

5.2 Radioactivity

01.0625_s23_qp_41 Q:9

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

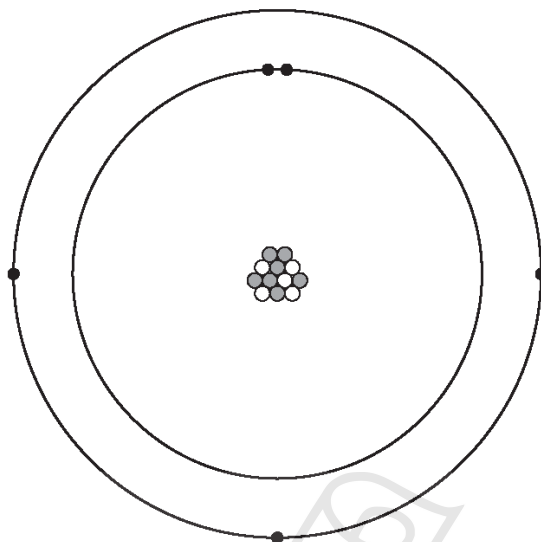


Fig. 9.1 (not to scale)

- (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.

.....

[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]



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5.2. RADIOACTIVITY

02. 0625_s23_qp_42 Q: 9

(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.

..... [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.

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]

03. 0625_s23_qp_43 Q: 8

(a) During β -decay, one of the neutrons in the nucleus changes.

(i) State what happens to this neutron.

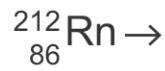
..... [1]

(ii) Explain how charge is conserved during this change.

.....

 [2]

(b) Complete the nuclide equation for the α -decay of radon-212 to form an isotope of polonium, symbol Po.



[3]

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04. 0625_w23_qp_41 Q: 9

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.



(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).

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

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.....
..... [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.

.....
..... [2]

05.0625_w23_qp_43 Q: 9

(a) For each application of radioactive isotopes, state and explain which type of radioactive emission is suitable and suggest an appropriate half-life for the isotope.

(i) household smoke alarm

type of radioactive emission

explanation

.....

half-life

[3]

(ii) measuring the thickness of aluminium strips produced in a factory

type of radioactive emission

explanation

.....

half-life

[3]

(b) Lead-208 ($^{208}_{82}\text{Pb}$) has the highest nucleon number of the stable isotopes of lead.

Explain why lead-214 ($^{214}_{82}\text{Pb}$) is radioactive.

.....

.....

.....

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[2]

(c) State **two** different sources of background radiation.

1

2

[2]

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06. 0625_m22_qp_42 Q: 10

The isotope americium-241 is represented by



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

(a) Complete the nuclide equation for this decay.



[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.

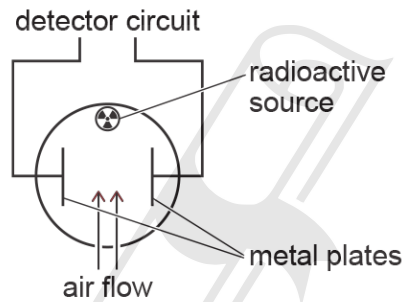


Fig. 10.1

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

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.....

.....

.....

.....

[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]

07. 0625_s22_qp_43 Q: 10

A student places a sample of an isotope of protactinium (Pa-234) near a radiation detector. The readings on the detector, taken every 20 s, are recorded in Table 10.1.

Table 10.1

time/s	$\frac{\text{count rate}}{\text{counts/min}}$
0	101
20	88
40	76
60	66
80	58
100	51
120	46
140	42
160	38
180	35

Fig. 10.1 shows a graph of the count rate **due to this sample** against time.

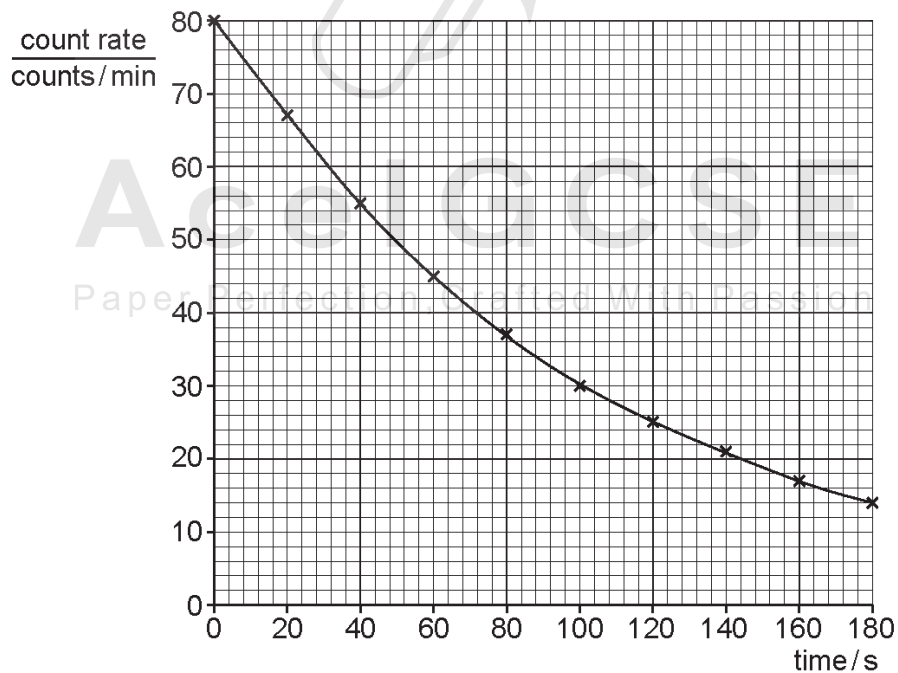


Fig. 10.1

(a) Explain why the readings in Table 10.1 are **not** the same as those plotted on the graph.

