TOPIC 25 Radioactivity

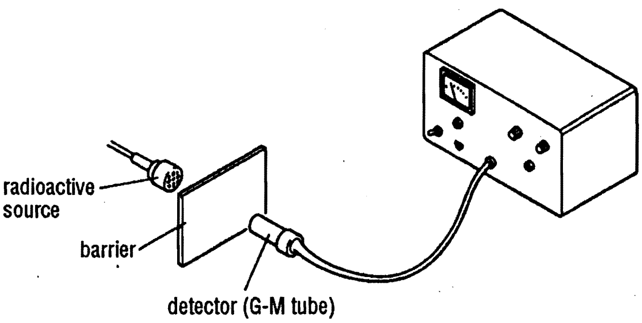
1 When an animal dies, each gram of carbon in its body emits about 16 β-particles each minute.

Each gram of carbon from some animal remains is found to emit 4 β-particles each minute.

Assuming that the half-life of radioactive carbon is 6000 years, how old are the animal remains?

A 1 500 years
B 3 000 years
C 6 000 years
D 12 000 years
E 24 000 years J90/I/37

2 The diagram shows the apparatus used in an experiment in which barriers of various materials were placed in turn between different radioactive sources and a detector.



The table shows the count rates recorded by the detector for five sources.

	count rate/counts/minute			
source	no barrier	paper	thin aluminium	thick lead
A	200	200	200	30
B	600	200	200	30
C	1200	30	30	30
D	1200	600	200	30
E	1200	1200	30	30

Which source emits alpha particles only? J90/I/38

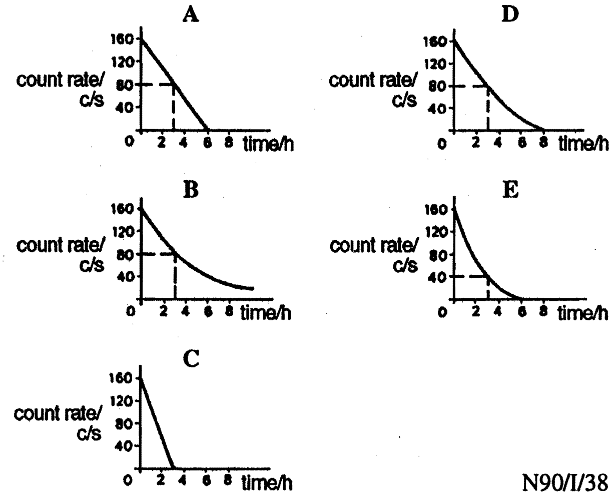
3 $^{90}_{38}Sr$ decays to $^{90}_{39}Y$ by

A emission of an alpha particle.
B emission of a beta particle.
C emission of a proton.
D gaining a neutron.
E gaining an electron. J90/I/40

4 From which of the following materials should a box for storing radioactive substances be made?

A aluminium
B glass
C graphite
D lead
E wood N90/I/37

5 Which graph best shows the radioactive decay of an isotope with a half-life of 3 hours?



N90/I/38

6 Radon decays to polonium by emission of alpha particles, as shown by the following equation.

$$^{x}_{y}Rn \longrightarrow {}^{218}_{84}Po + \alpha$$

What are the values of x and y?

	x	y
A	214	82
B	216	80
C	218	84
D	220	88
E	222	86

N90/I/40

7 The equation represents actinium decaying to thorium.

$$^{227}_{89}Ac \longrightarrow {}^{227}_{90}Th + Y$$

What particle does Y represent?

A an atom
B an electron
C a helium nucleus
D a neutron
E a proton J91/I/38; N97/I/38

8 Why are γ-rays undeflected by a magnetic field?

A They are strongly penetrating.
B They are weakly ionising.
C They have no mass.
D They have no charge.
E They travel at high speed. J91/I/39

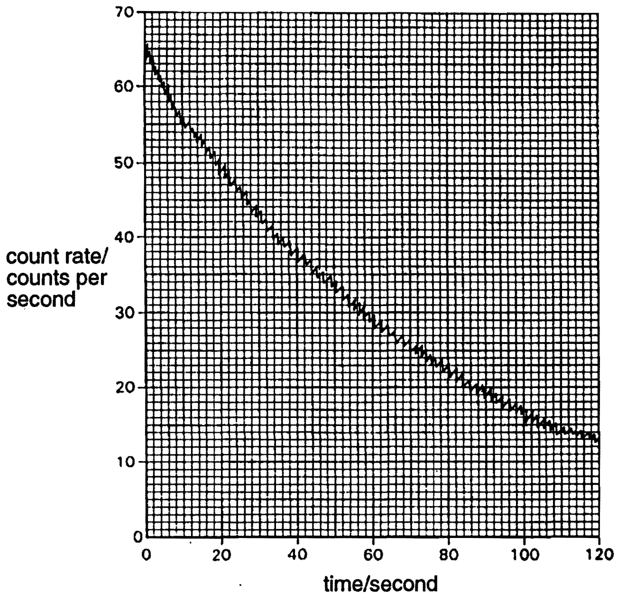
9 Ra decays to Rn with a half-life of 1600 s.

Rn decays to Po with a half-life of 52 s.

Po decays to Pb with a half-life of 9.1 s.

Pb decays to Bi with a half-life of 10.6 h.

The changing count rate for one of these radioactive nuclides is shown in the graph.

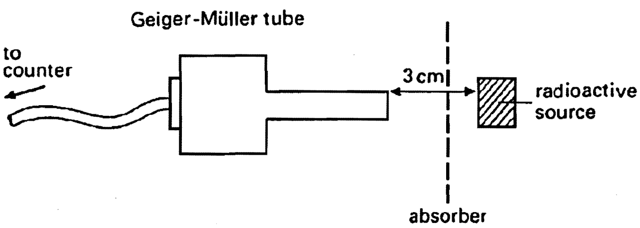


From the half-life shown by the graph, which was the decaying radioactive nuclide?

A	Ra	**D**	Pb
B	Rn	**E**	Bi
C	Po		

J91/I/40

10 A pupil investigated the penetrating power of radiation from a radioactive source.



The table shows her results.

background count	25 counts per minute
count with source only	630 counts per minute
count with source and paper absorber	630 counts per minute
count with source and aluminium absorber 3 mm thick	180 counts per minute

The source sent out

A	α-radiation only.	**D**	α- and β-radiation.
B	β-radiation only.	**E**	β- and γ-radiation.
C	γ-radiation only.		

N91/I/38

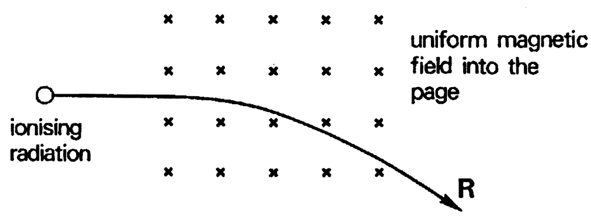
11 A factory buys 100 g of a radioactive chemical with a half-life of 5 years which decays to a stable compound.

How much of the chemical will still be radioactive in 10 years' time?

A	none	**D**	75 g
B	25 g	**E**	100 g
C	50 g		

J92/I/37

12 The diagram shows a narrow beam of ionising radiation entering a uniform magnetic field which is directed into the page. Ionising radiation is detected only in the region of **R**.



What type of ionising radiation does the beam contain?

A α-particles and β-particles
B α-particles and γ-rays
C α-particles only
D β-particles only
E γ-rays only

N92/I/37

13 A nucleus is represented by $^{230}_{91}Z$. It emits one α-particle and then one β-particle. What is the resulting nucleus?

