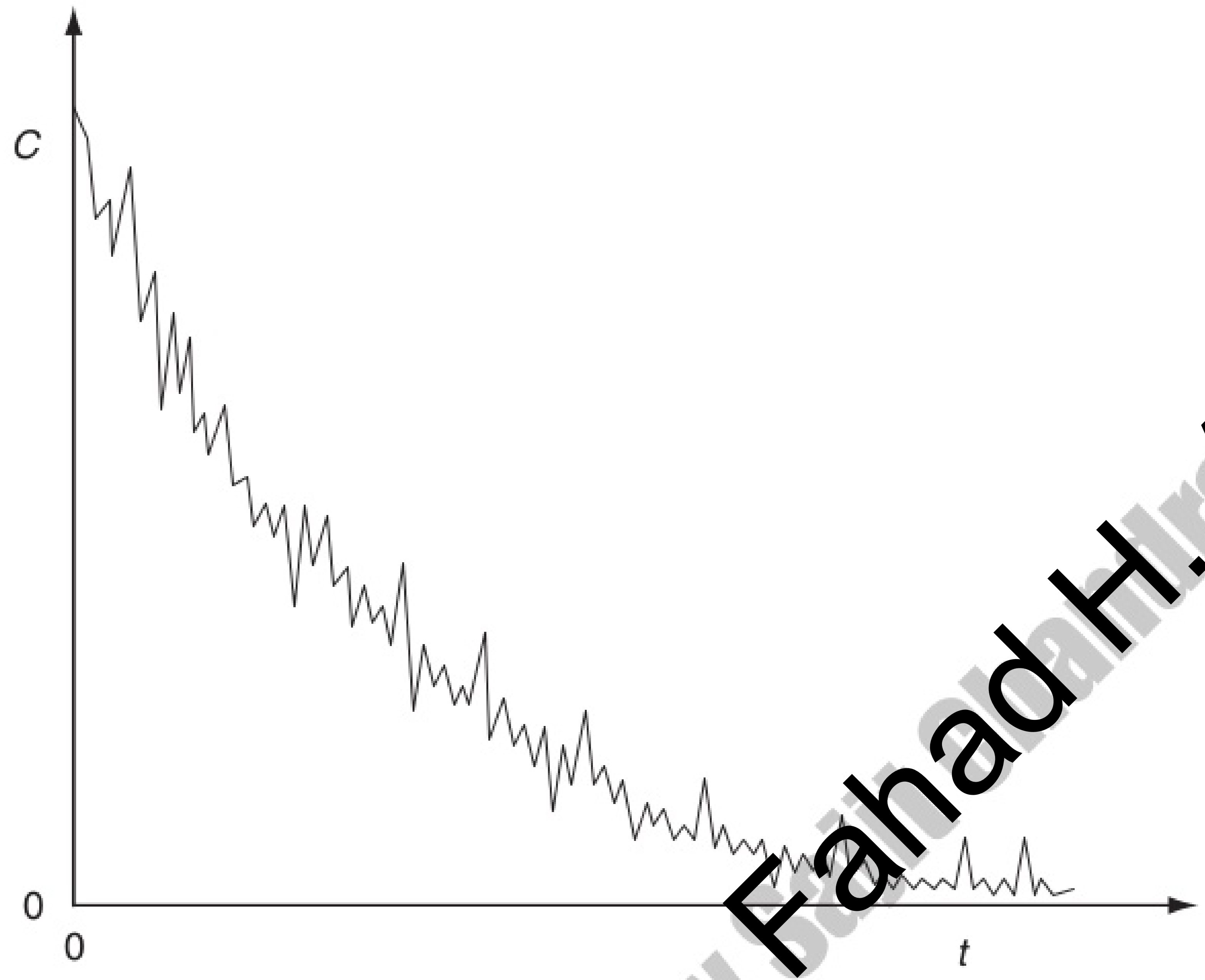

Fig. 8.1

Radioactive decay is said to be a random and spontaneous process.

(a) Explain, by reference to radioactive decay, what is meant by a *random* process.

....

....

.... [2]

(b) State the feature of Fig. 8.1 which indicates that the process is

(i) a decay process,

.... [1]

(ii) random.

.... [1]

(c) A second similar sample of thoron is prepared but it is at a much higher temperature. The variation with time of the count rate for this second sample is determined.
State the feature of the decay curves for the two samples that suggests that radioactive decay is a spontaneous process.