.....

..... [2]

5.2. RADIOACTIVITY

(b) Using the graph in Fig. 10.1, determine the half-life of this isotope of protactinium.

half-life = s [2]

(c) The nuclide notation for this isotope of protactinium is ${}_{91}^{234}\text{Pa}$.

Protactinium-234 decays to an isotope of uranium (U) by β -emission.

Write down the nuclide equation for this decay of protactinium-234.

[3]



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08.0625_w22_qp_41 Q: 9

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]

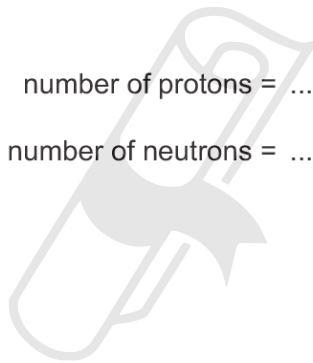
- (b) There are several artificially produced isotopes of gold.

Gold-198 ($^{198}_{79}\text{Au}$) 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.

number of protons =
 number of neutrons = [2]



5.2. RADIOACTIVITY

- (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.

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

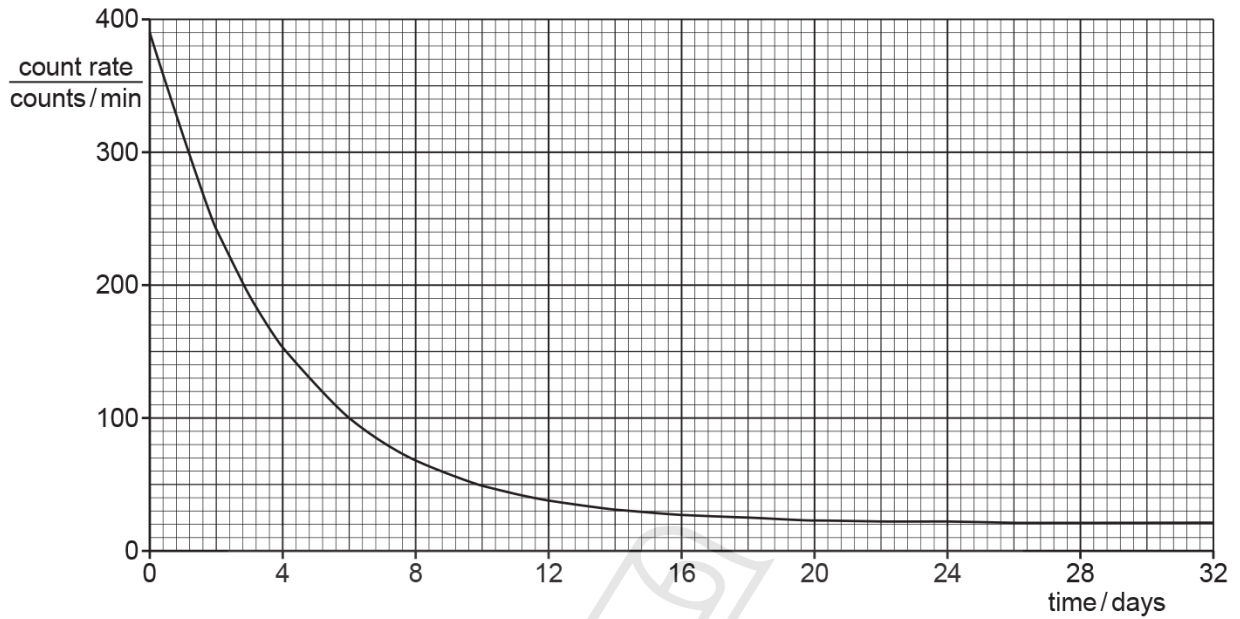


Fig. 9.1

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.

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half-life = [4]

09.0625_w22_qp_42 Q: 10

(a) The magnitude of the charge on a β (beta)-particle is $1.6 \times 10^{-19} \text{C}$.

(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.

Write down the nuclide equation for this decay.



[3]

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

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

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mass = [2]

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10. 0625_w22_qp_43 Q: 10

- (a) A cloud chamber can be used to detect α (alpha)-particles and β (beta)-particles. Alcohol in the cloud chamber exists as a vapour and condenses on ions produced in the air. This forms visible tracks.

Fig. 10.1 shows the tracks when a source of α -particles and β -particles is present in the cloud chamber.

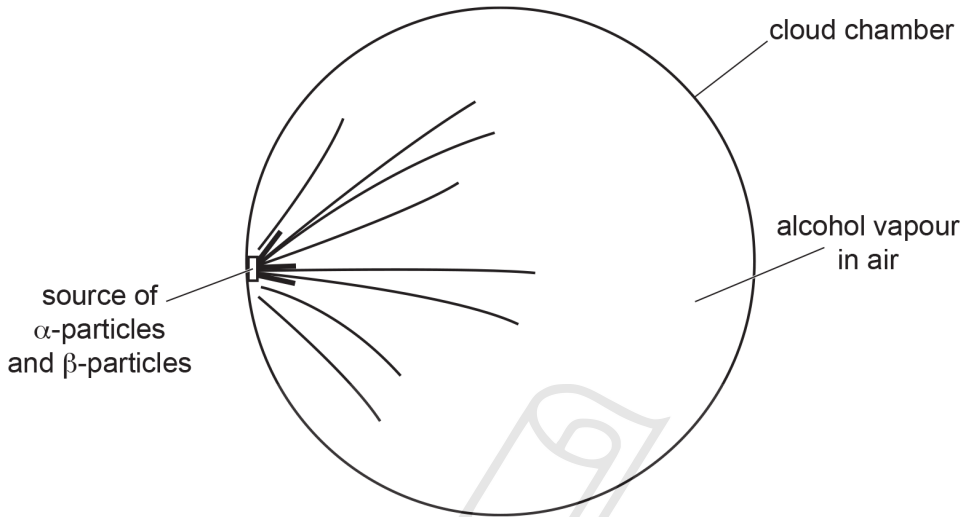


Fig. 10.1

Some of the tracks are short and thick. Other tracks are longer and thinner.

