5. Nuclear physics

5.2 Radioactivity

Paper 3 and 4

Question Paper

Paper 3

Questions are applicable for both core and extended candidates

1 **(a)** **(i)** Name **three** types of nuclear emission from radioactive sources.

1 .....

2 .....

3 .....

[2]

(ii) State the type of nuclear emission which has a relative charge of +2.

..... [1]

(iii) State the type of nuclear emission which is part of the electromagnetic spectrum.

..... [1]

(b) The isotope technetium-99m decays to technetium-99.

(i) The half-life of technetium-99m is 6 hours.

Determine the fraction of technetium-99m remaining in a sample after 18 hours.

fraction remaining = ... [2]

(ii) The nuclide notation for technetium-99 is:

$$^{99}_{43}\mathrm{Tc}$$

Complete the table below to show the number of each type of particle in a neutral atom of technetium-99.

Complete the table below to show the number of each type of particle in a neutral atom of technetium-99.

type of particle	number
electron	
neutron	
proton	

[2]

[Total: 8]

2 **(b)** Strontium-90 decays by emitting β-particles (beta-particles).

Describe the nature of β-particles.

..... [1]

(c) Strontium-90 decays with a half-life of 29 years.
A sample contains 16 mg of strontium-90.

Calculate the time taken for the strontium-90 to decay until only 2.0 mg of strontium-90 remains in the sample.

time = ... years [2]

[Total: 6]

3 **(a)** U-235 and U-238 are isotopes of uranium.

Fig. 10.1 shows the nuclide notation for U-235 and for U-238.

$^{235}_{92}U$ $^{238}_{92}U$

Fig. 10.1

(i) Compare the number of **protons** in one nucleus of U-235 with the number of protons in one nucleus of U-238.

.....

..... [1]

(ii) Compare the number of **neutrons** in one nucleus of U-235 with the number of neutrons in one nucleus of U-238.

.....

..... [1]

(b) A sample contains another isotope of uranium. The half-life of this isotope is 24 minutes.

Calculate the time taken for the mass of this isotope in the sample to decay from 16.0 mg to 4.0 mg.

time taken = ... minutes [3]

[Total: 5]

4 **(b)** A sample contains 8.0 mg of this isotope of actinium.

The isotope of actinium has a half-life of 10.0 days.

The graph in Fig. 10.1 shows the original mass of the actinium in the sample and its mass after 10 days.

On Fig. 10.1, plot **two** more points for the mass remaining after 20 days and 30 days. Draw the decay curve for the sample over 30 days.

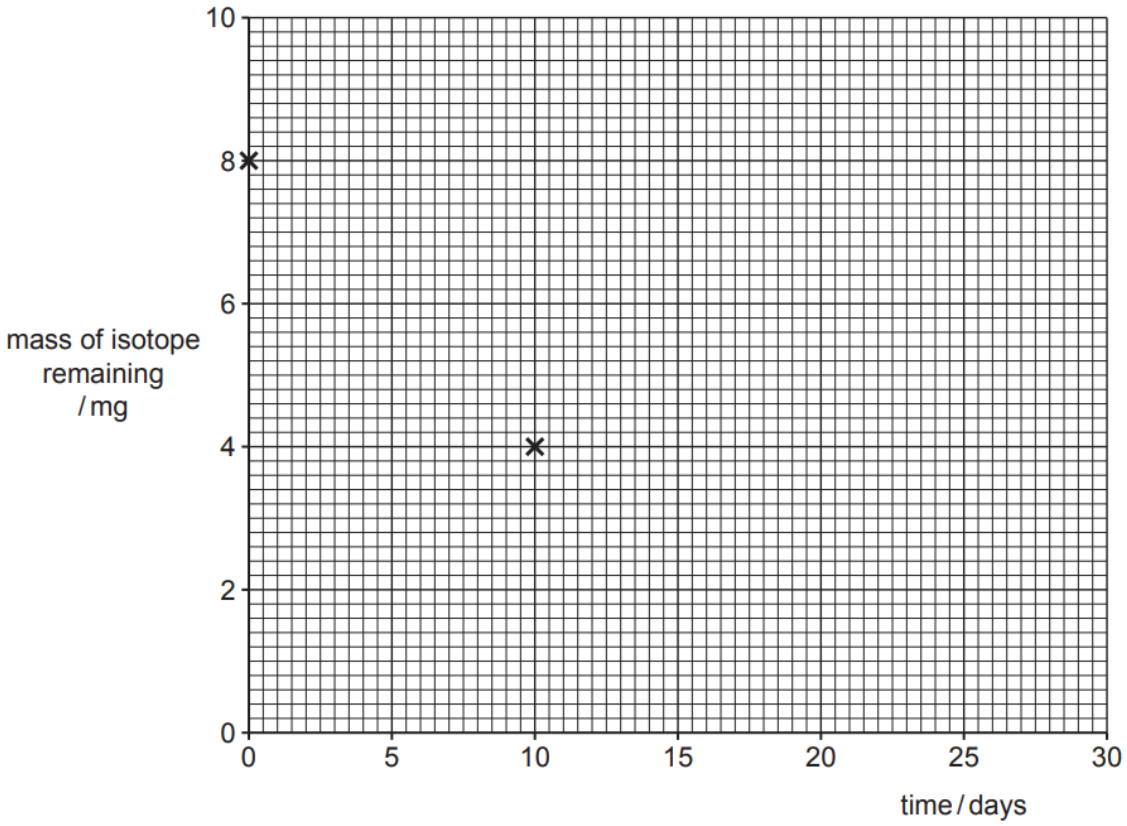


Fig. 10.1

[3]

[Total: 5]

5 **(b)** Fig. 11.2 shows four different particle diagrams, A, B, C and D.

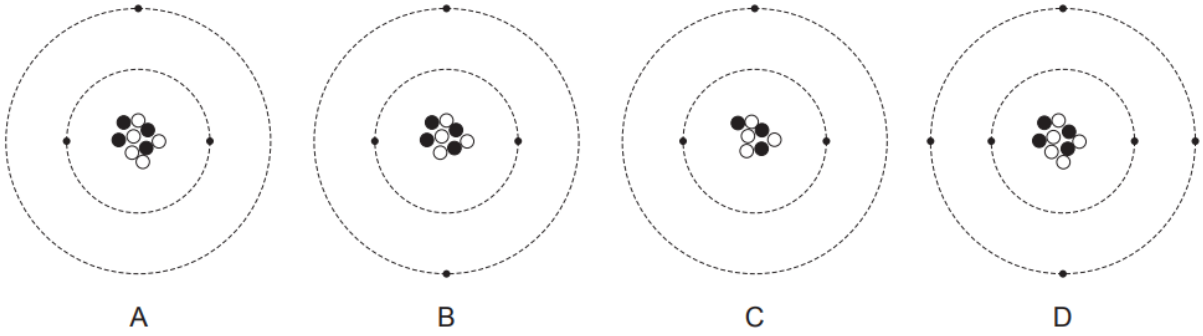


Fig. 11.2

(i) State which diagrams show an isotope of beryllium.

..... [1]

(ii) State which diagram shows a positive ion.

..... [1]

(c) A scientist uses a detector and counter to measure the count rate due to radiation emitted from a radioactive source.

The first measurement is 400 counts / min.

The scientist takes another measurement 6 hours later. This measurement is 50 counts / min.