A	$^{226}_{88}W$	**D**	$^{230}_{89}X$
B	$^{226}_{89}X$	**E**	$^{230}_{91}Z$
C	$^{226}_{90}Y$		

N92/I/38

14 In which type of nuclear reaction are the nuclei heavier after the reaction than they were before?

A α-decay
B β-decay
C γ-emission
D nuclear fission
E nuclear fusion

N92/I/39

15 A radioactive nucleus emits a β-particle.

What is the change in its nucleon (mass) number?

A It decreases by 2.
B It decreases by 1.
C It does not change.
D It increases by 1.
E It increases by 4.

J93/I/37

16 Which of the following statements is correct for γ-radiation?

A It can be stopped by paper.
B It can pass through thin aluminium.
C It is deflected by a magnetic field.
D It is positively charged.
E It travels at half the speed of light.

J93/I/38

17 In an experiment to find the half-life of a radioactive isotope, the following results were obtained .

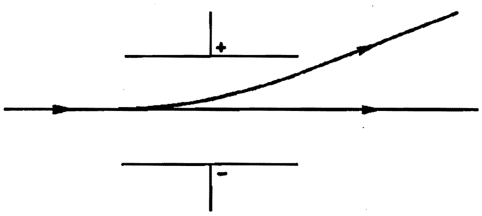
activity/counts per min	4100	2800	1900	1300	900	600
time/min	0	2	4	6	8	10

What is the approximate half-life of the isotope?

A 2 min
B 4 min
C 6 min
D 8 min
E 10 min

J93/I/39

18 The diagram shows two types of radiation passing through an electric field.



What are the types of radiation?

A α-particles and β-particles
B α-particles and γ-rays
C α-particles and neutrons
D β-particles and γ-rays
E γ-rays and neutrons

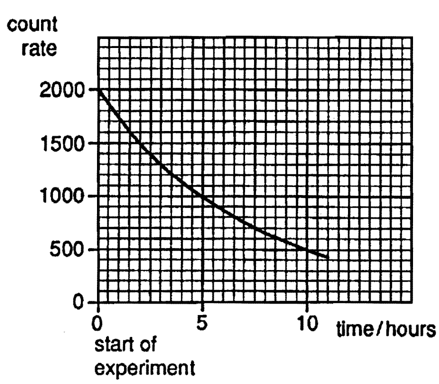
N93/I/38

19 Cs-137 is a radio-isotope used to determine the thickness of the walls of steel pipes. Cs-137 is chosen because it emits

A α-particles.
B β-particles.
C γ-rays.
D microwaves.
E radio-waves.

N93/I/40

20 The graph shows the count rate for a radioactive source over a few hours.



What will be the count rate after 20 hours?

A 0
B 62.5 units
C 125 units
D 250 units

J94/I/38

21 Which statement about the deflection of α-particles and β-particles moving at right-angles to a magnetic field is correct?

A α-particles are deflected but β-particles are not.

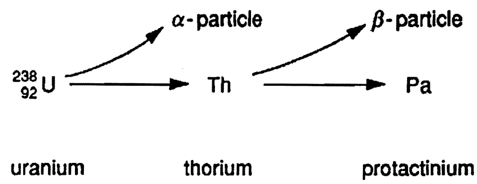
B β-particles are deflected but α-particles are not.

C Both α-particles and β-particles are deflected but in opposite directions.

D Both α-particles and β-particles are deflected in the same direction.

J94/I/37

22 The uranium atom $^{238}_{92}U$ emits an α-particle to become thorium, which then emits a β-particle to become protactinium.



What is the proton number (atomic number) of protactinium?

A 89
B 90
C 91
D 95

J94/I/39; J97/I/40

23 Which statement describes γ-radiation?

A It carries a negative charge and is absorbed by a thin sheet of aluminium.

B It carries a positive charge and is absorbed by a sheet of paper.

C It consists of electromagnetic waves and is not affected by electric or magnetic fields.

D It is the same as a helium nucleus and has powerful ionising effects.

N94/I/37

24 A $^{235}_{92}U$ nucleus decays by the emission of an α-particle.

What are the proton and nucleon numbers of the resulting nucleus?

	proton number	*nucleon number*
A	90	231
B	90	235
C	91	231
D	93	235

N94/I/38

25 When an animal dies, each gram of carbon in its body emits about 16 β-particles each minute. Each gram of carbon from some animal remains is found to emit about 4 β-particles each minute.

How old are the animal remains, assuming that the half-life of radioactive carbon is 6 000 years?

A 1 500 years
B 3 000 years
C 12 000 years
D 24 000 years N94/I/39

26 A worker at a nuclear plant walks into a room and is accidentally exposed to a small amount of γ-radiation.

On entering this room the worker will

A feel no effect.
B feel very hot.
C get skin blisters.
D lose consciousness. J95/I/36

27 Nuclide $^{225}_{90}X$ decays to nuclide Y with the emission of two α-particles and one β-particle.

What is the composition of nuclide Y?

A $^{221}_{89}Y$ **C** $^{217}_{85}Y$
B $^{217}_{87}Y$ **D** $^{216}_{89}Y$ J95/I/37

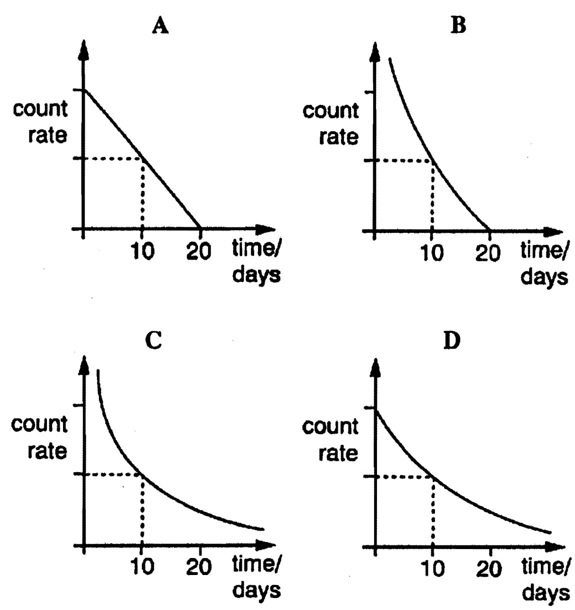
28 When some fresh foods are exposed to γ-rays, the foods' keeping qualities are improved and the foods are safe to eat.

Why can people eat these foods without suffering from the effects of radiation?

A γ-rays carry no electric charge.
B γ-rays do not make the food radioactive.
C γ-rays have very low energy.
D γ-rays have a very short half-life. N95/I/37

29 A radioactive nuclide has a half-life of 10 days.

Which graph shows how the count rate of the nuclide varies with time?



J96/I/37

30 A uranium nucleus ($^{238}_{92}U$) disintegrates by emitting first an α-particle and then a β-particle.

What is the atomic number of the product of these two disintegrations?

A 94 **C** 91
B 93 **D** 90 J96/I/38

31 A nucleus consists of 90 protons and 144 neutrons.

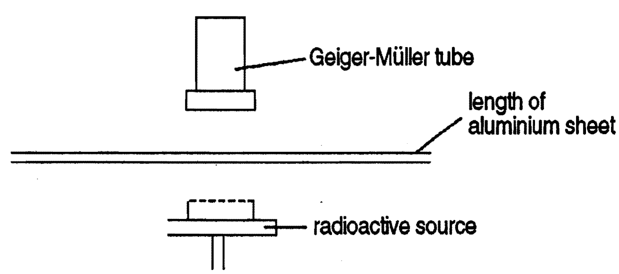
After emitting two beta particles followed by an alpha particle, this nucleus has

A 86 protons and 140 neutrons.
B 86 protons and 142 neutrons.
C 90 protons and 140 neutrons.
D 90 protons and 142 neutrons. N96/I/37

32 Why are radioactive sources stored in boxes lined with lead?

A Lead absorbs radiation and stops it from escaping into the room.
B Lead absorbs the radioactive source and makes it safe to handle.
C Lead completely stops the source from decaying and so it lasts longer.
D Lead slows down the rate at which the radioactive source decays. N96/I/38

33 An aluminium sheet is dragged between the radioactive source and the Geiger-Müller tube shown.



The table shows the counts per second recorded by the G-M tube.

distance along sheet, in cm														
10	20	30	40	50	60	70	80	90	100	110	120	130	140	150
counts per second														
50	50	51	50	49	50	50	55	60	75	80	65	50	49	50

Which statement explains what happened between 70 cm and 110 cm?