....

.... [1]

For Examiner's Use

12 An α-particle A approaches and passes by a stationary gold nucleus N. The path is illustrated in Fig. 7.1.

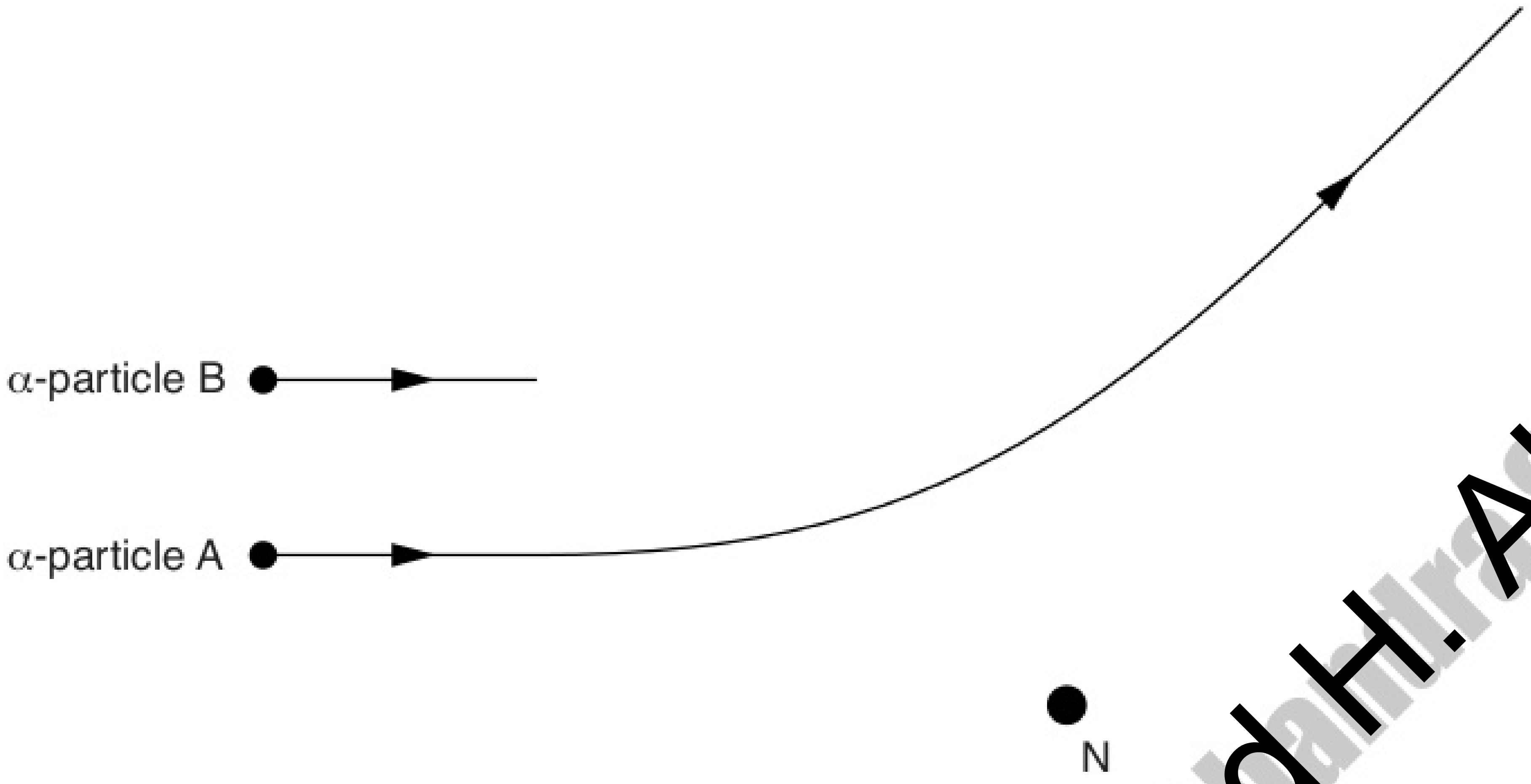

Fig. 7.1

(a) On Fig. 7.1, mark the angle of deviation *D* of this α-particle as a result of passing the nucleus N. [1]

(b) A second α-particle B has the same initial direction and energy as α-particle A.
On Fig. 7.1, complete the path of α-particle B as it approaches and passes by the nucleus N. [2]

(c) State what can be inferred about atoms from the observation that very few α-particles experience large deviations.