Calculate the half-life of the radioactive source.

half-life = ... h [2]

[Total: 6]

6 Fig. 11.1 represents all the particles in an atom which is a radioactive isotope of carbon.

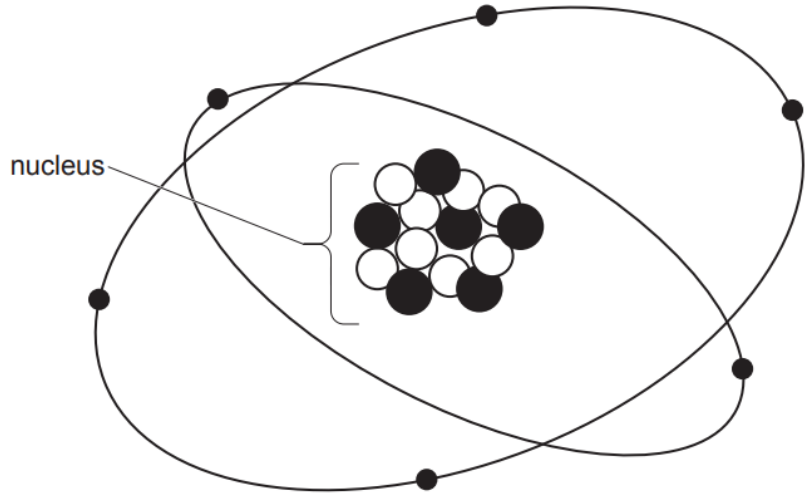


Fig. 11.1 (not to scale)

(a) Table 11.1 gives information about the particles shown in Fig. 11.1.

Using the information in Fig. 11.1, write in the empty boxes to complete Table 11.1.

Table 11.1

name of particle	number of particles	position of particle	relative charge of particle
electron			
neutron		in the nucleus	
	6		+1 (plus one)

[4]

(b) A museum displays an item made of ancient wood. When the wood was new, the item contained 8.00 mg of the isotope shown in Fig. 11.1. The item now contains 2.00 mg of the isotope. The half-life of the isotope is 5700 years.

Calculate the age of the wood in the item.

age of wood = ... years [3]

[Total: 7]

7 Iodine-131 is a radioactive isotope of the element iodine. Fig. 10.1 shows the nuclide notation for a nucleus of iodine-131.

$$^{131}_{53}\mathrm{I}$$

Fig. 10.1

(b) When a nucleus of iodine-131 decays, it emits a beta (β)-particle and a gamma (γ) ray.

State the nature of a beta-particle and a gamma ray.

A beta-particle is .....

A gamma ray is .....

[2]

(c) A sample contains 1.6 mg of iodine-131.
The half-life of iodine-131 is 8.0 days.

Calculate the mass of iodine-131 remaining in the sample after 24.0 days.

mass of iodine-131 remaining = ... mg [3]

[Total: 7]

8 **(a)** α (alpha)-particles, β (beta)-particles and γ (gamma)-rays have different characteristics.

Complete Table 10.1 by indicating with a tick (✓) the correct type of radiation for each characteristic. The first row is done for you.

Table 10.1

characteristic	type of radiation		
	α (alpha)-particles	β (beta)-particles	γ (gamma)-rays
electromagnetic wave			✓
least ionising			
least penetrating			
a helium nucleus			
negatively charged			

[3]

(b) The nucleus of an isotope of plutonium has 94 protons and 147 neutrons. The chemical symbol for plutonium is Pu.

Write the nuclide notation that describes this nucleus.

[2]

(c) A sample contains 8.0×10^{12} atoms of a radioactive isotope of plutonium.
The half-life of this isotope of plutonium is 14 years.

Calculate the number of atoms of this isotope of plutonium remaining in the sample after 28 years.

number of atoms of plutonium remaining = ... [3]

[Total: 8]

9 **(b)** Carbon-14 decays by emitting a β (beta)-particle.

State the nature of a β (beta)-particle.

..... [1]

(c) Scientists find an ancient wooden spoon. They find that the spoon contains 2000 atoms of carbon-14.

When the spoon was made, it contained 16 000 atoms of carbon-14.

The half-life of carbon-14 is 5800 years.

Calculate the age of the ancient spoon.

age of spoon = ... years [2]

[Total: 6]

10 A teacher determines the types of emission from a radioactive source. He uses different materials to absorb the emissions. Fig. 11.1 shows the equipment.

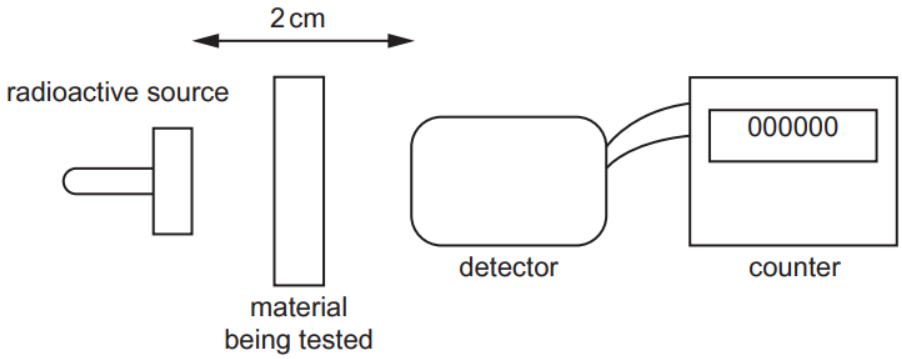


Fig. 11.1 (not to scale)

The teacher places a material between the radioactive source and the detector. The counter shows the count rate for the emission that reaches the detector. The teacher records the count rate. He repeats the experiment for different materials.

Table 11.1 shows the results.

Table 11.1

material being tested	count rate / counts/s
air (no object in gap)	480
thin sheet of paper	481
2 mm sheet of aluminium	479
10 mm block of lead	120

(a) State whether the source emits α (alpha)-particles.
Use information from Table 11.1 to give a reason for your answer.

.....

.....

..... [2]

(b) State whether the source emits γ (gamma)-rays.
Use information from Table 11.1 to give a reason for your answer.

.....

.....

..... [2]

[Total: 4]

11 **(a)** An isotope of americium has 95 protons and 146 neutrons in its nucleus.

Write the nuclide notation for the nucleus of this isotope. The chemical symbol for americium is Am.

[2]

(b) Fig. 11.1 shows how the count rate of a sample of americium changes with time.