State and explain which tracks are produced by α -particles and which tracks are produced by β -particles.

α -particles

β -particles

..... [3]

- (b) A radioactive isotope of sodium (Na) is used to detect leaks from water pipes. A nucleus of this isotope of sodium contains 11 protons and 13 neutrons. This nucleus decays by emitting a β -particle to form a nucleus of magnesium (Mg).

- (i) Describe what is meant by an isotope.

.....

 [2]

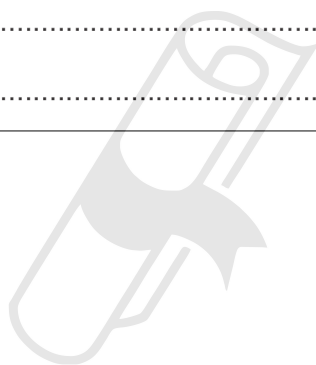
(ii) Write down the nuclide equation for the decay of this isotope of sodium to magnesium.

[3]

(iii) This isotope of sodium has a half-life of 15 hours. The isotope of magnesium is stable and does not undergo radioactive decay.

Suggest why these properties of the isotope of sodium and the isotope of magnesium make this isotope of sodium suitable to detect leaks from water pipes.

.....
.....
..... [2]



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11. 0625_m21_qp_42 Q: 10

(a) State the proton number, nucleon number and the value of the charge on an α -particle.

proton number

nucleon number

charge

[3]

(b) A nucleus of strontium-90 consists of 38 protons and 52 neutrons. Strontium-90 is radioactive and decays by β -emission to an isotope of yttrium. The symbol for strontium is Sr and the symbol for yttrium is Y. Write down the nuclide equation of this decay.

[3]

(c) The half-life of radon-220 is 56 s. A sample of radon-220 is in a container. After 112 s the mass of radon-220 is 9.2 mg.

Calculate the mass of the original sample.

mass = [2]

[Total: 8]

12. 0625_s21_qp_42 Q: 11

(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.

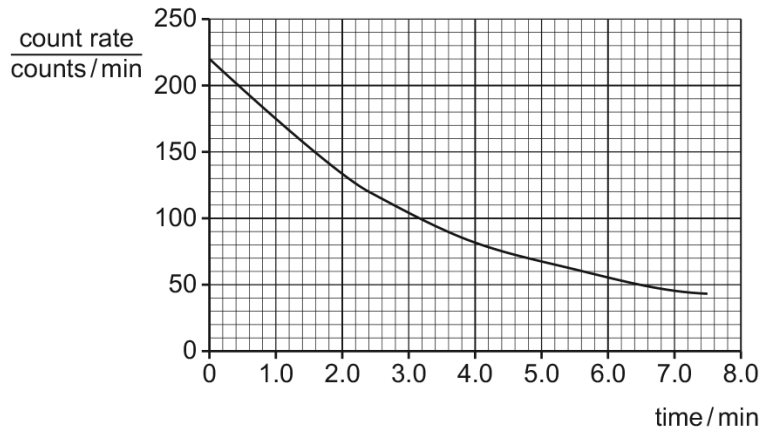


Fig. 11.1

The background radiation is 20 counts/min.

(i) Determine the half-life of the substance.

half-life = [3]

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

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 2mm.

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

statement

explanation

..... [3]

[Total: 8]

5.2. RADIOACTIVITY

13. 0625_s21_qp_43 Q: 10

- (a) Fig. 10.1 shows a beam of radiation in a vacuum. The beam contains α -particles, β -particles and γ -rays.



Fig. 10.1

The beam enters a region where there is a strong, uniform magnetic field. The direction of the magnetic field is out of the page.

On Fig. 10.1, mark and label the paths through the magnetic field of:

- (i) α -particles (label this path α) [1]
- (ii) β -particles (label this path β) [2]
- (iii) γ -rays (label this path γ). [1]

- (b) Radioactive sources have many uses in medicine.

State **two** safety precautions which hospital staff take when working with γ -ray sources.

- 1. [2]
- 2. [2]

(c) The radioactive isotope iodine-131 is used as a tracer in medical diagnosis. A nucleus of iodine-131 contains 53 protons and 78 neutrons. The symbol for iodine is I.

(i) Use nuclide notation to show this isotope of iodine.

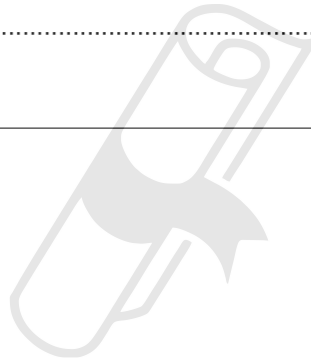
[1]

(ii) Iodine-131 emits γ -radiation. It has a half-life of 8 hours.

Explain why this emission and this half-life make iodine-131 a suitable material for a tracer in medical diagnosis.

.....
.....
.....
..... [2]

[Total: 9]



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5.2. RADIOACTIVITY

14. 0625_w21_qp_41 Q: 9

Uranium-235 ($^{235}_{92}\text{U}$) is a radioactive isotope of uranium that occurs naturally on Earth.

(a) Describe the composition and structure of a neutral atom of uranium-235.

.....
.....
.....
.....
..... [4]

(b) Another isotope of uranium is uranium-238.