....

....

.... [2]

(d) The nucleus N could be one of several different isotopes of gold.

Suggest, with an explanation, whether different isotopes of gold would give rise to different deviations of a particular α-particle.

....

....

.... [2]

For Examiner's Use

13 Tungsten-184 ($^{184}_{74}W$) and tungsten-185 ($^{185}_{74}W$) are two isotopes of tungsten.

Tungsten-184 is stable but tungsten-185 undergoes β-decay to form rhenium (Re).

(a) Explain what is meant by *isotopes*.

....

....

....

.... [2]

(b) The β-decay of nuclei of tungsten-185 is spontaneous and random.

State what is meant by

(i) *spontaneous* decay,

....

.... [1]

(ii) *random* decay.

....

.... [1]

(c) Complete the nuclear equation for the β-decay of a tungsten-185 nucleus.

$$^{185}_{74}W \rightarrow \ldots\ldots\ldots\ldots + \ldots\ldots\ldots\ldots$$ [2]

For Examiner's Use

7 One of the isotopes of uranium is uranium-238 ($^{238}_{92}U$).

(a) State what is meant by *isotopes*.

....

....

....[2]

(b) For a nucleus of uranium-238, state

(i) the number of protons,

number = ... [1]

(ii) the number of neutrons.

number = ... [1]

(c) A uranium-238 nucleus has a radius of 8.9×10^{-15} m.

Calculate, for a uranium-238 nucleus,

(i) its mass,

mass = ... kg [2]

(ii) its mean density.

density = ... $kg\,m^{-3}$ [2]

For Examiner's Use

(d) The density of a lump of uranium is $1.9 \times 10^4\,\text{kg}\,\text{m}^{-3}$.
Using your answer to **(c)(ii)**, suggest what can be inferred about the structure of the atom.

....

....

.... [2]

For Examiner's Use

7 **(a)** The radioactive decay of some nuclei gives rise to the emission of α-particles. State

(i) what is meant by an α-particle,

....[1]

(ii) two properties of α-particles.

1. ....

....

2. ....

....
[2]

(b) One possible nuclear reaction involves the bombardment of a stationary nitrogen-14 nucleus by an α-particle to form oxygen-17 and another particle.

(i) Complete the nuclear equation for this reaction.

$$^{14}_{7}\text{N} + \;^{\cdots\cdots}_{\cdots\cdots}\alpha \rightarrow \;^{17}_{8}\text{O} + \cdots\cdots\cdots\cdots$$ [2]

(ii) The total mass-energy of the nitrogen-14 nucleus and the α-particle is less than that of the particles resulting from the reaction. This mass-energy difference is 1.1 MeV.

1. Suggest how it is possible for mass-energy to be conserved in this reaction.

....

....[1]

2. Calculate the speed of an α-particle having kinetic energy of 1.1 MeV.

speed = ... m s^{-1} [4]

For Examiner's Use

7 One property of α-particles is that they produce a high density of ionisation of air at atmospheric pressure. In this ionisation process, a neutral atom becomes an ion pair. The ion pair is a positively-charged particle and an electron.

(a) State

(i) what is meant by an α-particle,

....

.... [1]

(ii) an approximate value for the range of α-particles in air at atmospheric pressure.

range = ... cm [1]

(b) The energy required to produce an ion pair in air at atmospheric pressure is 31 eV. An α-particle has an initial kinetic energy of 8.5×10^{-13} J.

(i) Show that 8.5×10^{-13} J is equivalent to 5.3 MeV.

[1]

(ii) Calculate, to two significant figures, the number of ion pairs produced as the α-particle is stopped in air at atmospheric pressure.

number = ...[2]

(iii) Using your answer in **(a)(ii)**, estimate the average number of ion pairs produced per unit length of the track of the α-particle as it is brought to rest in air.

number per unit length = ... [2]

For Examiner's Use

For Examiner's Use

7 (a) Uranium (U) has at least fourteen isotopes.
Explain what is meant by *isotopes*.

....

....

.... [2]

(b) One possible nuclear reaction involving uranium is

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{141}_{56}Ba + ^{92}_{Z}Kr + x^{1}_{0}n + \text{energy}.$$

(i) State three quantities that are conserved in a nuclear reaction.

1. ....

....

2. ....

....

3. ....