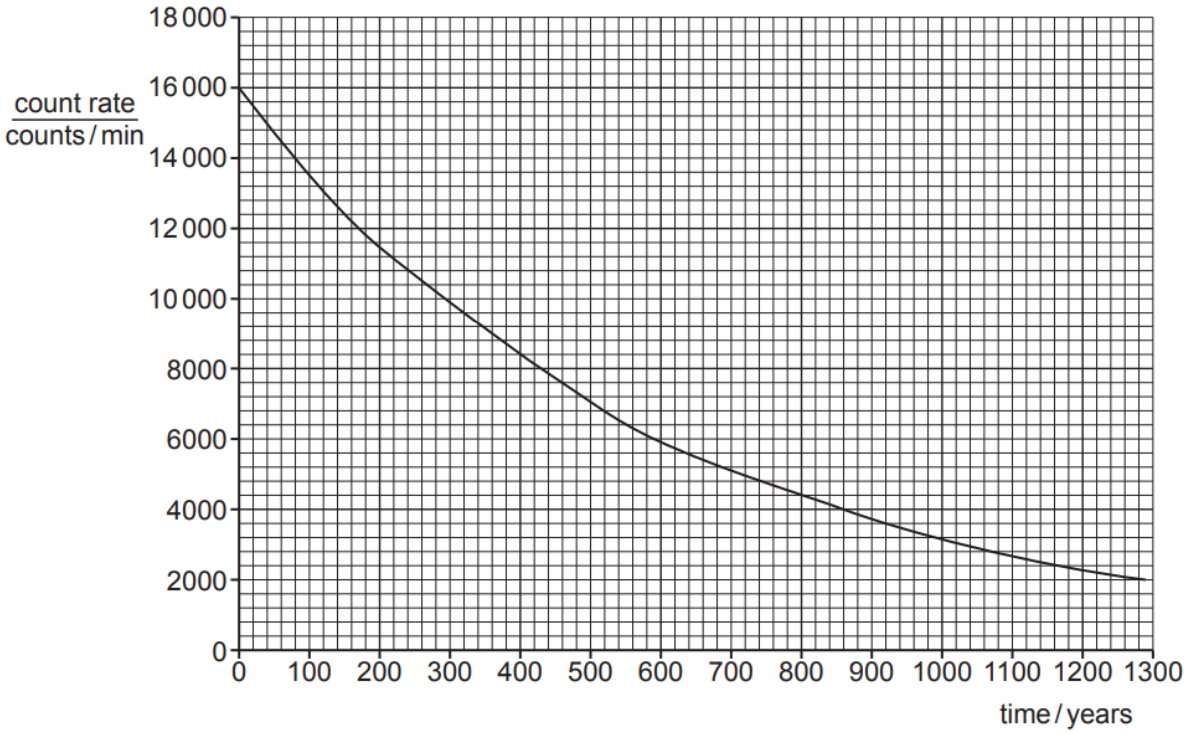


Fig. 11.1

Determine the half-life of the americium in the sample. Use information from Fig. 11.1.

half-life = ... years [2]

[Total: 4]

12 **(a)** α (alpha)-particles, β (beta)-particles and γ (gamma)-rays have different characteristics.

Complete Table 11.1 by indicating the correct type of radiation for each characteristic.
The first one is done for you.

Table 11.1

characteristic	type of radiation		
	α-particles (alpha-particles)	β-particles (beta-particles)	γ-rays (gamma-rays)
largest mass	✓		
most ionising			
most penetrating			
negatively charged			
greatest speed			

[3]

(b) A sample of radioactive material contains 80 mg of sodium-24.
The half-life of sodium-24 is 15 hours.

Calculate the mass of sodium-24 remaining in the sample after 45 hours.

mass remaining = ... mg [3]

[Total: 6]

13 **(a)** State which radioactive emission is:

(i) the most penetrating ..... [1]

(ii) the most ionising. ..... [1]

(b) Explain the meaning of the term *isotope*.

.....

..... [2]

(c) The isotope iodine-131 is used in hospitals. A sample of iodine-131 is prepared for use.

The half-life of iodine-131 is 8 days.

Determine the fraction of iodine-131 remaining in the sample after 16 days.

fraction remaining = ... [2]

[Total: 6]

14 **(a)** Table 12.1 describes four nuclides.

Table 12.1

name of nuclide	plutonium-238	thorium-234	uranium-235	uranium-238
nuclide notation	$^{238}_{94}Pu$	$^{234}_{90}Th$	$^{235}_{92}U$	$^{238}_{92}U$

(i) State which **two** nuclides have the same number of protons.

..... [1]

(ii) State which **two** nuclides have the same number of nucleons.

..... [1]

(iii) State which **one** of the four nuclides has the most electrons orbiting when it is in a neutral atom.

..... [1]

(b) Thorium-234 has a half-life of 24 days. A sample of radioactive material contains 40 mg of thorium-234.

Calculate the mass of thorium-234 remaining after 72 days.

mass of thorium-234 remaining = ... mg [3]

[Total: 6]

15 **(b)** The activity of a sample of a radioactive nuclide is measured in June of each year.
In June 2004 the activity was 80 000 counts / s.
In June 2014 the activity was 20 000 counts / s.

(i) Show that the half-life of the nuclide is 5 years.

[3]

(ii) Determine the year when the activity of the sample was 10 000 counts / s.

year = ... [2]

[Total: 7]

16 **(b)** The count rate of a radioactive sample is 2400 counts per minute at 10 am on one day. The half-life of the sample is two days.

Predict the count rate at 10 am four days later.

count rate = ... counts per minute [3]

17 A teacher is investigating radioactivity.

The teacher measures the background radiation in the laboratory.

(a) State **one** source of background radiation.

..... [1]

(b) A teacher measures the count rate of a radioactive isotope.

Fig. 12.1 shows the graph of her results.

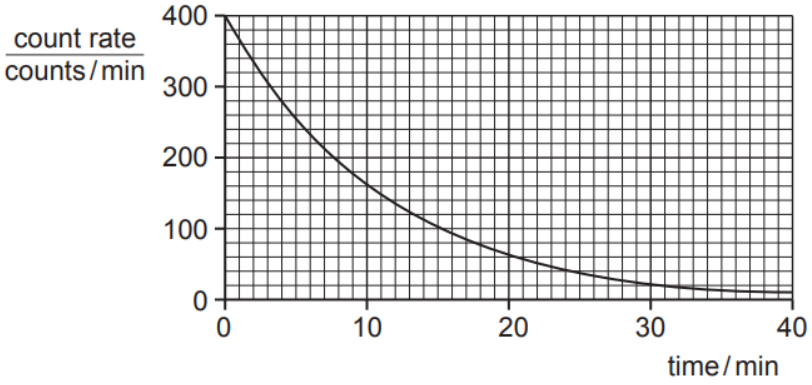


Fig. 12.1

(i) Determine the half-life of the radioactive isotope. Use information from Fig. 12.1.

Show on Fig. 12.1 how you obtained your value.

half-life = ... minutes
[3]

(ii) The radioactive isotope emits γ-radiation.

Describe **one** method of safely storing the radioactive isotope.

.....

..... [1]

[Total: 5]

18 Radioactive sources emit α-(alpha), β-(beta) and γ-(gamma) radiations.

(a) State which of these types of radiation can pass through paper.

..... [1]

(b) Barium-137 is a radioactive isotope. The nuclide notation for barium-137 is

$$^{137}_{56}\text{Ba}$$

Determine the number of neutrons in a nucleus of barium-137.

number of neutrons = ... [1]

(c) An isotope of barium-137 has a half-life of 3 minutes.

A radioactive source contains 36 mg of this isotope.

Calculate the mass of the isotope that remains in the source after 9 minutes.

mass of the isotope remaining = ... mg [3]

[Total: 5]

19 **(b)** Carbon-14 decays by emitting a β-particle.

State what happens to a nucleus of carbon-14 when it emits a β-particle.

..... [1]

(c) People working with radioactive sources need to take safety precautions.

(i) A shielding material can absorb ionising radiation and reduce the damage to living tissue.

State a suitable material that will absorb all types of naturally occurring nuclear radiation.

..... [1]

(ii) Apart from using shielding, state how a person can reduce the amount of ionising radiation they absorb when they handle samples of radioactive substances.

..... [1]

20 A teacher carries out two experiments at the same time.

(a) In the first experiment the count rate for a sample of a radioactive isotope is measured every 30 seconds for 6 minutes.

The results are shown in Table 12.1.