Describe how an atom of uranium-238 differs from an atom of uranium-235.

.....
..... [1]

(c) In the reactor in a nuclear power station, a nucleus of uranium-235 absorbs a slow-moving neutron and then undergoes nuclear fission.

Two neutrons, a nucleus of xenon-140 ($^{140}_{54}\text{Xe}$) and a nucleus of an element represented by E are produced.

Complete the equation for this fission reaction.



(d) Xenon-140 ($^{140}_{54}\text{Xe}$) is radioactive. It decays by β -emission to isotope Q.

Determine:

- (i) the proton number of Q [1]
- (ii) the nucleon number of Q. [1]

15. 0625_w21_qp_43 Q: 11

(a) A detector of radioactivity is placed in a laboratory where there are no radioactive samples. A student notices that the detector shows a count rate that varies between 20 counts/min and 24 counts/min.

(i) Suggest a source of these readings.

..... [1]

(ii) Explain why these readings are **not** constant.

..... [1]

(b) A nucleus of uranium (U) contains 92 protons and 146 neutrons. It decays by emitting an α -particle to become a nucleus of thorium (Th).

Complete the nuclide equation for this radioactive decay.



[3]

(c) An isotope of radon has a half-life of 3.8 days. It decays by emitting α -radiation.

Calculate the time taken for 16 mg of this isotope to decay to 2 mg of this isotope.

time = days [2]

17. 0625_s20_qp_41 Q: 10

Fig. 10.1 represents a neutral atom of an isotope of element X.

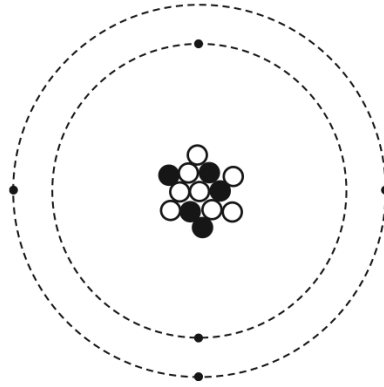


Fig. 10.1

(a) State **one** similarity between this atom and a neutral atom of a different isotope of element X.

.....
 [1]

(b) The isotope of element X is radioactive. It decays to form an isotope of element Y by emitting a β -particle.

(i) Using Fig. 10.1 deduce the nuclide notation for the isotope of Y produced by this decay.

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nuclide notation: ${}_{\dots}^{\dots}\text{Y}$ [3]

(ii) β -particles ionise the air they pass through less strongly than the same number of α -particles.

Suggest why this is so.

.....

 [3]

[Total: 7]

5.2. RADIOACTIVITY

18. 0625_s20_qp_42 Q: 10

Fig. 10.1 shows a vacuum tube with a radioactive source. The radioactive source emits α -particles, β -particles and γ -rays. There is a very strong magnetic field between the N pole and the S pole of the magnet.

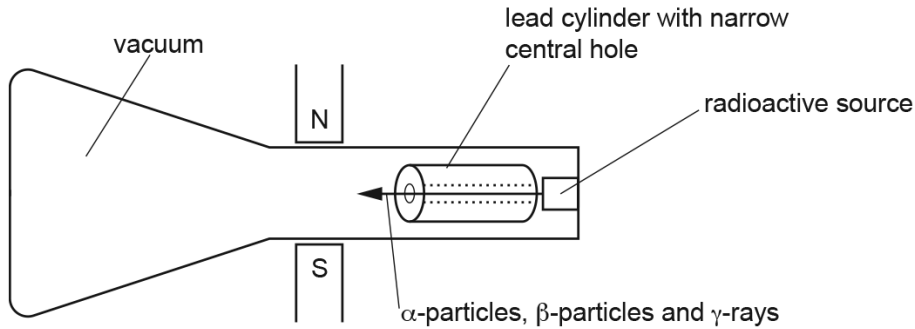


Fig. 10.1

(a) The lead cylinder has a narrow central hole. State and explain the effect of the lead cylinder.

.....
..... [2]

(b) Describe the paths of the α -particles, β -particles and γ -rays as they pass through the magnetic field. Explain your answers.

(i) α -particles

.....
.....
..... [2]

(ii) β -particles

.....
.....
.....
..... [2]

(iii) γ -rays

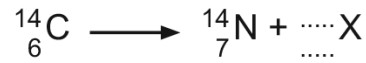
.....
.....
..... [2]

[Total: 8]

19. 0625_s20_qp_43 Q: 10

- (a) A radioactive nucleus of carbon decays to a nucleus of nitrogen by emitting a particle.

Complete the nuclide equation and state the name of the particle.



name of particle X [3]

- (b) A radiation detector in a laboratory records a reading of 10 counts/min. There are no radioactive samples in the laboratory.

- (i) Explain why the radiation detector records a reading and suggest a possible source.

explanation

source

..... [2]

- (ii) Carbon-14 has a half-life of 5700 years. There are atoms of carbon-14 in all living organisms.

An archaeologist digs up some ancient wood. In the same laboratory as in (b)(i), a sample of this ancient wood gives a reading of 20 counts/min. An equivalent sample of living wood gives a reading of 80 counts/min. It is suggested that the age of the ancient sample is 11 400 years.

Do a calculation to check whether this suggestion is correct.

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[Total: 9]

5.2. RADIOACTIVITY

20. 0625_w20_qp_41 Q: 10

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 $^{208}_{84}\text{Po}$. 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.

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[3]

21. 0625_w20_qp_42 Q: 11

(a) State **two** differences between nuclear fission and nuclear fusion.

- 1
-
- 2
-
- [2]

(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.
-
-
-
-
- [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.

Complete the nuclide equation for this decay.



(iii) Technetium-99 is a radioactive nuclide.