A The sheet got thinner.
B The sheet got thicker.
C The source became more radioactive.
D The source became less radioactive. N96/I/40

34 Boxes which are used to store radioactive substances are usually lined with lead. Why is this?

A It is a good thermal conductor.
B It prevents background radiation from entering the box and contaminating the contents.
C It prevents much of the radiation from escaping into the surroundings.
D It stops the box from being knocked over easily.

J97/I/38

35 Why are γ-rays **not** deflected by a magnetic field?

A They are strongly penetrating.
B They are weakly ionising.
C They have no charge.
D They have no mass. N97/I/37

36 A freshly made sample of radioactive material gives a count rate of 8000 counts per minute. After twenty days, it gives a count-rate of 500 counts per minute.

What is the half-life of the material?

A 4 days **C** 20 days
B 5 days **D** 80 days N97/I/39

37 Which material should be used to line a box for storing radioactive substances emitting γ-radiation?

A aluminium
B graphite
C lead
D plastic J98/I/35

38 A radioactive isotope has a half-life of 2 minutes.

What can be deduced from this statement?

A After $^1/_2$ minute, $^1/_4$ of the isotope remains.
B After 1 minute, $^1/_4$ of the isotope remains.
C After 4 minutes, $^1/_4$ of the isotope remains.
D After 4 minutes, none of the isotope remains.

J98/I/36

39 Which type of radiation would be stopped completely by a thin piece of cardboard?

A α-particles **C** γ-rays
B β-particles **D** X-rays N98/I/35

40 A beam consisting of α-particles, β-particles and γ-rays passes through a magnetic field at right angles to the direction of the beam.

What happens?

	α-particles	β-particles	γ-rays
A	deflected	deflected	deflected
B	deflected	deflected	not deflected
C	deflected	not deflected	deflected
D	not deflected	deflected	deflected

J99/I/35

41 The half-life of isotope X is four days and its initial mass is 32 mg.

What mass of the isotope X will remain after twelve days?

A 4 mg **C** 12 mg
B 8 mg **D** 16 mg J99/I/36

42 An α-particle is the same as

A a helium nucleus.
B a high speed electron.
C a hydrogen nucleus.
D electromagnetic radiation of short wavelength.

N99/I/35

43 The half-life of a given radioactive isotope is 10 years. The original mass of the isotope is 12 g.

What mass of this isotope remains undecayed after 20 years?

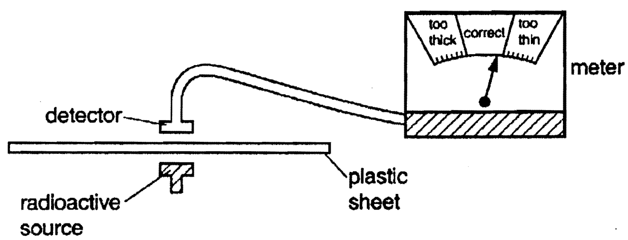
A 0.6 g **C** 3.0 g
B 1.2 g **D** 6.0 g N99/I/36

44 A radioactive nucleus is represented by $^{227}_{85}X$. It emits an alpha particle and forms a different nucleus of element Y.

Which of the following represents the new nucleus?

A $^{223}_{83}Y$ **C** $^{223}_{86}Y$
B $^{223}_{84}Y$ **D** $^{223}_{85}Y$ J2000/I/35

45 A factory uses a radioactive source and a detector to monitor the thickness of plastic sheets. The arrangement is as shown.



Which type of radioactive source would be best for this device?

	radiation	half-life
A	α	1 day
B	α	10 years
C	β	1 day
D	β	100 years

J2000/I/36

46 Which action will most increase a person's exposure to radioactivity?

A eating food that has been sterilised by exposure to gamma rays
B going for a flight in a high-flying aircraft
C opening the windows of a house
D using a Geiger-Müller tube and counter N2000/I/36

47 The table shows how the activity of a radioactive substance changes over a period of time. (Allowance has been made for the background radiation.)

time / minutes	0	5	10	15	20	25	30	35	40
activity/counts per second	114	102	90	83	73	65	57	51	45

What is the half-life of the substance?

A 73 minutes
B 57 minutes
C 30 minutes
D 20 minutes N2000/I/38

48 A radioactive isotope of radium $^{226}_{88}$Ra emits alpha particles and becomes radon. Write down an equation to show this radioactive decay. What information about the radium nucleus is given by the numbers 226 and 88?

A radioactive sample contains mainly $^{226}_{88}$Ra and also some other isotopes which emit beta and gamma radiation.

With the aid of labelled diagrams, describe experiments to show

(i) that some of the radiation is alpha,

(ii) that some of the radiation is gamma.

What effect does the emission of a beta particle have on the nucleus of the emitting atom?

Describe with the aid of a labelled diagram, the behaviour of beta rays when a strong uniform magnetic field is applied at right angles to their direction of motion. J79/II/12

49 *(a)* Copy and complete the following equation, which represents the decay of a nuclide of radioactive sodium with the emission of β-particle.

$$^{24}_{11}\text{Na} \longrightarrow \text{Mg} + {}^{0}_{-1}\text{e}$$

State the mass number of the $^{24}_{11}$Na nuclide and the number of neutrons present in it.
Describe an experimental arrangement and procedure to show that the emission from a radioactive source which emits *β*-particles is *random.*

A radioactive source is emitting 1000 particles per second. If the half-life of the source is 30 minutes, after how long will the rate of emission be 125 particles per second?

(b) A radioactive source which emits only *one* type of radiation is placed 10 mm from an appropriate detector. A count rate of 1000 per second is observed. Write down an approximate value for the count rate you would expect to observe when a sheet of aluminium 1 mm thick is inserted between the source and the detector, giving an answer for each of the three types of radiation, *α*, *β* and *γ*. When the source is removed completely the count rate becomes very small but not zero. Explain this observation. N79/II/12

50 A radioactive sample has a half-life of 20 minutes, and at a certain time a detector records 120 counts per second.

Calculate the count-rate recorded by the detector one hour later.

The sample emits *α*-particles. State briefly the nature of these particles. J80/I/13

51 *(a)* A nitrogen nuclide is written as $^{14}_{7}$N. What information about the structure of the nitrogen atom can be deduced from this symbol for the nuclide?

(b) A nuclide whose symbol is $^{16}_{7}$N is an isotope of nitrogen. In what way is an atom of this type of nitrogen different from the atom in *(a)*?

(c) The nuclide $^{16}_{7}$N decays to become an oxygen nuclide by emitting an electron. Write down an equation to show this process.

(d) The half-life of the nuclide $^{16}_{7}$N is 7.3 s. What does this mean? A sample of this type of nitrogen is observed for 29.2 s. Calculate the fraction of the original radioactive isotope remaining after this time.