Table 12.1

time / minutes	count rate / counts / second
0.0	1246
0.5	1036
1.0	941
1.5	810
2.0	686
2.5	621
3.0	550
3.5	468
4.0	421
4.5	368
5.0	318
5.5	280
6.0	242

Estimate the half-life of the radioactive isotope. Use the information in the table.

half-life = ... minutes [1]

(b) In the second experiment the teacher repeats the procedure with another sample of the same radioactive isotope. The mass of the second sample is greater than that of the first sample.

Suggest a value for the count rate for this sample at the start of the experiment.

count rate = ... counts / second [1]

(c) One type of particle emitted during radioactive decay is an α-particle (alpha particle).

Describe:

(i) the nature of an α-particle

..... [1]

(ii) the ionising ability of an α-particle

..... [1]

(iii) the penetrating ability of an α-particle.

..... [1]

[Total: 5]

21 A radioactive substance decays by emitting an α-particle.

(a) The nuclide notation for an α-particle is

$$^{4}_{2}\alpha$$

(i) State the term given to the number 4, written in the nuclide notation.

..... [1]

(ii) State the term given to the number 2, written in the nuclide notation.

..... [1]

(b) Fig. 12.1 shows the decay curve for a radioactive material.

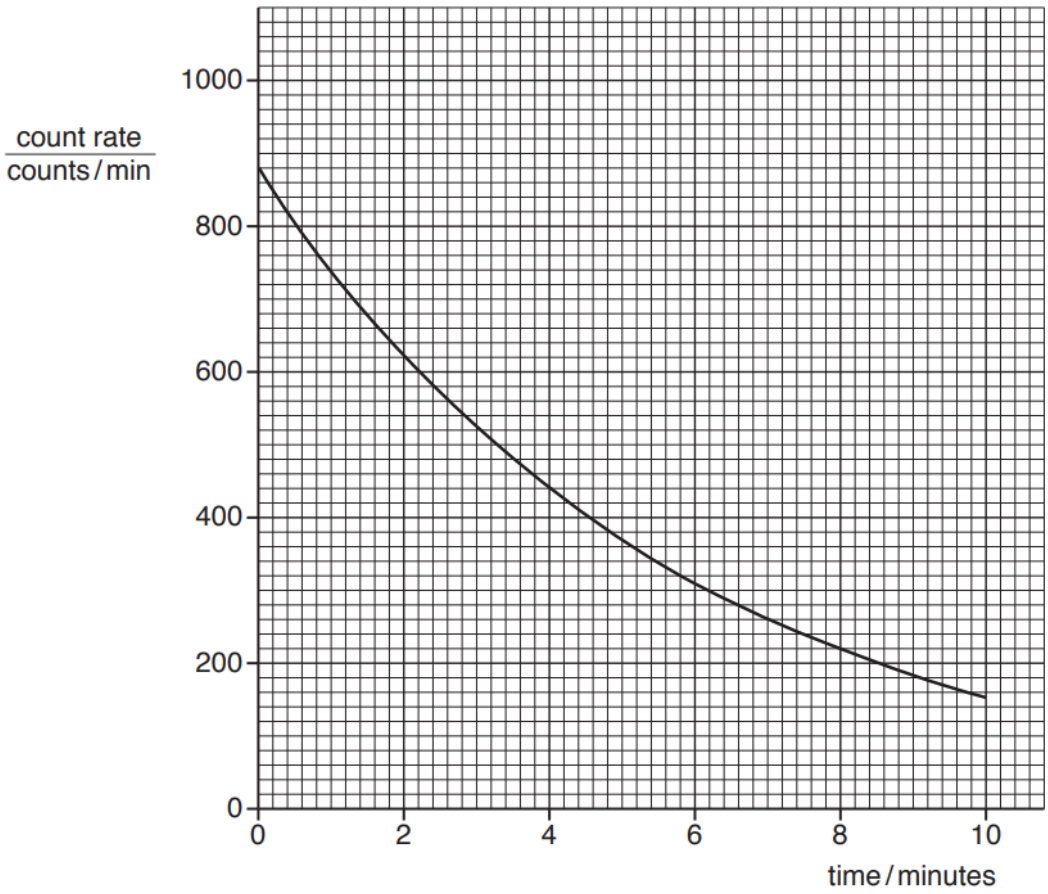


Fig. 12.1

(i) Use information from the graph in Fig. 12.1 to determine the half-life of the material. Clearly show how you used the graph to obtain your answer.

half-life = ... minutes [3]

(ii) Another radioactive material with the same half-life has an initial count rate of 600 counts/min. On Fig. 12.1 sketch the decay curve for this material. [1]

[Total: 6]

22 **(a)** Radioactive emission is a random process.

Explain the meaning of the word *random*.

.....

..... [1]

(b) The table compares three types of radioactive emission.

emission	relative ionising ability	relative penetrating ability
alpha		
beta		
gamma		

Table 12.1

Complete the table by choosing words from the box.

high	low	medium

[3]

(c) A radioactive substance decays by emitting an α-particle.

An α-particle can be represented as $^{4}_{2}\alpha$.

Draw a labelled diagram showing the composition of an α-particle.

[3]

[Total: 7]

23 **(b)** Carbon-14 is an isotope of carbon. Carbon-12 is another isotope of carbon.
Compare the nucleus of carbon-14 with the nucleus of carbon-12.

State the similarities and differences.

.....

.....

.....

.....

.....[3]

(c) Scientists use carbon-14 to estimate the age of wood that is very old.

A very old sample of wood contains 1.0×10^8 carbon-14 atoms.
When the sample was new, it contained 8.0×10^8 carbon-14 atoms.

The half-life of carbon-14 is 5700 years.

Estimate the age of the sample of wood.

age of wood = ... years [3]

[Total: 9]

24 **(b)** Tritium is an isotope of hydrogen. It can be represented by ${}^{3}_{1}\mathrm{H}$.

(i) Explain the meaning of the term *isotope*.

.....

.....

..... [2]

(ii) Fig. 12.1 shows how the activity of a sample of tritium varies with time.

