Name: _____

Expanding Radioactivity

Questions

Date:

Time:

Total marks available:

Total marks achieved: _____

Questions

Q1. When measuring the count rate from a radioactive source it is usual to also measure the background count rate.

The background count rate must be

- ☒ **A** as large as possible for an accurate experiment.
- ☒ **B** measured when the source is in place.
- ☒ **C** recorded for the same time as the count rate.
- ☒ **D** subtracted from the count rate measured from the source.

(Total for Question = 1 mark)

Q2.

Radioactive decay is sometimes described as being spontaneous. In this context spontaneous means

- ☒ **A** nothing can influence the decay.
- ☒ **B** the decay is random.
- ☒ **C** the decay can be predicted.
- ☒ **D** the decay is exponential.

(Total for question = 1 marks)

Q3.

The ionising properties of radiations determine their penetrating power.

Which of the following statements is correct?

- ☒ **A** α-particles are not very ionising so they are stopped by thin paper.
- ☒ **B** α-particles are very ionising so can only travel a few centimetres in air
- ☒ **C** γ-radiation is very penetrating because it is very ionising
- ☒ **D** γ-radiation is not very penetrating because it is very ionising

(Total for question = 1 marks)

Q4.

Answer the question with a cross in the box you think is correct (☒). If you change your mind about an answer, put a line through the box (☒) and then mark your new answer with a cross (☒).

A nucleus of protactinium, $^{231}_{91}Pa$, decays by emitting an α particle.

The nucleus formed is

☐ **A** $^{233}_{95}Am$

☐ **B** $^{235}_{93}Np$

☐ **C** $^{227}_{89}Ac$

☐ **D** $^{229}_{87}Fr$

(Total for question = 1 mark)

Q5.

A radioactive source is placed a few cm away from a detector. There is no change in the count rate when a thin aluminium foil is placed between the source and the detector, but the count rate is reduced to the background rate when a 0.5 cm aluminium plate is introduced.

These observations show that the source must be emitting

☒ **A** alpha and beta radiation.

☒ **B** beta and gamma radiation.

☒ **C** beta radiation only.

☒ **D** gamma radiation only.

(Total for Question = 1 mark)

Q6.

In a famous thought experiment, Schrödinger imagined that a cat is locked in a box, along with a radioactive atom that is connected to a tube containing a deadly poison. If the atom decays, it causes the tube to smash and the cat to die.

The random nature of radioactive decay means that the radioactive atom will

☐ **A** decay after one half-life.

☒ **B** probably decay after one half-life.

☒ **C** have a fixed probability of decaying in a given time interval.

☒ **D** have a number of possible decay paths.

(Total for Question = 1 mark)

Q7.

In an experiment to measure the activity of a radioactive source the measured activity should always be corrected by

☒ **A** adding the background count.

☒ **B** adding the background count rate.

☒ **C** subtracting the background count.

☒ **D** subtracting the background count rate.

(Total for question = 1 mark)

Q8.

The table below gives the range and number of ion pairs per centimetre produced by β particles, compared to α particles of the same energy.

Select the row from the table which shows the correct comparison.

	Range of β particles	Number of ion pairs per centimetre
☐ **A**	greater	greater
☐ **B**	smaller	greater
☐ **C**	greater	smaller
☐ **D**	smaller	smaller

Q9.

Answer the question with a cross in the box you think is correct (☒). If you change your mind about an answer, put a line through the box (☒) and then mark your new answer with a cross (☒).

Select the row of the table that describes the relative ionisation and relative penetration of nuclear radiations.

	Most ionising	Most penetrating
☒ **A**	α	α
☒ **B**	α	γ
☒ **C**	γ	α
☒ **D**	γ	γ

(Total for question = 1 mark)

Q10.

Radioactive decay is said to be a spontaneous process.

This means that

☒ **A** we cannot know when a nucleus will decay.

☒ **B** we cannot know which nucleus will decay next.