J81/II/4

52 A nucleus of the radioactive isotope $^{222}_{88}$ Rn emits an α-particle when it decays to a nucleus of element Po. Complete the equation representing this event:

$$^{222}_{88}\text{Rn} \longrightarrow \quad \text{Po} + \quad \text{He}$$

What is the atomic number of the $^{222}_{88}$Rn nucleus? N81/I/15

53 *(a)* A particular radioactive source is known to emit *α* and *γ* radiation. Describe an experiment to establish whether or not it also emits *β* radiation. Illustrate your answer with a carefully labelled diagram of the experimental arrangement.

In an experiment using a radioactive source which emits *only β* radiation, the number of counts recorded in successive periods of 10 s were:

5030, 4960, 4970, 5040 Average: 5000.

An hour later, using the same source, the experiment was repeated and the counts recorded in periods of 10 s were

1230, 1220, 1270, 1280 Average: 1250

(i) Explain how these readings illustrate that radioactive decay is *random* in time.

(ii) Use the two sets of readings to find a value for the half-life of the source. N81/I/12*(a)*

54 *α*, *β* and *γ* radiations are forms of radioactive emission.

State in each of the cases (i) to (iv) below which one of these radiations has the properties mentioned.

(i) Positively charged and absorbed after travelling a few centimetres in air.

(ii) When emitted from an atom, the atomic number increases but the mass number is unchanged.

(iii) Passes readily through several centimetres of lead and carries no electric charge.

(iv) When emitted from an atom, both the atomic number and mass number of the atom are decreased.

J82/I/15

55 A nuclide of radon, Rn, has mass number 222 and atomic number 86.

(a) Use this information to complete the symbol of this particular nuclide.

(b) Use this information to describe the composition of one *atom* of this nuclide.

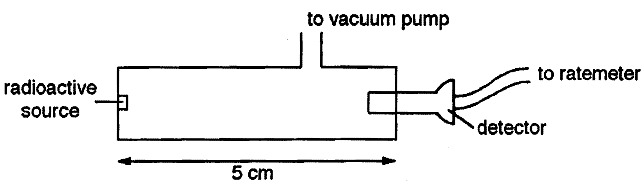
(c) This radon nuclide decays by the emission of an alpha particle forming a nuclide of polonium, symbol Po.

Write an equation to represent this decay.

J82/II/6*(a, b, c)*

56 State the changes that take place in the nucleus of an atom of a radioactive source when an α particle is emitted. Illustrate your answer by an equation for the emission of an α-particle from the nuclide $^{A}_{Z}X$.

The arrangement illustrated in the diagram is set up and a ratemeter is connected to the detector.



A low count rate is observed on the ratemeter when the pressure of the air in the vessel is atmospheric. As the air is pumped out, the count rate rises to a maximum value of 2000 per second.

The experiment is repeated six hours later. Similar observations are made except that the maximum count rate observed is only 250 per second.

(a) Identify the radiation emitted from the source, explaining fully how you reach your conclusion.

(b) Calculate a value for the half-life of the radioactive source. Indicate, with a reason, whether or not the half-life is affected by variations in air pressure.

Suggest reasons why

(i) α-particles produce much denser tracks in a cloud-chamber than do β-particles,

(ii) β-particles are much more readily deflected by electric field than are α-particles.

N82/II/12

57 A radioactive source was placed near a Geiger-Müller tube connected to a ratemeter. A count rate of 1600 counts per second was recorded. Four hours later, the count rate had fallen to 100 counts per second. What is the half-life of the material of the source?

[Assume the back-ground count rate to be negligible.]

Another reading of the count rate was then taken immediately and it was observed to be slightly larger at 104 counts per second. Suggest a reason for this result.

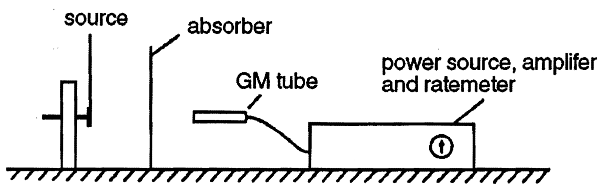
J83/I/15

58 State the nature of α-particles, β-particles and γ-rays.

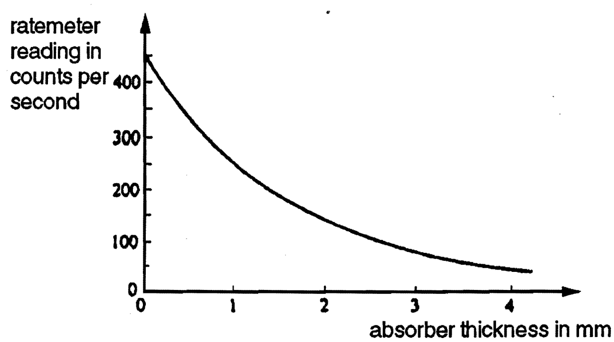
With the aid of a labelled diagram to show the arrangement of the apparatus, describe experiments by which the emission *(a)* from a β-emitting radioactive source, *(b)* from a γ-emitting radioactive source, could be identified.

State, and explain very briefly, **two** methods by which human beings can be protected against the emissions produced by radioactive sources. J83/II/12

59 An apparatus for detecting radioactive emission is set up as shown in the diagram.



(a) Plastic absorbers of increasing thickness are inserted successively in the position shown and ratemeter readings are taken for each one. The graph of the results is shown below.

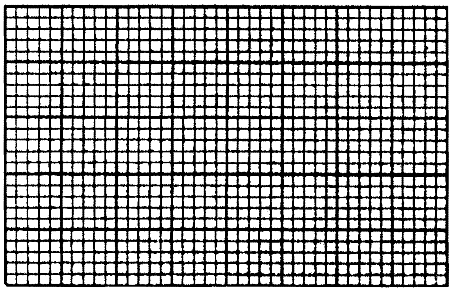


Give that the source has a long half-life and emits only **one** type of radiation, deduce whether the source is an α-, a β- or a γ-emitter. Explain your reasoning.

(b) It is found that even when absorbers several centimetres thick are placed in position, the ratemeter still records a very small reading. Explain why this is so.

(c) Suggest how a manufacturer of plastic sheeting 0.5 mm thick might use the above arrangement as the basis of a device for monitoring the thickness of his product.

(d)



Using the apparatus with a different source and without any absorber the ratemeter reading is observed at intervals. The initial reading was 400 counts per second and the half-life of the source was 0.5 h. On the grid below, plot a graph of the ratemeter reading against time from 0 h to 2 h. J84/II/5

60 A radiation counter is set up and a background count of 20 counts per minute is recorded. A radioactive sample is placed less than a centimetre from the detector and the counter then records 820 counts per minute. After 20 min., the count rate falls to 420 counts per minute. What would you expect the count rate to be 60 min. affer placing the radioactive sample in front of the detector?

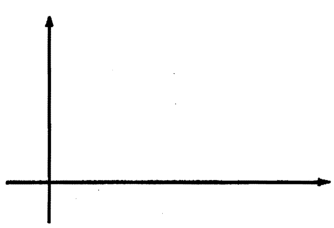
A similar sample placed directly in front of the detector also gives an immediate reading of 820 counts per minute. Moving the source 4 cm further away from the detector causes the reading to fall to 20 counts per minute. What can you deduce about the nature of the radioactive emission from the source? N84/I/15

61 $^{14}_{6}C$ represents a radioactive isotope of carbon: it decays to $^{14}_{7}N$.

(a) Using this information, write down an equation for the decay of carbon 14.

(b) What is meant by the half-life of a nuclide?

(c) Carbon 14 has a half-life of 5 600 years. A sample of carbon 14 had an initial count rate of 1 280 counts/min. Sketch a graph of count rate against time to illustrate the decay of the sample.



(d) A standard sample of living wood gives a carbon 14 count rate of 1 280 counts/min. A standard sample from a sunken wreck gives a carbon 14 count of 750 counts/min.