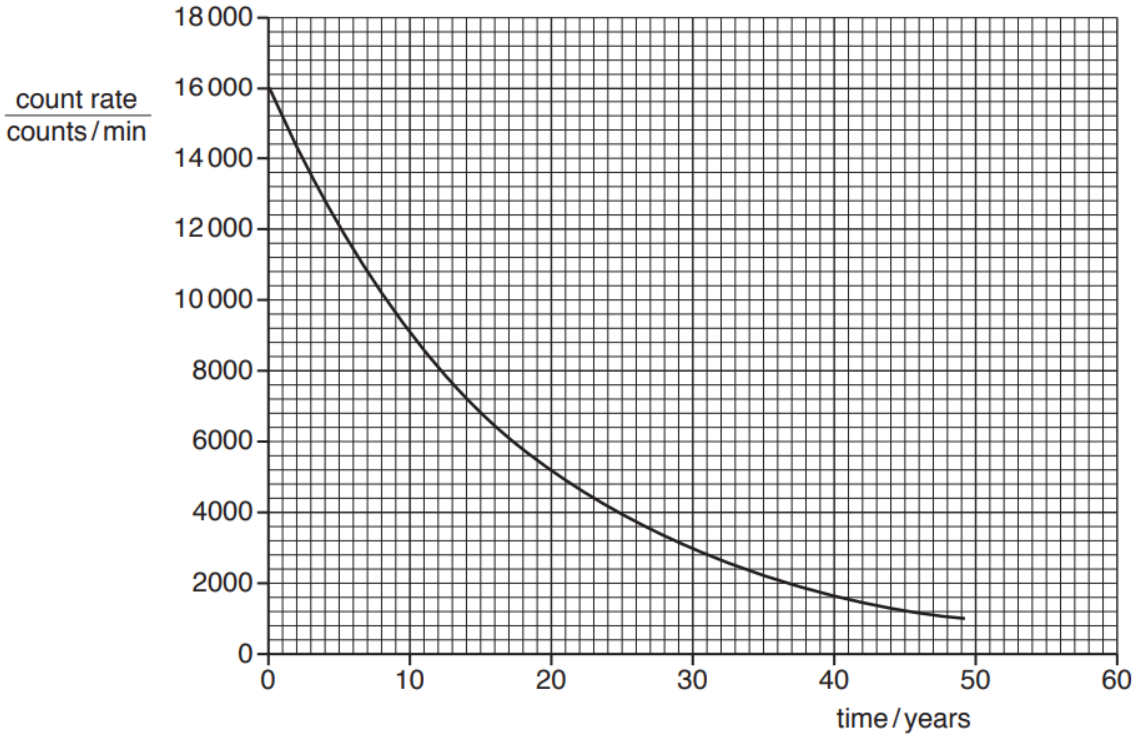


Fig. 12.1

Use Fig. 12.1 to calculate the half-life of tritium. Show clearly how you used the graph.

half-life = ... years [3]

[Total: 8]

25 Radioactive decay may include the emission of:

α-radiation
β-radiation
γ-radiation

(a) (i) From the list, state the type of radiation which has the **greatest** ionising effect.

.....[1]

(ii) From the list, state the type of radiation which has the **lowest** penetrating ability.

.....[1]

(b) In a factory, rollers press aluminium metal to make thin foil sheets. An automatic system for controlling the thickness of the foil uses a radioactive source. The automatic system changes the gap between the top and bottom roller. Fig. 12.1 shows the equipment.

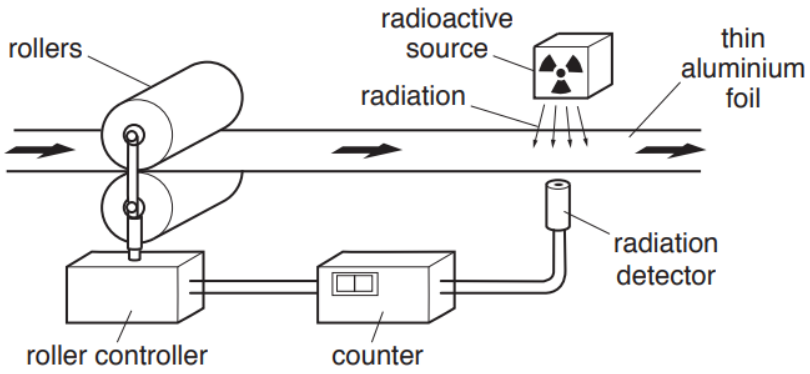


Fig. 12.1

(i) Use your ideas about the properties of radiation to suggest and explain the type of radiation used.

type of radiation .....

explanation .....

.....

.....

.....

[2]

(ii) The aluminium foil passing the radiation detector is too thin. Describe how this fault affects the reading on the counter.

.....[1]

(iii) Suggest how the fault in **(b)(ii)** is corrected. State what happens to the rollers.

.....[1]

(iv) The source used is strontium-90. A nucleus of strontium-90 can be described as $^{90}_{38}Sr$. State the number of protons in a nucleus of strontium-90.

.....[1]

[Total: 7]

26 **(b)** **(i)** One radioactive isotope has a half-life of 6.0 years.
A sample of this isotope has a mass of 12 mg.

Calculate the mass of this isotope that remains in the sample after 18 years.

mass remaining = ... mg [3]

(ii) The sample decays by emitting a β-particle.

Describe the nature of a β-particle.

.....

.....[2]

(iii) Describe how the nucleus of the isotope changes due to the emission of a β-particle.

.....

.....[1]

Paper 4

Questions are applicable for both core and extended candidates unless indicated in the question

27 **(c)** Carbon-14 decays by beta (β) emission.

(i) State the name of a particle that is identical to a beta-particle.

..... [1]

(ii) Describe the change that takes place in carbon-14 as a beta-particle is emitted.
(extended only)

.....

..... [1]

(d) The half-life of carbon-14 is 5700 years.

A very old object is made of wood. It contains 1.2×10^{11} atoms of carbon-14. When it was manufactured, it contained 9.6×10^{11} atoms of carbon-14.

Determine the time that has passed since it was manufactured.

time passed = ... [3]

28 Carbon-14 ($^{14}_{6}C$) is a radioactive isotope of carbon. Carbon-12 ($^{12}_{6}C$) is not radioactive.

(a) Explain how an atom of carbon-14 ($^{14}_{6}C$) differs from an atom of carbon-12 ($^{12}_{6}C$).

.....

..... [2]

(b) All living organisms contain both carbon-12 atoms and carbon-14 atoms. The ratio of carbon-14 to carbon-12 is $1 : 1 \times 10^{12}$.

Carbon-14 has a half-life of 5700 years.

(i) When an organism dies no new carbon is absorbed. The amount of carbon-12 in the dead organism remains fixed.

Describe how the amount of carbon-14 in the dead organism decreases with time.

.....

.....

..... [2]

(ii) A sample of wood contains carbon-14 to carbon-12 atoms in the ratio $1 : 4 \times 10^{12}$.

Calculate how many years ago the tree died.

..... years ago [3]

(c) Other radioactive isotopes have different half-lives. **(extended only)**

Suggest a use of a radioactive isotope with a half-life of one hour.

Explain why a short half-life is suitable for this use.

use .....

explanation .....

.....

[2]

[Total: 9]

29 The isotope thallium-208 ($^{208}_{81}Tl$) is radioactive. It decays by β-decay.

(a) Thallium-208 decays to an isotope of lead (Pb).

(i) Complete the equation for this decay. **(extended only)**

$$^{208}_{81}Tl \longrightarrow {}^{\cdots\cdots}_{\cdots\cdots}Pb + {}^{\cdots\cdots}_{\cdots\cdots}\beta$$

[3]

(ii) The β-emission of thallium-208 is accompanied by γ-emission from the nucleus. **(extended only)**

Explain why this γ-emission does **not** affect the numbers in the equation in **(a)(i)**.

.....

..... [1]

(iii) Suggest **one** reason why a nucleus of thallium-208 is unstable. **(extended only)**

.....

..... [1]

(b) A sample of thallium-208 is placed in a thick lead container. Fig. 8.1 shows a narrow beam of β-particles and γ-radiation emerging from a small hole in one side of the container. **(extended only)**

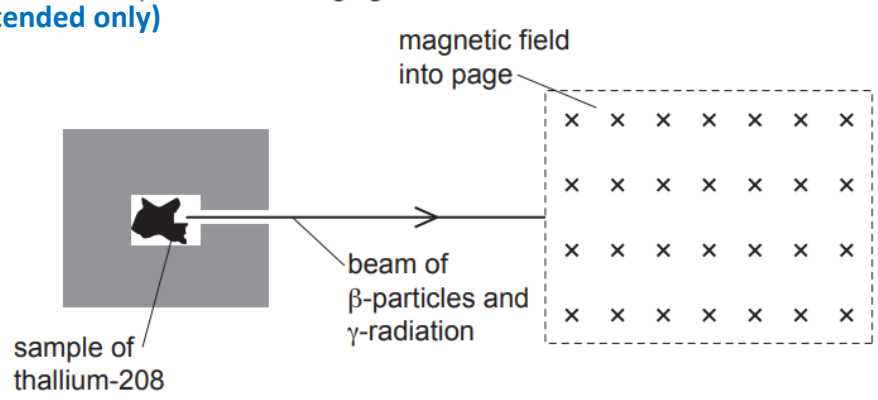


Fig. 8.1

The narrow beam enters a region where there is a magnetic field that is directed into the page.