State another use of radioactive nuclides in medicine.

-
-
- [1]

5.2. RADIOACTIVITY

22. 0625_m19_qp_42 Q: 11

(a) (i) One isotope of iridium-194 is represented by



This isotope decays by β -emission to a stable isotope of platinum (Pt).

Complete the nuclide equation for this decay.



(ii) The half-life of iridium-194 is 19 hours. A sample of iridium-194 has an initial count-rate of 1100 counts/min.

Calculate the count-rate from this sample after 38 hours.

count-rate = [2]

(b) State **two** ways in which γ -emission differs from β -emission.

1

2 [2]

[Total: 7]

23. 0625_s19_qp_42 Q: 11

- (a) A radon-222 nucleus contains 86 protons and 136 neutrons. It decays by emitting an α -particle and becomes a nucleus of an isotope of polonium. The symbol for radon is Rn and the symbol for polonium is Po.

Write down the nuclide equation for this decay.

[3]

- (b) Carbon-14 is radioactive with a half-life of 5700 years. An animal bone is dug up in an archaeological excavation. The quantity of carbon-14 in the bone is 25% of what it was when the bone was buried.

Calculate the time that has elapsed since it was buried.

time = years [2]

[Total: 5]

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5.2. RADIOACTIVITY

24. 0625_s19_qp_43 Q: 11

- (a) Americium (Am) is a radioactive isotope. A nucleus of americium contains 95 protons and 146 neutrons. It decays by emitting an α -particle to form a nucleus of an isotope of neptunium (Np).

Write down the nuclide equation for the decay of americium to neptunium.

[4]

- (b) Ionisation smoke detectors contain americium and two small electrodes with a small voltage between them. The air between the electrodes is ionised by α -particles so that there is a small electric current between the electrodes.

- (i) Suggest and explain the effect of smoke on the current between the electrodes in the smoke detector.

Suggestion:

.....

Explanation:

..... [1]

- (ii) Suggest **two** reasons for using an α -particle emitter in a smoke detector.

Reason 1

.....

Reason 2

..... [2]

[Total: 7]

25. 0625_w19_qp_41 Q: 9

(a) The chemical symbol of the element lithium is Li. The proton number of lithium is 3.

Fig. 9.1 is a representation of a nucleus of a radioactive isotope of lithium that is about to decay.



Fig. 9.1

(i) Write down, using nuclide notation, the symbol that represents this isotope of lithium.
 [1]

(ii) This isotope of lithium decays by β -particle emission to form another nucleus.

Complete Fig. 9.2 to represent this decay by:

- using the same representation as in Fig. 9.1 and in the space after the arrow, draw a diagram of the nucleus formed by the decay
- writing the name of the particle that is identical to a β -particle on the answer line provided.



Fig. 9.2

[3]

(b) A radiation detector is set up in a laboratory where there are no radioactive samples.

On **six** separate occasions, the detector is switched on for 1.0 minute and the background count is recorded. The counts are:

23 27 25 24 20 25

(i) State why the readings are **not** all identical.
 [1]

(ii) Suggest a possible source for this background radiation.
 [1]

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- (iii) A sample containing only one radioactive isotope is brought into the laboratory. The half-life of the isotope is 15 hours.

The sample is placed near to the radiation detector in this laboratory. The detector is switched on and, after 1.0 minute, a count of 440 is recorded.

The sample is left next to the detector and the experiment is repeated 45 hours later.

The detector is switched on for 1.0 minute.

Predict the reading for the count obtained on this occasion.

reading [3]

[Total: 9]



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26. 0625_w19_qp_42 Q: 10

- (a) The nucleus of a hydrogen atom is a proton. The mass of a proton is m and the size of the charge on a proton is e . Complete Table 10.1. Express your answers in terms of m and e . Three spaces have already been completed.

Table 10.1

particle or emission	mass	charge
proton	m	e
neutron	m	
γ -ray		
nucleus of helium-4 (${}^4_2\text{He}$)		

[4]

- (b) Many schools and colleges use radioactive isotopes for teaching and research. Describe how these radioactive isotopes are handled, used and stored in a safe way.

.....

.....

.....

.....

.....

.....

.....

..... [3]

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27. 0625_w19_qp_43 Q: 11

- (a) The circles shown in Fig. 11.1 represent three gold nuclei. Three α -particles are approaching the gold nuclei.

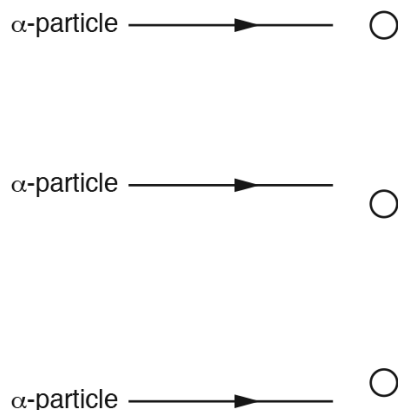


Fig. 11.1

On Fig. 11.1, complete the path of each α -particle. [3]

- (b) A detector of radioactivity in a laboratory indicates an average of 16 counts/min when no radioactive samples are present. A radioactive sample of half-life 1.5 days is placed close to the detector, which indicates a count rate of 208 counts/min.

Calculate the count rate that is indicated 6 days later.

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count rate = counts/min [4]

5.2. RADIOACTIVITY

28. 0625_m18_qp_42 Q: 11

(a) To ensure the safety of workers in laboratories where radioactive sources are used, describe how radioactive materials

(i) should be stored,

.....
 [1]

(ii) should be handled.