Given that the count rate for carbon 14 begins to fall only when a tree dies, use your graph to estimate the age of the wreck.

State *one* important assumption made in reaching your conclusion. J85/II/6

62 The nuclide $^{184}_{78}Pt$ emits an alpha-particle and decays to another nuclide Osmium, Symbol Os.

(a) Write down

(i) the number of neutrons in an atom of a $^{184}_{78}Pt$ nuclide,

(ii) the number of electrons in each atom of this element,

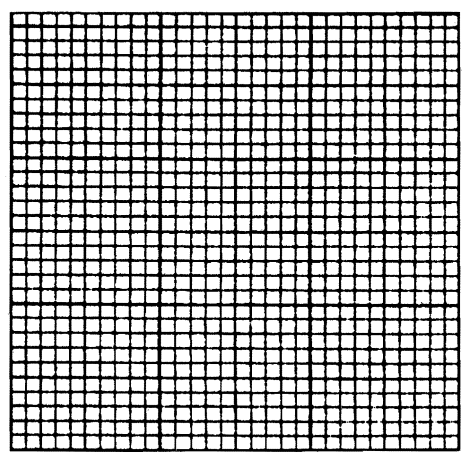
(iii) the number of protons in one atom of Osmium,

(iv) the total number of particles in one atom of Osmium.

(b) A sample of $^{184}_{78}Pt$ emitting α-particles produced the following results when its emission was measured at a fixed distance from it.

Count rate/minute	510	330	210	138	102
Time/minute	0	15	30	45	60

The count rate from background radiation was taken and found to be 20 per minute. Taking the background radiation into consideration, plot a graph of the count rate due to α-emission against time on the grid below.



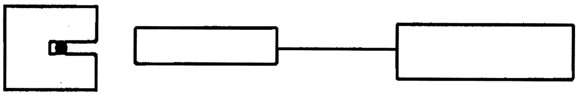
From the graph determine the half-life of the sample.

Suggest the origin of the background radiation. N85/II/5

63 The symbol $^{60}_{27}Co$ represents a radioactive isotope of cobalt. What information about the nucleus of this isotope does this symbol convey? $^{60}_{27}Co$ decays by β emission to the element Nickel (Ni); write down the equation representing this decay.

Other isotopes of cobalt exist; explain the meaning of the term *isotope*.

The apparatus in the diagram was set up to determine the type of radioactive emission from a source (not of $^{60}_{27}Co$).



When different absorbers were placed between the source and the G.M. tube the count rates observed were as shown in the table.

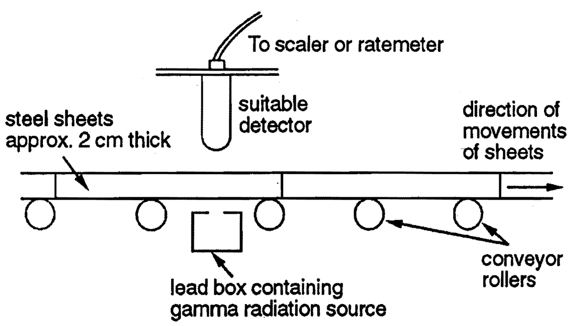
Absorber	Count rate (counts/min)
none	500
paper sheet	200
lead sheet 5 mm thick	190

When the source was removed a count rate of 15 per minute was observed.

Deduce the type (or types) of radioactive emission from the source giving a reason for your answer. Explain why the count rate did not reduce to zero when the source was taken away.

The experiment was repeated a month later using the same source. It was found that all the count rates, except that taken without a source present, had noticeably decreased. Explain these observations. J86/II/12

64 The arrangement illustrated is one way of measuring the thickness of steel plates. The conveyor is brought to rest whilst each test is made.



Explain how this apparatus could be used to test that all plates have equal thickness.

Suggest reasons for using Bamma rays rather than alpha or beta particles.

Describe and explain how the readings of the detector would be affected, if at all, by

(i) the random nature of the gamma ray emission,

(ii) the magnetic nature of the steel sheets.

State one advantage and one disadvantage of stopping the conveyor once only for each plate.

An operator working near this machine would need protection against the danger of radioactivity.

(i) What are these dangers?

(ii) Suggest two ways of reducing the danger to the operator. N86/II/12

65 How many neutrons does the nucleus of one atom of $^{234}_{90}$Th contain?

$^{234}_{90}$Th decays by beta emission to become palladium, symbol Pa. Write an equation to represent this decay.

What is meant by the statement that the half-life of $^{234}_{90}$Th is 24 days?

N86/I/15

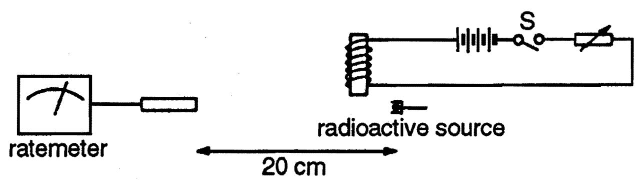
66 Complete the following table which contains data relating to the decay of a radioactive source, the half-life of which is 3.0 min.

Number of original atoms remaining, in millions	*Time elapsed since start of observations, in min*
512	0
	3.0
64	

Suggest an application in which use is made of knowledge of the half-life of a radioactive source.

J87/I/15

67 *(a)* A radioactive source is placed 20 cm in front of a suitable detector connected to a ratemeter, as shown in the diagram. A powerful electromagnet is arranged, as indicated, near the source.



A count rate of 5000 counts/min is observed when the switch S is open and a much smaller count rate when S is closed.

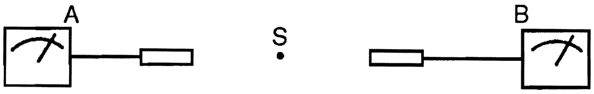
(i) Suggest a reason for the decrease in count rate.

(ii) The source emits only one type of radiatlon. State which type you consider it to be. Give a reason, in each case, for rejecting the other two likely types of radiation.

(b) When the same source and detector are placed the same distance apart in a glass tube and the air is withdrawn, a reading of more than 5000 counts/min is obtained.

Give an explanation of the fact thát the count rate has increased.

(c) A radioactive source which emits radiation in all directions is placed, as shown, midway between two identical detectors, each connected to a ratemeter.



The meters show equal count rates; how would you expect the readings to change as the source S is moved towards A?

Give a reason for your answer.

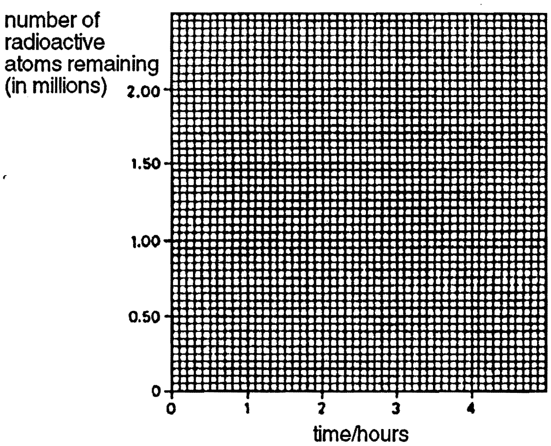
(d) One feature of an unmanned weather station is a radioactive source suspended midway between two counters so that the source can swing in the wind.

Indicate two practical problems that would be encountered in trying to obtain reliable readings of wind speed from this arrangement. J87/II/5

68 A sample of a radioactive isotope contains 2.0 million radioactive atoms. Two hours later the number of radioactive atoms has decreased to 0.5 million.

Calculate the half-life of this isotope.

Use your calculated value for the half-life to deduce the number of radioactive atoms remaining at two other instants. On the grid below plot a graph showing all 4 points.