On Fig. 8.1:

- draw a line **labelled β** to indicate the path of the β-particles in the magnetic field
- draw a line **labelled γ** to indicate the path of the γ-radiation in the magnetic field.

[3]

[Total: 8]

30 **(a)** Radioactive isotopes that emit ionising radiation are used in hospitals.

(i) State and explain **two** safety precautions necessary for the use of these isotopes in medical procedures. **(extended only)**

safety procedure 1 .....

explanation .....

.....

safety procedure 2 .....

explanation .....

.....

[2]

(ii) Give **two** reasons why alpha-emitters are **not** used as radioactive tracers inside the body.

1 .....

.....

2 .....

.....

[2]

(b) Sodium-24 is an isotope of sodium (Na) that has a proton number of 11 and a nucleon number of 24. **(extended only)**

Sodium-24 decays by emission of a beta-particle to form an isotope of magnesium (Mg).

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

[3]

[Total: 7]

31 Many household smoke alarms contain a sample of the radioactive isotope americium-241 (Am).

(a) Americium-241 is the isotope of the element americium that has the nucleon number (mass number) 241.

(i) State how the composition of a nucleus of americium-241 differs from that of a nucleus of americium-242.

.....

..... [1]

(ii) An atom of a different element has a nucleon number of 241.

State **two** differences between the composition of a nucleus of this atom and a nucleus of americium-241.

1 .....

2 .....

[2]

(b) Americium-241 decays to an isotope of neptunium (Np) by alpha-particle (α-particle) emission.

(i) Complete the equation for this decay. **(extended only)**

$$^{241}_{\ \ \ldots\ \ }\mathrm{Am} \longrightarrow {}^{\ldots\ldots}_{93}\mathrm{Np} + {}^{\ \ \ldots\ \ }_{\ldots\ldots}\alpha$$

[3]

(ii) One reason for using an isotope that emits α-particles in a smoke detector is that α-particles are more strongly ionising than beta-particles (β-particles). **(extended only)**

Explain why α-particles are more strongly ionising than β-particles.

.....

.....

..... [2]

(iii) The isotope of neptunium produced by americium-241 is also radioactive.

The decay of this isotope of neptunium produces an isotope of protactinium which decays by β-emission. β-particles are more penetrating than α-particles.

The half-life of neptunium is longer than two million years.

Using this information, explain the advantage of this long half-life for the use and safe disposal of a household smoke alarm. **(extended only)**

.....

.....

..... [2]

[Total: 10]

32 Fig. 9.1 represents all the particles in a neutral atom of a radioactive isotope X1.

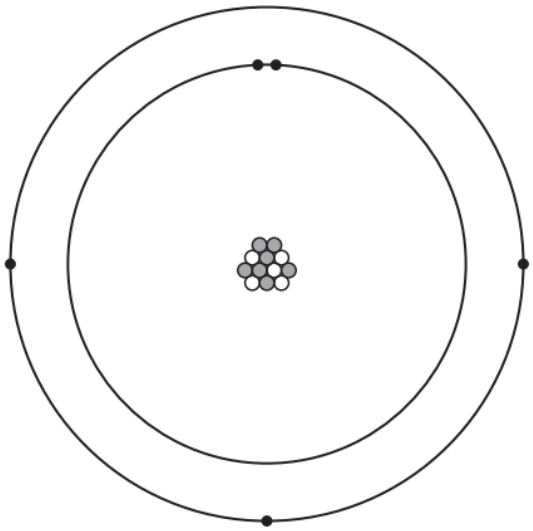


Fig. 9.1 (not to scale)

(a) Determine the number of neutrons in this atom and explain how the answer is obtained.

number of neutrons = ...

explanation

.....

.....

[2]

(b) The isotope X1 is a beta emitter that decays to the stable isotope X2.

(i) Describe how a nucleus of X2 differs from a nucleus of X1.

.....

..... [2]

(ii) Suggest why isotope X2 is stable whereas X1 is **not** stable. **(extended only)**

.....

..... [1]

(c) The half-life of X1 is approximately 20 ms.

(i) Define the term half-life.

.....

.....

..... [2]

(ii) Suggest **one** reason why isotopes with very short half-lives are especially hazardous.

.....

..... [1]

[Total: 8]

33 **(a)** Table 9.1 shows some properties and values for α-particles, β-particles and γ-radiation.

Complete Table 9.1.

Table 9.1

type of radiation	number of protons	number of neutrons	charge / C	stopped by
α	2		$+ 3.2 \times 10^{-19}$	thin sheet of paper
β		0		thin sheet of aluminium
γ	0			

[3]

(b) State how β-decay changes the nucleus of an atom. **(extended only)**

..... [1]

(c) A radiation detector used in a laboratory detects a background count rate of 30 counts / min. A radioactive source is placed in front of the radiation detector. The initial reading on the detector is 550 counts / min. The half-life of the source is 25 minutes. **(extended only)**

Calculate the expected reading on the detector after 75 minutes.

reading = ... counts / min [4]

(d) State **two** safety precautions taken when moving, using or storing radioactive sources in a laboratory.

1 .....

2 .....

[2]

[Total: 10]

34 Only one isotope of gold occurs naturally on Earth.

(a) State what this indicates about the nuclear structure of all the naturally occurring atoms of gold on Earth.

.....

..... [1]

(b) There are several artificially produced isotopes of gold.

Gold-198 ($^{198}_{79}$Au) is an artificial isotope which is used in medicine and in scientific research.

Gold-198 decays by β (beta)-emission to a stable isotope of mercury.

(i) Determine the number of protons and the number of neutrons in a nucleus of this isotope of mercury. **(extended only)**

number of protons = ...

number of neutrons = ...

[2]

(ii) A sample of gold-198 is placed near to a radiation detector in a research laboratory. The count rate is recorded at the same time every day for 32 days. **(extended only)**

The results are used to plot the graph shown in Fig. 9.1.