.....
 [1]

(b) Complete the table below for three types of emission from radioactive sources.

type of emission	nature	range in air	absorbed by
	electromagnetic radiation	several km	
	helium nucleus		0.2mm paper
	electron		

[3]

(c) State the type of radiation emitted when

(i) an americium nucleus ($^{241}_{95}\text{Am}$) decays into a neptunium nucleus ($^{237}_{93}\text{Np}$),

..... [1]

(ii) a phosphorus nucleus ($^{32}_{15}\text{P}$) decays into a silicon nucleus ($^{32}_{16}\text{Si}$).

..... [1]

[Total: 7]

29. 0625_s18_qp_41 Q: 11

Radon-222 is radioactive. It can be represented as ${}^{222}_{86}\text{Rn}$.

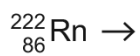
(a) For a neutral atom of radon-222, state

1. the number of protons,
2. the number of neutrons,
3. the number of electrons.

[2]

(b) A radon-222 nucleus decays by α -particle emission to a polonium (Po) nucleus.

Complete the equation for the decay of radon-222.



[2]

(c) Radon-222 has a half-life of 3.8 days.

At a certain time, a sample contains 6.4×10^6 radon nuclei.

Calculate the number of α -particles emitted by the radon nuclei in the following 7.6 days.

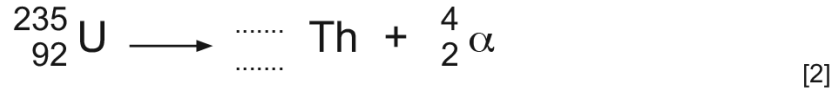
number =[3]

[Total: 7]

5.2. RADIOACTIVITY

30. 0625_s18_qp_42 Q: 11

- (a) A radioactive nucleus of uranium-235 decays to a nucleus of thorium and emits an α -particle. Complete the equation.



- (b) A nucleus of uranium-235 undergoes nuclear fission in a reactor.

- (i) State what is meant by *nuclear fission*.

.....
.....
..... [1]

- (ii) Suggest why a nuclear reactor is surrounded by thick concrete walls.

.....
.....
.....
..... [2]

- (iii) State one environmental advantage and one environmental disadvantage of using a fission reactor to generate electrical energy in a power station.

advantage

.....

disadvantage

..... [2]

- (c) The thorium produced by the decay in (a) is also radioactive and has a half-life of 26 hours. At a certain time, a pure sample of this isotope initially contains 4.8×10^9 atoms.

Calculate the number of atoms of this sample that decay in the following 52 hours.

number = [3]

[Total: 10]

31. 0625_s18_qp_43 Q: 11

(a) State the type of radioactive emission that causes

- (i) the proton number of a nuclide to increase by 1,
[1]
- (ii) the nucleon number of a nuclide to decrease by 4,
[1]
- (iii) no change in the proton number and no change in the nucleon number of a nuclide.
[1]

(b) The isotope radon-220 is radioactive and it decays by α -particle emission.

(i) Fig. 11.1 shows a beam of α -particles entering the electric field between two charged plates.

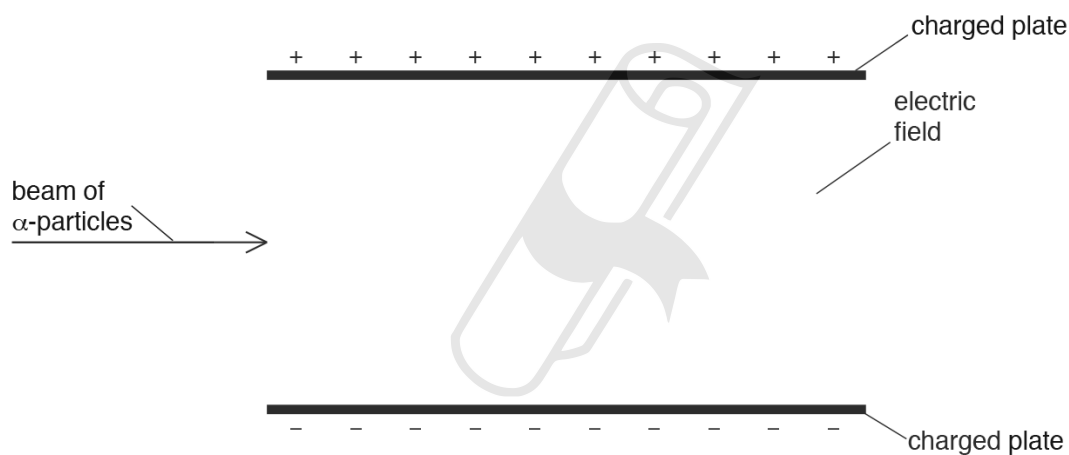


Fig. 11.1
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On Fig. 11.1, sketch the path that the beam of α -particles follows in the electric field. [1]

(ii) The half-life of radon-220 is 56 s.

A sample of this isotope contains 7.2×10^6 atoms.

Predict the number of α -particles that the radon-220 in the sample emits in the next 168 s.

number of α -particles emitted =[3]

[Total: 7]

5.2. RADIOACTIVITY

32. 0625_w18_qp_41 Q: 11

(a) Fig. 11.1 shows data about nine elements.

proton number	element	symbol
2	helium	He
3	lithium	Li
4	beryllium	Be
5	boron	B
6	carbon	C
7	nitrogen	N
8	oxygen	O
9	fluorine	F
10	neon	Ne

Fig. 11.1

Carbon-14 is a radioactive isotope with a nucleon number of 14. It decays by emitting β -particles.

Use any data you need from Fig. 11.1 to write down the nuclide equation for this decay.

[4]

- (b) A radioactive sample is placed close to a detector. The radioactive isotope in the sample has a long half-life. The detector records a count rate of 597 counts/s.