Use the graph to estimate the number of radioactive atoms present atter 1.5 hours. N87/I/1

69 The nuclide $^{14}_{6}C$ decays by the emission of beta particles. Describe fully, with the aid ot a labelled diagram, the structure of one *atom* of this nuclide. [6]

(a) With the aid of a labelled diagram, describe experiments which could be used to show that the nuclide $^{14}_{6}C$

(i) is radioactive

(ii) does not emit alpha particles,

(iii) does not emit gamma rays. [8]

(b) The emission of beta particles from a radioactive source is said to be *random.*

Explain what this means by relerence to (i) time, (ii) direction. [3]

N87II/12

70 State two practical steps that can be taken to reduce the danger to persons working on an experiment in which a radioactive source which emits γ-rays is used.

Explain briefly why each step is effective.

Step 1 ....

Reason ....

Step 2 ....

Reason ....

[2, 2]

J88/I/14

71 *(a)* Describe an experiment which could be used to show that the emission from a radioactive source is random in both direction and time. Indicate the procedure you would adopt using a source which emits only α-particles. Make clear how the random nature of the emission would be deduced from the readings or observations. [6]

(b) A radioactive source was placed close to a suitable detector connected to a ratemeter. Aluminium absorbers of varying thickness were placed between the source and the detector. Readings were obtained for each thickness, and after correction for background radiation, the following results were obtained.

Absorber thickness/mm	0	1.0	2.0	3.0
Count rate/(counts/min)	600	278	129	60

(i) Explain the meaning of "correction for background radiation".

(ii) The source emits only one type of radiation. For each type of radiation, α, β, γ, state whether or not it is emitted, giving a reason for your answer in each case.

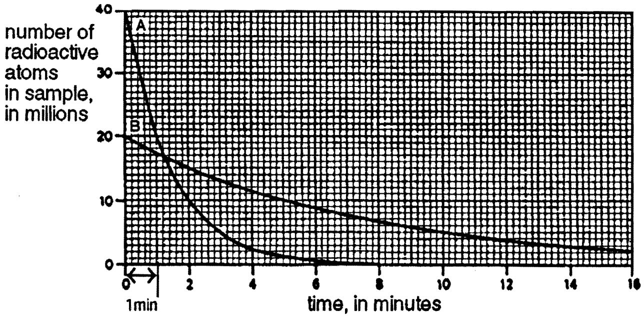
(iii) The half-life of the source is 30 min. What corrected readings would you expect to obtain, with no absorber present, one hour after the original readings were taken. [8]

(c) (i) A source and detector are to be used in a factory to monitor the thickness of aluminium sheet. Why is it advantageous to use a source with a half-life much greater than 30 min?

(ii) A radioactive liquid and a detector are used in a factory to detect a leak in a pipe. Why is it advantageous to use a source with a short half-life? [3]

J88/II/12

72 The graphs show the decay of two radioactive samples **A** and **B**. Each sample contains a single radioactive nuclide which decays to a stable nuclide.



(a) (i) After what time are there equal numbers of radioactive atoms in each sample?

(ii) How many radioactive atoms are there in each sample at this time? [2]

(b) What is the half-life of the nuclide in sample A? [1]

(c) Comment on the amount of radiation coming from A and B after 8 minutes. [1]

N88/I/15

73 *(a)* Describe experiments by which alpha and beta radiation may be detected. [6]

(b) State the changes which take place in a radioactive nucleus when beta radiation is emitted. [3]

(c) What is the nature of gamma radiation? [2]

(d) The total mass of the particles resulting from a nuclear change is often less than the total mass before the change. How do you account for this? [2]

(e) Explain why safety precautions are essential in performing experiments with radioactive sources. Indicate briefly the precautions which should be taken. [4]

N88/I/12

74 *(a)* A given radioactive source emits beta particles and gamma rays only.

Describe, with the aid of a diagram, experiments to demonstrate clearly the presence of each type of radiation.

Explain carefully whether the observations made would be affected by (i) background radiation, and (ii) the random nature of radioactive emissions. [10]

(b) A radioactive source has a half-life of 20 minutes. At one instant, a detector placed near to the source records a count-rate of 4000 counts/minute. After how long is the count-rate reduced to 250 counts/minute? Explain how you arrived at your answer. [3]

(c) State two precautions which can be taken to protect people using radioactive sources. In each case, explain briefly why the precaution is effective. [4]

J89/II/11

75 *(a)* $^{207}_{81}$Tl is an isotope of thallium which emits beta radiation and is converted into an isotope of lead (Pb). The half-life of the decay process is 4.8 minutes.

(i) Write an equation which represents the decay of the thallium nucleus.

(ii) Describe the changes which take place in the nucleus as the beta particle is produced.

(iii) Explain what is meant by *'a half-life of 4.8 minutes'*. [6]

(b) Describe in detail an experiment which could be used to make an accurate determination of the half-life of a radioactive isotope, assuming that the half-life is known to be about 5 minutes. Your account should include a diagram showing the arrangement of the apparatus, a description of the procedure to be adopted, and you should show how the result would be obtained from the observations. [9]

(c) State two safety precautions which should be taken when handling radioactive materials. [2]

N89/II/12

76 Complete the following table to show the nature of and, where relevant, the nucleon number and proton number of each of the types of particle or radiation emitted from radioactive materials.

particle or radiation	*nature*	*nucleon number*	*proton number*
alpha particles			
beta particles			
gamma rays			

[4]

J90/II/9

77 *(a)* $^{135}_{53}$I is a radioactive isotope of iodine. What do the numbers 53 and 135 tell us about the nucleus of an atom of the isotope? [3]

(b) The table below shows the counts recorded in successive minutes by a detector placed close to a small sample of $^{135}_{53}$I.

Counts	1880	1960	1940	1820	1980

(i) Calculate the average value of the counts.

(ii) Assuming that the half-life of $^{135}_{53}$I is 7.0 hours, what average value for the count would you expect to obtain if the experiment was repeated 21 hours later? Show how you obtained your answer. [3]

N90/II/8

78 Fig. 1.1 shows the paths of three emissions **J**, **K** and **L**, from a radioactive source, **S**, when that source is placed in a strong electric field.

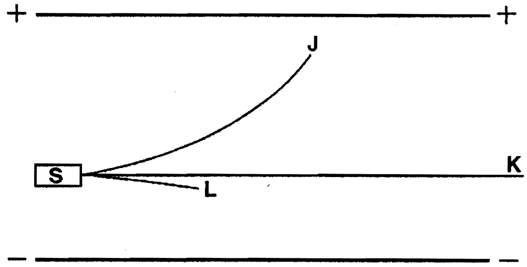
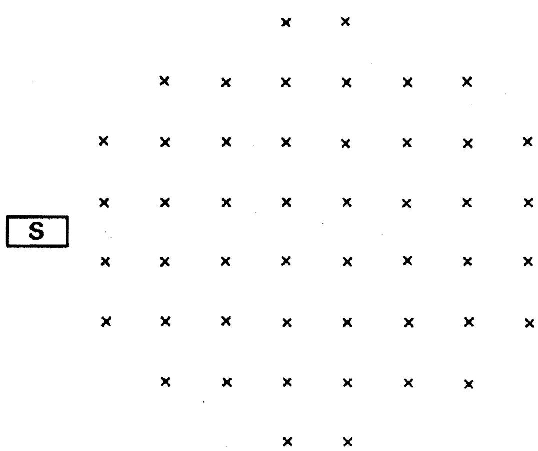


Fig. 1.1

(a) **On Fig. 1.1**, write the nature of each of the emissions against the letters **J**, **K** and **L**, using the symbols α, β, γ.