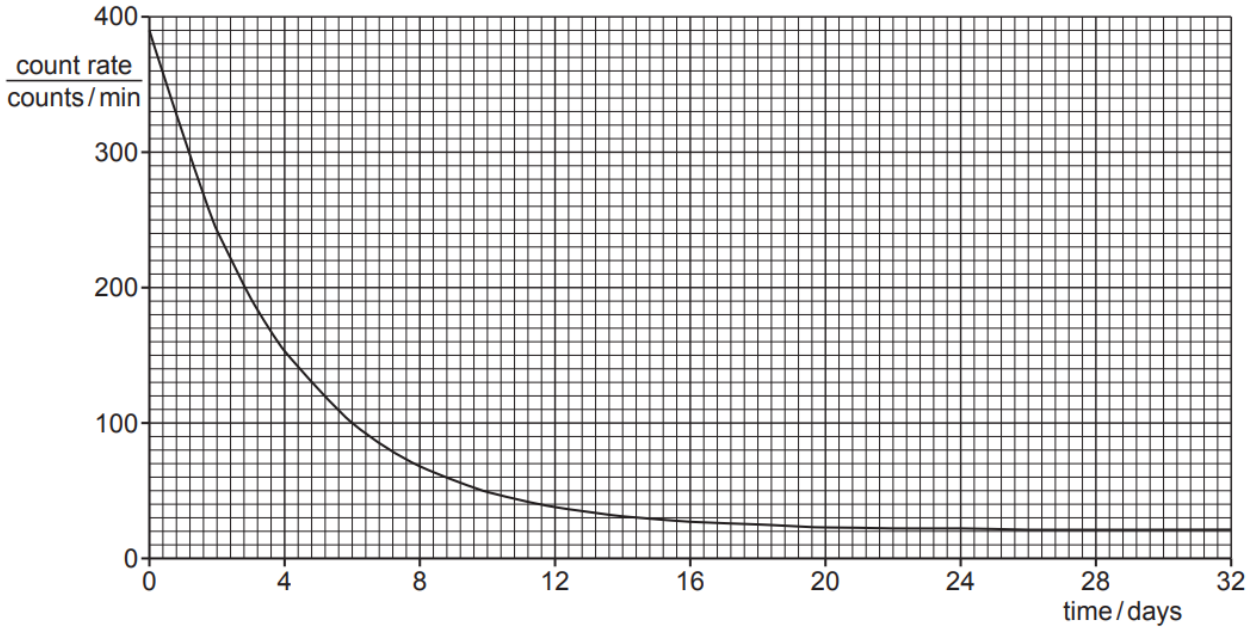


Fig. 9.1

Using Fig. 9.1, determine the background count rate in the research laboratory.

count rate = ... [1]

(iii) Using Fig. 9.1, determine the half-life of gold-198. **(extended only)**

half-life = ... [4]

[Total: 8]

35 **(a)** The magnitude of the charge on a β (beta)-particle is 1.6×10^{-19} C.

(i) State the proton number and nucleon number of an α (alpha)-particle.

proton number .....

nucleon number .....

[2]

(ii) Determine the magnitude of the charge of an α (alpha)-particle.

charge .....

[1]

(b) A nucleus of radium-230 consists of 88 protons and 142 neutrons. Radium-230 is radioactive and decays by β (beta)-emission to an isotope of actinium. The symbol for radium is Ra and the symbol for actinium is Ac. **(extended only)**

Write down the nuclide equation for this decay.

[3]

(c) The half-life of radium-230 is 93 min. A sample contains 9.6×10^{-12} g of radium-230.

Calculate the mass of radium in the sample after 279 min.

mass = ... [2]

[Total: 8]

36 **(a)** Fig. 11.1 shows the paths of three α-particles moving towards a thin gold foil. Four gold nuclei are shown.

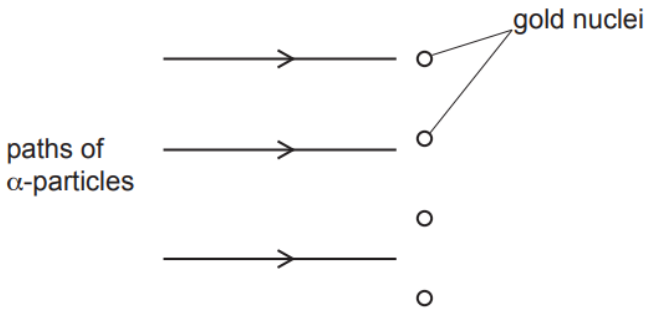


Fig. 11.1 (not to scale)

(i) On Fig. 11.1, complete the paths of the **three** α-particles. **(extended only)** [3]

(ii) State the sign of the charge on the α-particles.

..... [1]

(b) The nuclide notation for a nucleus of gold-198 is $^{198}_{79}Au$.

State the numbers of electrons, neutrons and protons in a neutral atom of gold-198.

number of electrons = ...

number of neutrons = ...

number of protons = ...

[3]

[Total: 7]

37 **(b)** A radioactive isotope decays by β-emission to form an isotope of barium with nucleon number 135. **(extended only)**

Table 11.1

element	symbol	proton number
iodine	I	53
xenon	Xe	54
caesium	Cs	55
barium	Ba	56
lanthanum	La	57
cerium	Ce	58
praseodymium	Pr	59

Use data from Table 11.1 to write down the nuclide equation for this decay.

[4]

[Total: 8]

38 **(a)** Two identical radioactive sources emit α-particles and γ-rays into two vacuum tubes.

(i) Fig. 8.1 shows two electrically charged plates on either side of one of the vacuum tubes. **(extended only)**

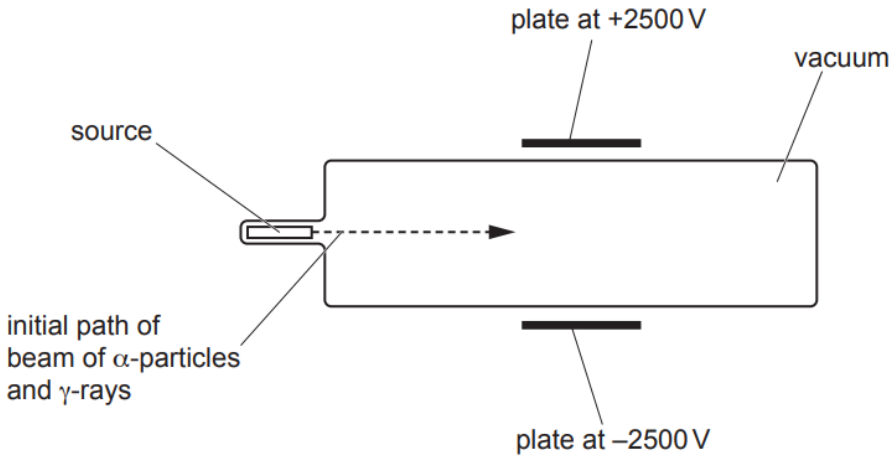


Fig. 8.1

Write the symbol α **once** in Table 8.1 to indicate any deflection of the α-particles.

Write the symbol γ **once** in Table 8.1 to indicate any deflection of the γ-rays.

Table 8.1

into page	out of page	no deflection	towards bottom of page	towards top of page

[2]

(ii) Fig. 8.2 shows the poles of a very strong magnet on either side of the other vacuum tube. **(extended only)**

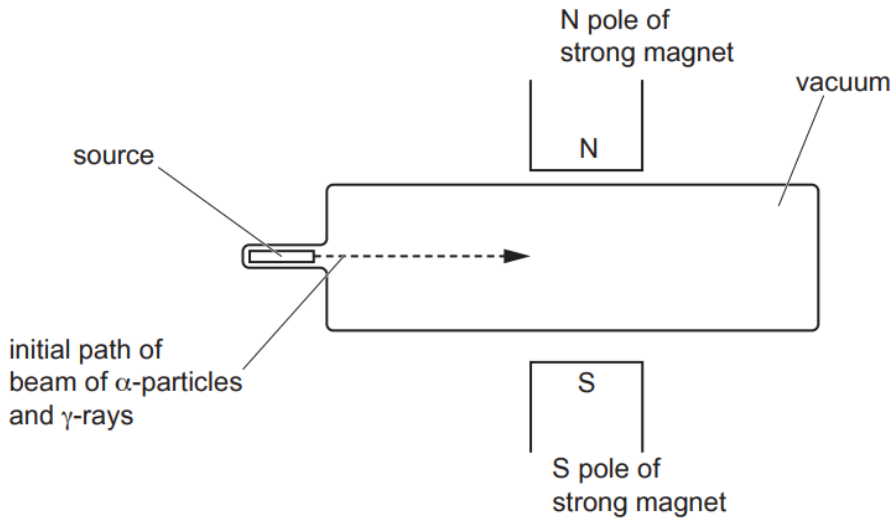


Fig. 8.2

Write the symbol α **once** in Table 8.2 to indicate any deflection of the α-particles.