Fig. 11.2 shows the readings when different materials are placed between the radioactive sample and the detector.

material	count rate counts/s
a sheet of paper	602
a piece of thin aluminium	598
a piece of thin lead	510

Fig. 11.2

Explain whether any α -particles, β -particles or γ -rays are emitted by the radioactive sample.

α -particles

.....

β -particles

.....

γ -rays

.....

[3]

[Total: 7]

5.2. RADIOACTIVITY

33. 0625_w18_qp_42 Q: 10

- (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.
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.

Name of ionising radiation	Property	Use
X-ray	It is the most ionising radiation and is most easily absorbed by very small amounts of substance	Remotely detecting leaks in underground water pipes
α -particle	Penetration is affected by small changes in the amount of solid it is passing through	Detecting fractures in bones
β -particle	It is highly penetrating and is poorly ionising	Detecting smoke in a fire alarm system
γ -ray	Can pass easily through soft living tissue. Calcium absorbs more than soft tissue	Detecting a change in the thickness of aluminium foil during its manufacture

[3]

[Total: 10]

5.2. RADIOACTIVITY

34. 0625_w18_qp_43 Q: 10

Thorium-234 (${}^{234}_{90}\text{Th}$) is radioactive. It decays by β -emission to form an isotope of protactinium (Pa).

(a) Complete the nuclide equation for this decay.



[2]

(b) A pure sample of thorium-234 emits β -particles at a count rate of 2480 counts/second. The half-life of thorium-234 is 24 days.

Calculate the count rate for the emission of β -particles from the thorium in the sample after 72 days have passed.

count rate[3]

(c) The isotope of protactinium in (a) is also radioactive. It decays by β -emission and has a half-life of 70 seconds.

State and explain how this would affect the **observed** count rate for the sample in (b) after 72 days.

.....

.....

.....

.....[3]

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[Total: 8]

35. 0625_m17_qp_42 Q: 11

A radioactive source is placed 20 mm from a radiation detector, as shown in Fig. 11.1.

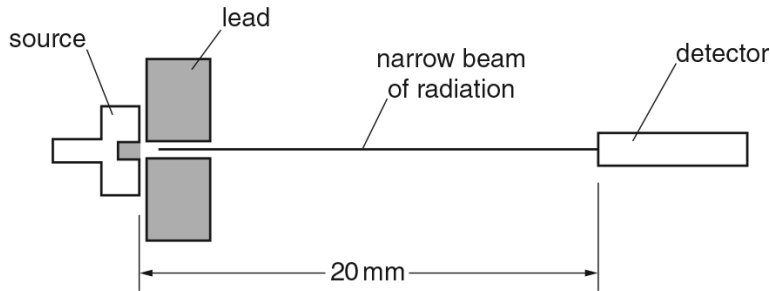


Fig. 11.1 (not to scale)

The initial count rate recorded by the detector is 150 counts/s.

A sheet of paper is placed between the source and the detector. The count rate recorded by the detector falls to 60 counts/s.

With the paper still in place, a magnetic field is set up perpendicular to the direction of the radiation. The count rate recorded by the detector falls to 20 counts/s.

The count rates have not been corrected for background. The background count is measured as 20 counts/s.

(a) State the evidence that each type of radiation is present in, or absent from, the radiation emitted by the source.

α -particles

.....

β -particles

.....

γ -rays

.....

[5]

5.2. RADIOACTIVITY

(b) Determine how much of the original count rate of 150 counts/s, if any, is due to each type of radiation.

α -particles counts/s

β -particles counts/s

γ -rays counts/s
[2]

[Total: 7]



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36. 0625_s17_qp_41 Q: 11

- (a) A radioactive source is tested over a number of hours with a radiation detector. The readings are shown in Table 11.1.

Table 11.1

time/hours	0	1	2	3	4	5	6	7	8	9	10
detector reading/(counts/s)	324	96	39	23	21	17	21	20	19	20	18

Use the readings to suggest a value for the background count rate during the test, and to determine the half-life of the sample.

background count rate =

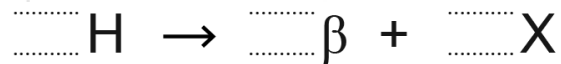
half-life of sample =

[4]

- (b) Hydrogen-3 (tritium) has one proton and two neutrons. The nucleon number of tritium is three. It decays by emitting a β -particle.

Complete the nuclide equation to show this decay. The symbol X represents the nuclide produced by this decay.

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[3]

5.2. RADIOACTIVITY

- (c) The arrows in Fig. 11.1 show the paths of three α -particles moving towards gold nuclei in a thin foil.

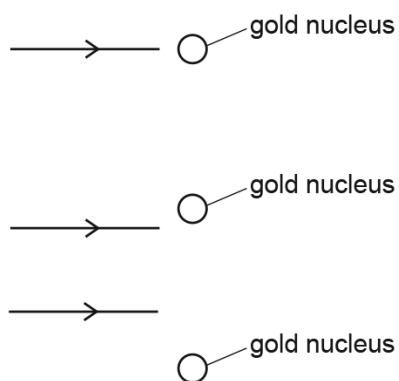


Fig. 11.1

On Fig. 11.1, complete the paths of the three α -particles.

[3]

[Total: 10]



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37. 0625_s17_qp_42 Q: 11

- (a) The arrows in Fig. 11.1 represent the paths of three α -particles moving towards gold nuclei in a thin foil. The gold nuclei are shown as shaded circles.