(b) Complete Fig. 1.2 below to show the effect of placing the source **S** and its emissions in a strong magnetic field with its direction at right-angles and INTO the plane of the paper.



strong magnetic field **into** the paper

Fig. 1.2 [5]

J91/II/8

79 Iodine-131, proton number 53, is a beta-emitter with a half-life of about 8 days.

(a) (i) Write down the nucleon number of the daughter nucleus.

(ii) Write down the proton number of the daughter nucleus.

(b) Iodine-131 is sometimes used as a tracer for medical purposes.

(i) State why beta-emitters are better than alpha-emitters for this use.

(ii) Estimate the number of days it takes for the activity of a sample of Iodine-131 to fall to 1/64 of its original value. [5]

N91/II/8

80 The three emissions, α, β and γ have different *ionising effects* and different penetrating powers and they behave differently when passing through an electric field.

(a) Explain what is meant by *ionising effects.* [3]

(b) State whether the penetrating power of each emission is small, medium or large and whether each would be attracted, repelled or unaffected by a positively charged body placed near its path.

emission	penetrating power	effect of positively charged body
α		
β		
γ		

[3]

J92/II/6

81 *(a)* (i) State the natures of α-emissions, β-emissions and γ-emissions.

(ii) State the size of the charge, if any, on each of these emissions in terms of the charge on an electron; i.e. call the charge on an electron –1. [3]

(b) Radium-228 is a radioactive isotope which decays by α-emission to an isotope of radon (Rn). Two further α-emissions give, in turn, isotopes of polonium (Po) and lead (Pb). The lead isotope normally decays by β-emission to an isotope of bismuth (Bi). There is significant γ-emission with the decays of the radium and the lead.

The proton (atomic) number Z of Radium (Ra) is 88.

Draw up a table showing the nucleon (mass) numbers, proton (atomic) numbers and neutron numbers of the radium, radon, polonium, lead and bismuth isotopes described above. [5]

(c) Sodium-24 is a radioactive isotope which can be used to detect leaks in underground water pipes. It is a β-emitter and a γ-emitter and it decays to a stable isotope of magnesium. The table gives the count-rate of a freshly prepared sample of sodium-24 over a period of 60 hours.

$\frac{\text{time}}{\text{h}}$	0	12	24	36	48	60
$\frac{\text{count-rate}}{\text{counts/second}}$	100	58	33	19	11	6

(i) Plot a graph of *count-rate* (y-axis) against *time* (x-axis).

(ii) Use your graph to determine the half-life of sodium-24. [7]

N93/II/10

82 The radioactive radium isotope $^{225}_{88}Ra$ decays by β-emission to an isotope of actinium.

The emission has a half-life of 15 days.

(a) State the proton number *Z* and the nucleon number *A* of the actinium isotope.

Z = ...

A = ... [2]

(b) Estimate the time it would take for the activity of samples of radium-225 to decay by β-emission to

(i) one quarter,

(ii) one thousandth of the original value.

Time to fall to one quarter ....

Time to fall to one thousandth .... [3]

J95/II/8

83 Figure 2.1 shows a radioactive source of *β*-particles and the path of the *β*-particles between a pair of uncharged plates.

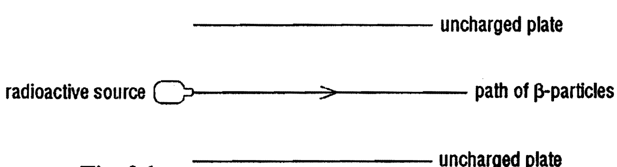


Fig. 2.1

(a) In Fig 2.2, the plates have been charged as shown but the path of the particles is missing. On Fig. 2.2, draw a possible path of the *β*-particles. [2]

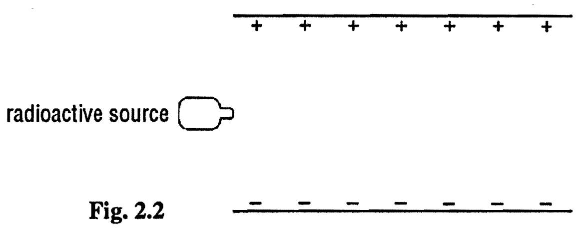


Fig. 2.2

(b) In Fig. 2.3 the beam of *β*-particles is directed at right-angles to a uniform magnetic field. The direction of the magnetic field is perpendicular to the plane of the diagram and downwards through that plane.

On Fig. 2.3, draw a possible path of the *β*-particles in the magnetic field. [2]

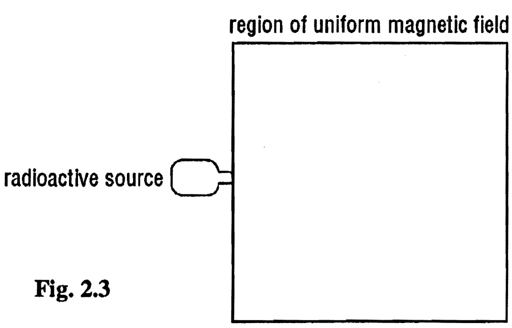


Fig. 2.3

N95/II/7

84 In an investigation into the nature of the emissions from a sample of a radioactive isotope, the sample is set 10 mm away from a sensitive detector. Various absorbers are placed between the sample and the detector, and several values of count-rate (in counts/min) are obtained in each case. The table shows the averages of those values.

absorber	*none*	*cardboard*	*aluminium*	*lead*
thickness/mm		0.2	3.0	9.0
average count-rate (counts/min)	860	850	25	25

Average value of background count-rate = 25 counts/min

What do you conclude about the nature(s) of the emission(s) from the isotope?

Justify your answer. [3]

J96/II/8

85 $^{60}_{27}Co$ is a β-emitter with a half-life of 5.3 years.

(a) What is the nature of β-emission? [1]

(b) What are the proton number and the nucleon number of the nucleus after a β-emission from a $^{60}_{27}Co$ nucleus? [2]

(c) Estimate the time required for the activity of a freshly prepared sample of $^{60}_{27}Co$ to fall to less than 1% of its initial value. [2]

N96/II/8

86 *(a)* State

(i) the natures of the three types of emission from radioactive sources,

(ii) the differences in the properties of these emissions. [8]

(b) Carbon-14 is a radioactive isotope of carbon; its proton number is 6 and its nucleon number is 14. It decays by β-emission with a half-life of approximately 5600 years.

(i) State what is meant by each of the terms *isotope, proton number and nucleon number.*

(ii) State the proton number and the nucleon number of the product of the decay.

(iii) **On graph paper**, sketch a decay curve for a sample of Carbon-14 over a period of 20 000 years. [7]

J97/II/10

87 *(c)* Radiation workers who handle radioactive materials wear badges to show how much ionising radiation they have received. In one type of badge, a photographic film is wrapped in paper and this is held in a plastic and aluminium holder as shown in Fig. 3, which is drawn to full size.

The developed film will be black where radiation has hit it.

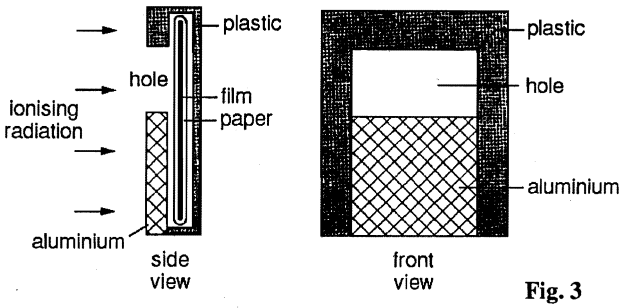


Fig. 3

(i) State why the badge does not detect any α-particles.

(ii) The film may be divided into three parts: a part behind the hole, a part covered by the plastic and a part covered by the aluminium.