....
[3]

(ii) For this reaction, determine the value of

1. *Z*,

Z = ... [1]

2. *x*.

x = ... [1]

For Examiner's Use

7 The results of the α-particle scattering experiment provided evidence for the existence and small size of the nucleus.

(a) State the result that provided evidence for

(i) the small size of the nucleus, compared with the atom,

....

....

.... [2]

(ii) the nucleus being charged and containing the majority of the mass of the atom.

....

....

.... [2]

(b) The α-particles in this experiment originated from the decay of a radioactive nuclide. Suggest two reasons why β-particles from a radioactive source would be inappropriate for this type of scattering experiment.

1. ....

....

2. ....

....

[2]

For Examiner's Use

9 **(a)** Explain what is meant by *radioactive decay*.

....

....

.... [2]

(b) **(i)** State how the random nature of radioactive decay may be inferred from observations of the count rate.

....

.... [1]

(ii) A radioactive source has a long half-life so that, over a period of several days, its rate of decay remains constant.
State the effect, if any, of a rise in temperature on this decay rate.

.... [1]

(iii) Suggest why some radioactive sources are found to contain traces of helium gas.

....

....

.... [2]

7 **(a)** Two isotopes of the element uranium are $^{235}_{92}U$ and $^{238}_{92}U$.

Explain the term *isotope*.

....

....

.... [2]

(b) **(i)** In a nuclear reaction, proton number and neutron number are conserved. Other than proton number and neutron number, state a quantity that is conserved in a nuclear reaction.

.... [1]

(ii) When a nucleus of uranium-235 absorbs a neutron, the following reaction may take place.

$$^{235}_{92}U + ^{a}_{b}n \rightarrow ^{141}_{x}Ba + ^{y}_{36}Kr + 3\ ^{a}_{b}n$$

State the values of *a*, *b*, *x* and *y*.

a = ...

b = ...

x = ...

y = ... [3]

(c) When the nucleus of $^{238}_{92}U$ absorbs a neutron, the nucleus decays, emitting an α-particle. State the proton number and nucleon number of the nucleus that is formed as a result of the emission of the α-particle.

proton number = ...

nucleon number = ... [2]

For Examiner's Use

7 (a) State the experimental observations that show radioactive decay is

(i) spontaneous,

....

.... [1]

(ii) random.

....

.... [1]

(b) On Fig. 7.1, complete the charge and mass of α-particles, β-particles and γ-radiation. Give example speeds of α-particles and γ-radiation emitted by a laboratory source.

	α-particle	β-particle	γ-radiation
charge			0
mass	4u		
speed		up to 0.99c	

Fig. 7.1

[3]

(c) Explain the process by which α-particles lose energy when they pass through air.

....

....

.... [2]

6 Two horizontal metal plates are separated by distance *d* in a vacuum. A potential difference *V* is applied across the plates, as shown in Fig. 6.1.