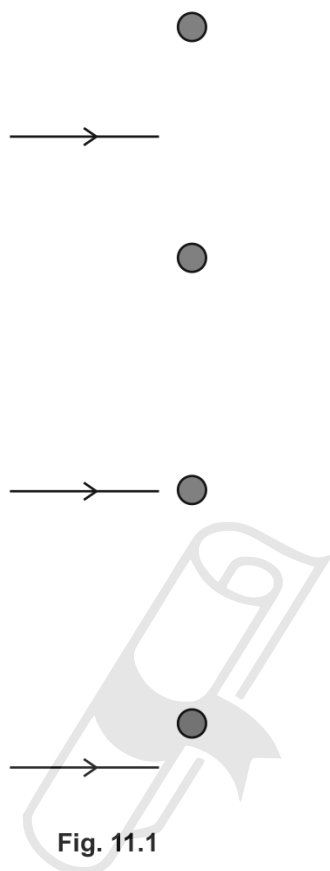


Fig. 11.1

On Fig. 11.1, complete the paths of the three α -particles.

[3]

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5.2. RADIOACTIVITY

(b) Fig. 11.2 shows a geologist holding a radiation detector near a rock.



Fig. 11.2

She holds the detector in a fixed position and records the readings shown in Table 11.1.

Table 11.1

time / minutes	0	1	2	3	4	5
detector reading counts / minute	16	14	17	13	17	15

Explain the changes in the detector readings.

.....

.....

.....

..... [2]

(c) A technician is handling a solid radioactive sample that emits α -particles and β -particles.

The technician wears thick rubber gloves.

Explain why this may provide some protection from the radiation, but it is not sufficient protection.

.....

.....

.....

..... [2]

[Total: 7]

38. 0625_s17_qp_43 Q: 11

- (a) Fig. 11.1 shows equipment that is used to investigate the effect of a magnetic field on the path of a beam of γ -rays.

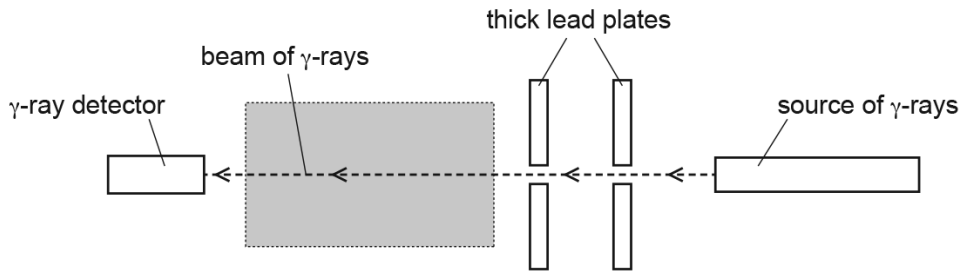


Fig. 11.1

A radioactive source emits γ -rays. The γ -rays pass through two small holes in thick lead plates. Then the γ -rays pass through the shaded region and into the detector.

- (i) Suggest the purpose of the two lead plates.

.....
[1]

- (ii) A magnetic field, directed into the page, is set up in the shaded region.

State and explain what happens to the reading of the detector.

.....

[3]

- (b) State the relative ionising effects of α -particles, β -particles and γ -rays. Suggest an explanation for the differences.

.....

[3]

[Total: 7]

5.2. RADIOACTIVITY

39. 0625_w17_qp_41 Q: 11

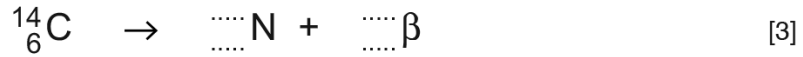
The radioactive isotope carbon-14 ($^{14}_6\text{C}$) emits β -particles as it decays.

(a) The decay of carbon-14 produces an isotope of nitrogen (N).

(i) State the nature of a β -particle and state where it is produced.

.....
.....[2]

(ii) Complete the nuclide equation for the radioactive decay of carbon-14.



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

Explain what is meant by the term *half-life*.

.....
.....[1]

(c) A workman operates a machine that uses β -particles to determine the level of liquid in a plastic water bottle that is being filled.

Suggest why

(i) α -particles are **not** suitable for the same purpose,

.....
.....[1]

(ii) γ -rays are **not** suitable for the same purpose.

.....
.....[1]

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[Total: 8]

40. 0625_w17_qp_42 Q: 11

The radioactive isotope bismuth-210 (${}_{83}^{210}\text{Bi}$) decays by β -particle emission to an isotope of polonium (Po).

(a) Complete the nuclide equation that represents this decay.



(b) A radiation detector is placed on a bench in a laboratory where there are no artificial sources of radiation. The detector is switched on.

In seven one-minute periods, the detector displays these readings.

24 22 25 25 21 20 24

(i) Explain why, in the absence of any artificial source, there are readings on the detector. Suggest **one** origin of this effect.

.....

 [2]

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

.....
 [1]

(iii) The half-life of bismuth-210 is 5.0 days. A sample of bismuth-210 is brought close to the detector and in one minute, the reading displayed is 487. The equipment is left in the same place for exactly 10 days.

Predict the reading in a one-minute period at the end of this time.

reading = [3]

[Total: 9]



5.2. RADIOACTIVITY

41. 0625_w17_qp_43 Q: 10

(a) State the nature of γ -rays.

.....
.....[2]

(b) A nucleus of technetium-99 ($^{99}_{43}\text{Tc}$) emits only a γ -ray.

State any effect of this on

(i) the proton number of the nucleus,

.....[1]

(ii) the nucleon number of the nucleus.

.....[1]

(c) In a laboratory a radiation detector displays a count rate of 16 counts/minute due to background radiation.

(i) State what is meant by *background radiation*.

.....
.....[1]

(ii) A sample of a radioactive isotope is placed near to the radiation detector and a count rate of 112 counts/minute is recorded.

After 18 hours, the count rate recorded is 28 counts/minute.

Determine the half-life of this isotope.



half-life =[3]

(d) Radioactive isotopes are stored in thick lead containers.

State **two** precautions to be taken when radioactive isotopes are **used**.

1.
 2.
- [2]

[Total: 10]



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