Write the symbol γ **once** in Table 8.2 to indicate any deflection of the γ-rays.

Table 8.2

into page	out of page	no deflection	towards bottom of page	towards top of page

[2]

39 **(a)** A student investigates a radioactive substance in a laboratory.

Fig. 11.1 is a graph showing the count rate detected as the substance decays for 7.5 minutes.

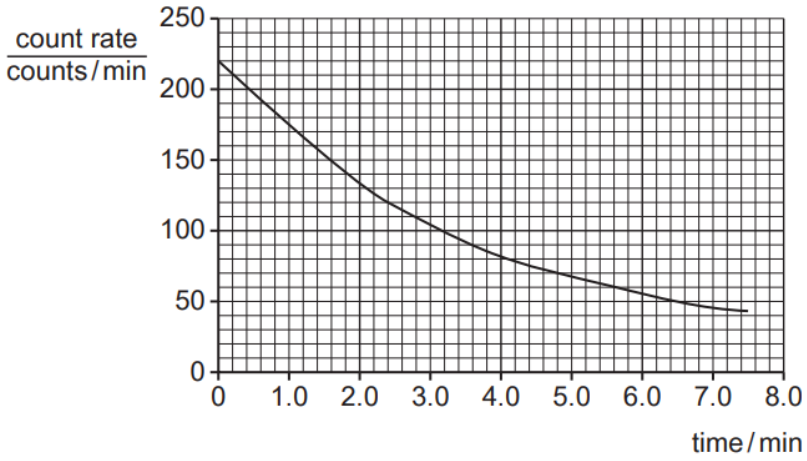


Fig. 11.1

The background radiation is 20 counts / min.

(i) Determine the half-life of the substance. **(extended only)**

half-life = ... [3]

(ii) Calculate the count rate detected at time = 9.6 minutes. **(extended only)**

count rate = ...counts / min [2]

(b) The substance emits α-particles and γ-rays. The student suggests that it is safe to store the substance in a plastic container of thickness 2 mm.

State and explain whether the student's suggestion is correct.

statement .....

explanation .....

..... [3]

[Total: 8]

40 A radiation detector is placed on the bench in a laboratory. It detects a background count rate of 40 counts / minute.

(a) State what is meant by background radiation. Suggest one source for it.

.....

.....

..... [2]

(b) A sample containing atoms of the radioactive isotope polonium-208 is removed from a lead container and brought close to the detector. The average count rate increases to 890 counts / minute.

When two sheets of paper are inserted between the sample and the detector, the average count rate returns to 40 counts / minute.

Polonium-208 is represented by the symbol $^{208}_{84}Po$. It decays to an isotope of lead (Pb).

(i) Deduce the type of radiation emitted by polonium-208. Explain your answer.

.....

.....

.....

..... [2]

(ii) Write down the nuclide equation for the decay of polonium-208. **(extended only)**

[3]

[Total: 7]

41 **(b)** Radioactive tracers emitting γ-rays can be used in medicine. The half-life of the source of these γ-rays is 6 hours.

(i) Explain why a source of γ-rays used in this way should not have a half-life shorter or longer than about 6 hours. **(extended only)**

.....

.....

.....

..... [2]

(ii) Technetium-99 is a source of γ-rays often used as a radioactive tracer. It is produced from molybdenum-99 which emits β-particles. The symbol for technetium is Tc and the symbol for molybdenum is Mo. **(extended only)**

Complete the nuclide equation for this decay.

$$^{99}_{42}\text{Mo} \rightarrow {}^{\cdots\cdots}_{\cdots\cdots}\text{Tc} + {}^{\cdots\cdots}_{\cdots\cdots}\beta$$

[3]

(iii) Technetium-99 is a radioactive nuclide. **(extended only)**

State another use of radioactive nuclides in medicine.

.....

..... [1]

42 **(a)** A detector of ionising radiation measures the background count rate in a classroom where there are no radioactive samples present.

The readings, in counts/minute, taken over a period of time are shown in Table 10.1.

Table 10.1

counts/minute	16	12	14	16	15	17

(i) State **two** possible sources of this background radiation.

.....

.....[2]

(ii) Explain why the readings are not the same.

.....

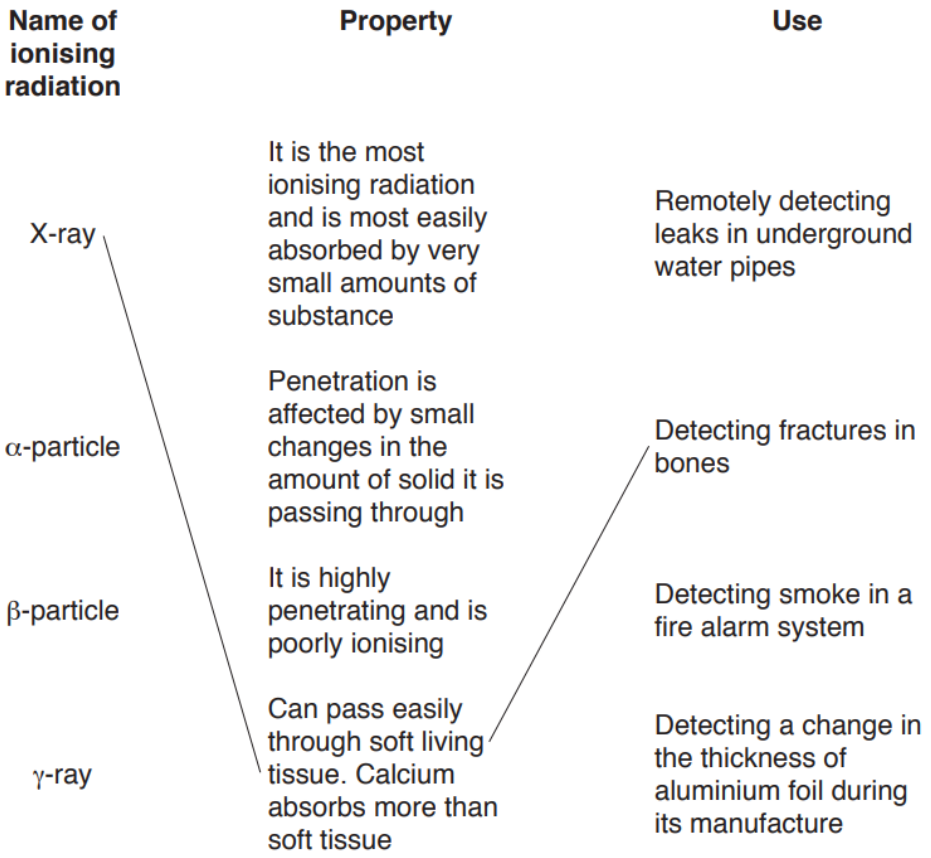
.....[1]

(b) With no radioactive sample present, a scientist records a background radiation count of 40 counts/minute. **(extended only)**
He brings a radioactive sample close to the detector. The count rate increases to 200 counts/minute.
After 24 days the count rate is 50 counts/minute.

Calculate the half-life of the radioactive sample.

half-life = ...[4]

(c) Draw a line between each type of ionising radiation and its property and another line between the property and its use. One has been done for you. **(extended only)**



[3]

[Total: 10]