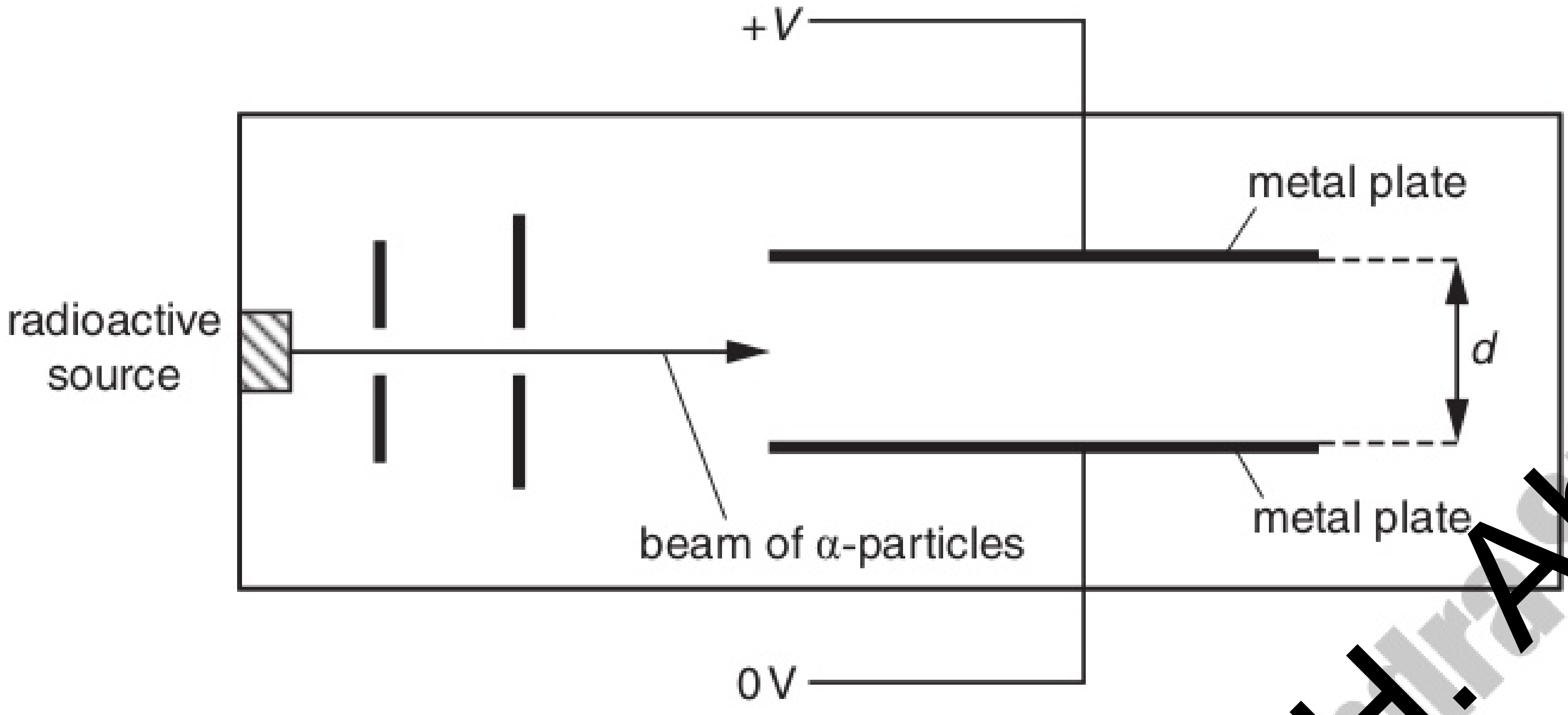

Fig. 6.1

A horizontal beam of α-particles from a radioactive source is made to pass between the plates.

(a) State and explain the effect on the deflection of the α-particles for each of the following changes:

(i) The magnitude of *V* is increased.

....

....[1]

(ii) The separation *d* of the plates is decreased.

....

....[1]

(b) The source of α-particles is replaced with a source of β-particles.
Compare, with a reason in each case, the effect of each of the following properties on the deflections of α- and β-particles in a uniform electric field:

(i) charge

....

....

....[2]

(ii) mass

....

....

....[2]

(iii) speed

....

....

....[1]

(c) The electric field gives rise to an acceleration of the α-particles and the β-particles. Determine the ratio

$$\frac{\text{acceleration of the } \alpha\text{-particles}}{\text{acceleration of the } \beta\text{-particles}}.$$

ratio = ...[3]

7 **(a)** The spontaneous decay of polonium is shown by the nuclear equation

$$^{210}_{84}\text{Po} \rightarrow {}^{206}_{82}\text{Pb} + \text{X}.$$

(i) State the composition of the nucleus of X.

....

....[1]

(ii) The nuclei X are emitted as radiation. State two properties of this radiation.

1. ....

....

2. ....

....

[2]

(b) The mass of the polonium (Po) nucleus is greater than the combined mass of the nuclei of lead (Pb) and X. Use a conservation law to explain qualitatively how this decay is possible.

....

....

....[3]

For Examiner's Use

7 (a) A nuclear reaction occurs when a uranium-235 nucleus absorbs a neutron. The reaction may be represented by the equation:

$$^{235}_{92}\text{U} + ^{W}_{X}\text{n} \rightarrow ^{93}_{37}\text{Rb} + ^{141}_{Z}\text{Cs} + Y^{W}_{X}\text{n}$$

State the number represented by the letter

W ....

X ....

Y ....

Z ....

[3]

(b) The sum of the masses on the left-hand side of the equation in **(a)** is not the same as the sum of the masses on the right-hand side.

Explain why mass seems not to be conserved.

....

....

.... [2]

For Examiner's Use

7 A radioactive source emits α-radiation and γ-radiation.

Explain how it may be shown that the source does not emit β-radiation using

(a) the absorption properties of the radiation,

....

....

....