☒ **C** we cannot know how many nuclei will decay.

☒ **D** we cannot influence when a nucleus will decay.

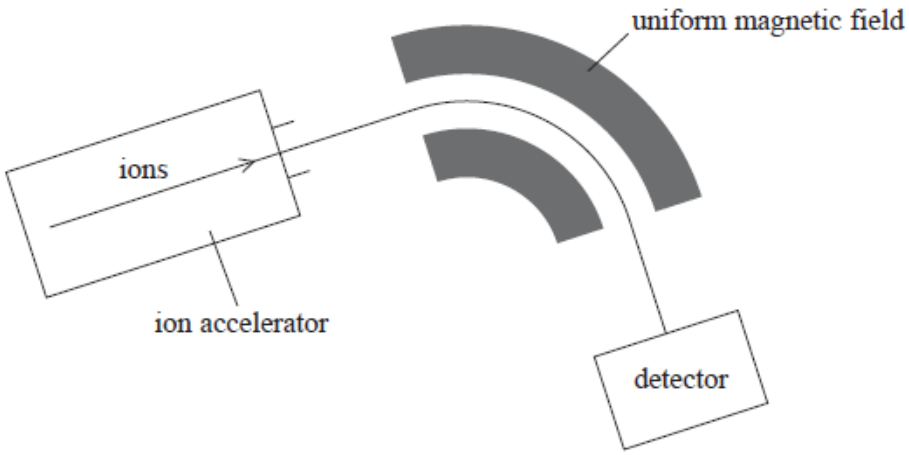
(Total for question = 1 mark)

Q11.

Mass spectrometry is a technique used to separate ions based on their charge to mass ratio.

The atoms in a sample are ionised and then accelerated and formed into a fine beam.
This beam is passed into a region of uniform magnetic field and the ions are deflected by

different amounts according to their mass.



Analysis of mass spectrometer data shows that chlorine exists in nature as two isotopes, chlorine-35 and chlorine-37.

State what is meant by isotopes.

(1)

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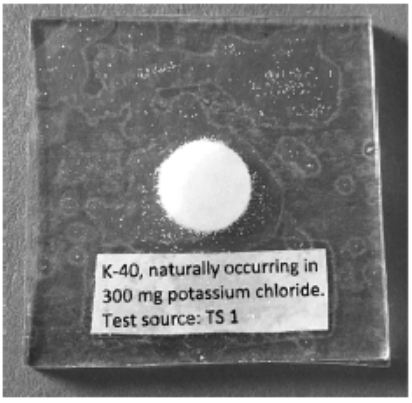
(Total for question = 1 mark)

Q12.

A school science department keeps a sample of potassium chloride to use as a test source for Geiger-Müller tubes.



Potassium contains 0.012% of the unstable isotope potassium-40.

The science department also has a sample of strontium-90. This undergoes beta decay with a half-life of 29 years.

State why the half-life of potassium-40 makes the potassium chloride a more suitable material than strontium-90 for the test.

(1)

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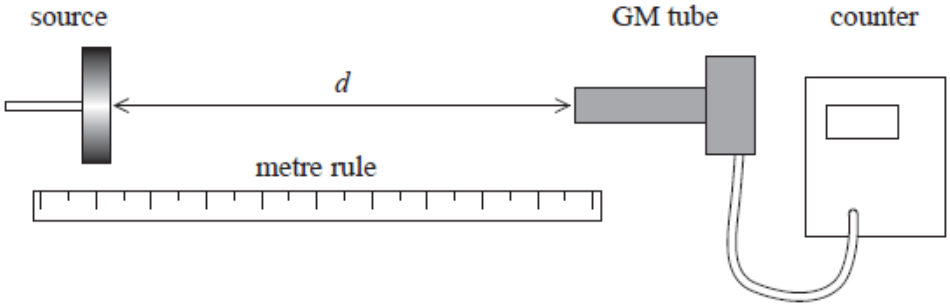
(Total for question = 1 mark)

Q13.