1. Explain which part(s) of the developed film will be black if the operator has been exposed to β-particles.

2. Explain which part(s) of the developed film will be black if the operator has been exposed to γ-rays.

(iii) Describe the safety precautions that operators should take when handling and storing radioactive materials in order to minimise their exposure to the radiation that the materials emit. [7]

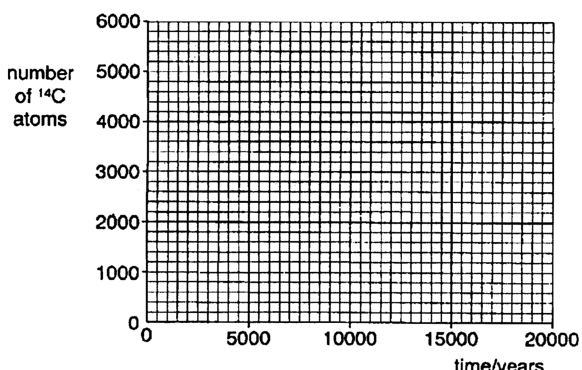
J98/II/10

88 *(a)* ^{14}C is a radioactive isotope of carbon which decays by β-particle emission with a half-life of 6000 years.

(i) What is a β-particle?

(ii) A radioactive sample contains 5000 atoms of ^{14}C.

On the axes below, plot the graph of the number of ^{14}C atoms in the sample over the next 18 000 years.



[3]

(b) A radioactive source emits β-particles and γ-rays. Fig. 4 shows how the two types of radiation are deflected when travelling in a vacuum through a uniform magnetic field is applied at right angles to the plane of the paper.

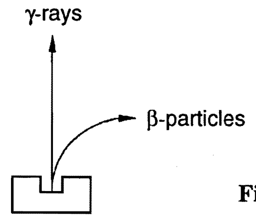


Fig. 4

(i) Explain why the γ-rays are not deflected.

(ii) Explain why the β-particles are deflected. [2]

N98/II/8

89 *(c)* Radioactive isotopes are used in medicine and in industry. Describe and explain one use that is made of a radioactive isotope. In your account, indicate whether the isotope should have a long or a short half-life. [5]

J99/II/10*(c)*

90 A radioactive source and a detector are used to check the level of fruit juice in a carton. Cartons of fruit juice pass between the detector and the radioactive source, as shown in Fig. 5. The radioactive source emits , β-particles.

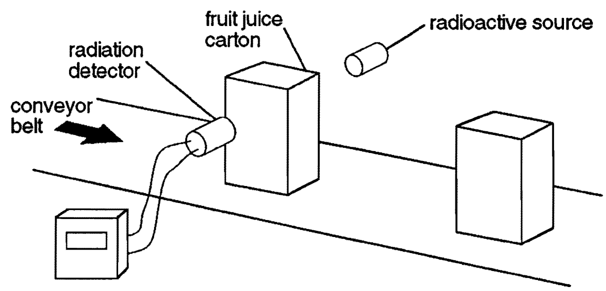


Fig. 5

(a) State the name of a suitable detector of the *β*-particles. [1]

(b) What is a *β*-particle? [1]

(c) Explain why the level of detected radiation falls when a full carton of juice goes past the detector. [1]

(d) Explain

(i) why a source emitting α-particles is not used,

(ii) why a source emitting γ-rays is not used. [2]

N99/II/7

91 *(a)* A radioactive source emits *α*-particles only.

(i) Describe, with the aid of a diagram, an experiment that demonstrates that the source emits α-particles but not β-particles.

(ii) Describe how you would demonstrate that the radioactive emission from the source is random.

(iii) State one safety precaution that you would take when handling any radioactive source. [8]

(b) A radioactive isotope of radon (Rn-220) is represented as $^{220}_{86}Rn$. The nucleon number (mass number) of this

nuclide is 220 and the proton number (atomic number) is 86. Radon-220 decays into polonium (Po-216) by the emission of an α-particle.

(i) State the number of neutrons in a nucleus of Rn-220.

(ii) The nuclear equation that represents the decay of Radon-220 is written as

$$^{220}_{86}\text{Rn} \longrightarrow {}^{\cdots}_{\cdots}\alpha + {}^{216}_{\cdots}\text{Po}.$$

Copy this equation and complete it by adding the missing nucleon number and proton number for the α-particle and the missing proton number for the polonium nucleus.

(iii) During the decay, there is an apparent decrease in mass of 1.14×10^{-29} kg. Calculate the energy released in the decay.

[speed of light = 3.0×10^8 m/s] [7]

J2000/II/9

92 A smoke detector contains a radioactive source that emits α-particles.

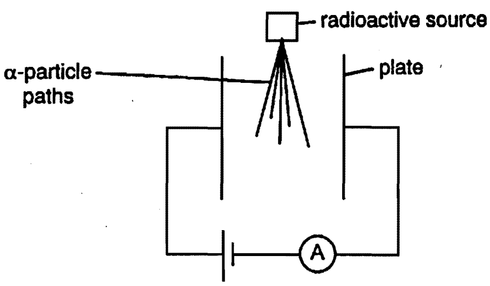


Fig. 6

Fig. 6 shows the structure of a simple smoke detector. The α-particles ionise the air between the plates. Positive ions and negative ions are created in the air and, as a result, a current is produced in the circuit. When smoke is present, the current decreases.

(a) State the nature of an α-particle. [1]

(b) Explain why a source that emits β-particles is not used in this detector. [1]

(c) State how a current is produced in the air between the plates. [1]

(d) The radioactive source that emits α-particles contains Americium-241.

A nucleus of Americium-241 is represented as $^{241}_{95}$Am. It decays into a nucleus of Neptunium-237.

The chemical symbol for neptunium is Np.

Write down the nuclear equation that represents the emission of an α-particle from a nucleus of $^{241}_{95}$Am. [2]

N2000/II/7

ANSWERS

1. **D**	2. **C**	3. **B**	4. **D**	5. **B**
6. **E**	7. **B**	8. **D**	9. **B**	10. **E**
11. **B**	12. **D**	13. **C**	14. **E**	15. **C**
16. **B**	17. **B**	18. **D**	19. **C**	20. **C**
21. **C**	22. **C**	23. **C**	24. **A**	25. **C**
26. **A**	27. **B**	28. **B**	29. **D**	30. **C**
31. **C**	32. **A**	33. **A**	34. **C**	35. **C**
36. **B**	37. **C**	38. **C**	39. **A**	40. **B**
41. **A**	42. **A**	43. **C**	44. **A**	45. **C**
46. **D**	47. **C**			

49. *(a)* 90 mins

50. 15 counts/sec

51. $^1/_{16}$ th

52. $^{222}_{86}\text{Rn} \rightarrow {}^{218}_{84}\text{Po} + {}^{4}_{2}\text{He}$; 86

56. *(b)* 2 hrs

57. 1 hr

60. 120 count/min

61. *(d)* 4300 yrs

62. *(a)* (i) 106 (ii) 78
(iii) 76 (iv) 256
(b) 22.5 mins

68. 1 hr ; 0.70 to 0.75 million

71. *(b)* (iii) 150 count/min.

72. *(a)* (i) 1.2 min (ii) 17
(b) 1 min

77. *(a)* 8.2
(b) (i) 1916 (ii) 239.5

79. *(a)* (i) 131 (ii) 54
(b) (i) 48

82. *(a)* $z = 89$; $A = 225$
(b) (i) 30 days; (ii) 150 days

85. *(a)* Electron, negatively charged particle
(b) Proton number = 28
Nucleon number = 60
(c) 37 yrs.

91. *(b)* (i) 134
(ii) $^{220}_{86}\text{Rn} \rightarrow {}^{4}_{2}\alpha + {}^{216}_{84}\text{Po}$
(iii) 1.026×10^{-12} J