....

.... [2]

(b) the effects of a magnetic field on the radiation.

....

....

....

....

.... [2]

For Examiner's Use

6 **(a)** β-radiation is emitted during the spontaneous radioactive decay of an unstable nucleus.

(i) State the nature of a β-particle.

.... [1]

(ii) State two properties of β-radiation.

1. ....

2. .... [2]

(iii) Explain the meaning of *spontaneous radioactive decay*.

....

.... [1]

(b) The following equation represents the decay of a nucleus of hydrogen-3 by the emission of a β-particle.

Complete the equation.

$$^{3}_{1}H \rightarrow {}^{\cdots\cdots}_{\cdots\cdots}He + {}^{\cdots\cdots}_{\cdots\cdots}\beta$$ [2]

(c) The β-particle is emitted with an energy of 5.7×10^3 eV.

Calculate the speed of the β-particle.

speed = ... $m\,s^{-1}$ [3]

(d) A different isotope of hydrogen is hydrogen-2 (deuterium). Describe the similarities and differences between the atoms of hydrogen-2 and hydrogen-3.

....

....

.... [2]

For Examiner's Use

7 A nuclear reaction between two helium nuclei produces a second isotope of helium, two protons and 13.8 MeV of energy. The reaction is represented by the following equation.

$$^{3}_{2}\text{He} + ^{3}_{2}\text{He} \rightarrow ^{\dots\dots}_{\dots\dots}\text{He} + 2\,^{\dots\dots}_{\dots\dots}\text{p} + 13.8\,\text{MeV}$$

(a) Complete the nuclear equation. [2]

(b) By reference to this reaction, explain the meaning of the term *isotope*.

....

....

....[2]

(c) State the quantities that are conserved in this nuclear reaction.

....

....

....

....

....[2]

(d) Radiation is produced in this nuclear reaction.

State

(i) a possible type of radiation that may be produced,

....[1]

(ii) why the energy of this radiation is less than the 13.8 MeV given in the equation.

....[1]

(e) Calculate the minimum number of these reactions needed per second to produce power of 60 W.

number = ... s^{-1} [2]

For Examiner's Use

6 (a) Describe the structure of an atom of the nuclide $^{235}_{92}U$.

....

....

....

.... [2]

(b) The deflection of α-particles by a thin metal foil is investigated with the arrangement shown in Fig. 6.1. All the apparatus is enclosed in a vacuum.

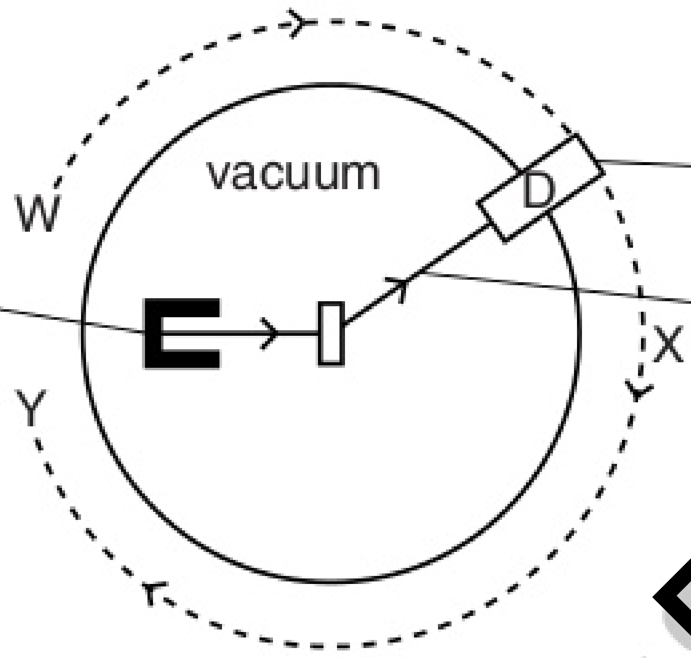

Fig. 6.1

The detector of α-particles, D, is moved around the path labelled WXY.

(i) Explain why the apparatus is enclosed in a vacuum.

....

.... [1]

(ii) State and explain the readings detected by D when it is moved along WXY.

....

....

....

....

....

.... [3]

Question 6 continues on page 16.

For Examiner's Use

(c) A beam of α-particles produces a current of 1.5 pA. Calculate the number of α-particles per second passing a point in the beam.

number = ... s^{-1} [3]