A student investigated the way in which gamma radiation spreads out from a source.
He placed a cobalt-60 source in a source holder and set up a Geiger-Müller (GM) tube a short distance *d* away. He connected the GM tube to a counter as shown.



The student recorded the count for 2 minutes.

Describe how to determine the corrected count rate from the source.

(2)

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(Total for question = 2 marks)

Q14.

A student investigated the way in which gamma radiation spreads out from a source.
He placed a cobalt-60 source in a source holder and set up a Geiger-Müller (GM) tube a short distance *d* away. He connected the GM tube to a counter as shown.

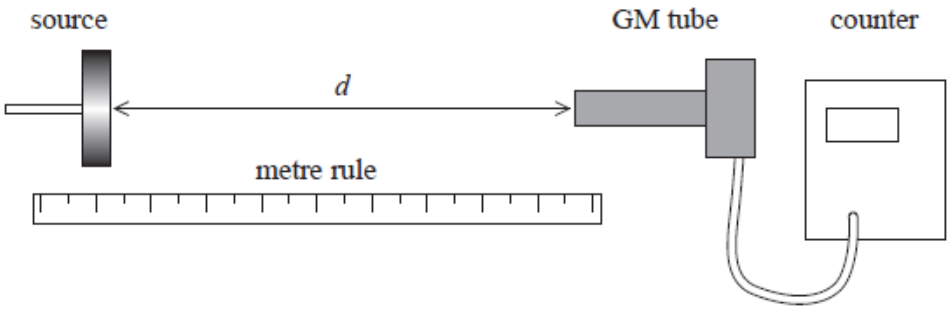

Figure 1

The student recorded the count for 2 minutes.

His teacher turned the GM tube through 90° so that the side of the tube faced the source as shown below.

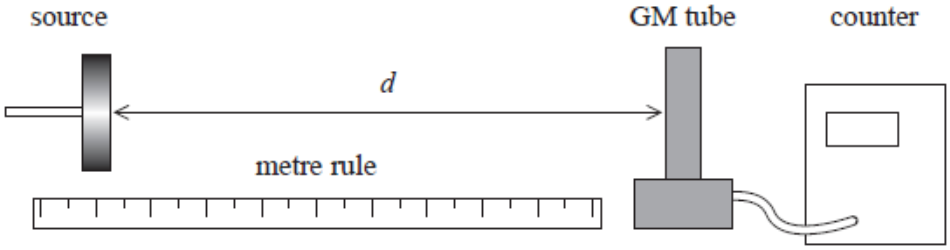

Figure 2

It is suggested that the investigation into the way in which gamma radiation spreads out from a source, using the apparatus as shown in **Figure 2**, could be carried out successfully using a radium-226 source.

Radium-226 emits α, β and γ radiation.

Justify this suggestion.

(2)

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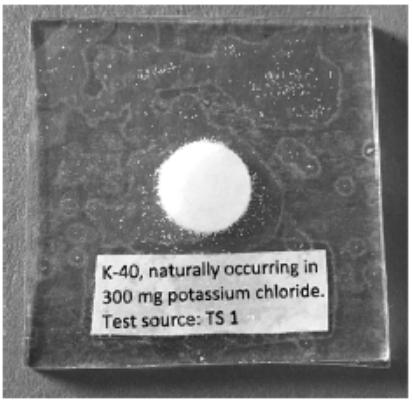
(Total for question = 2 marks)

Q15.

A school science department keeps a sample of potassium chloride to use as a test source for Geiger-Müller tubes.



Potassium contains 0.012% of the unstable isotope potassium-40.

Potassium-40 undergoes β^- decay, producing a stable isotope of calcium.

Complete the nuclear equation for this decay.

(2)

$$^{40}_{19}\text{K} \rightarrow \text{.....Ca} + \text{.....}\beta$$

(Total for question = 2 marks)

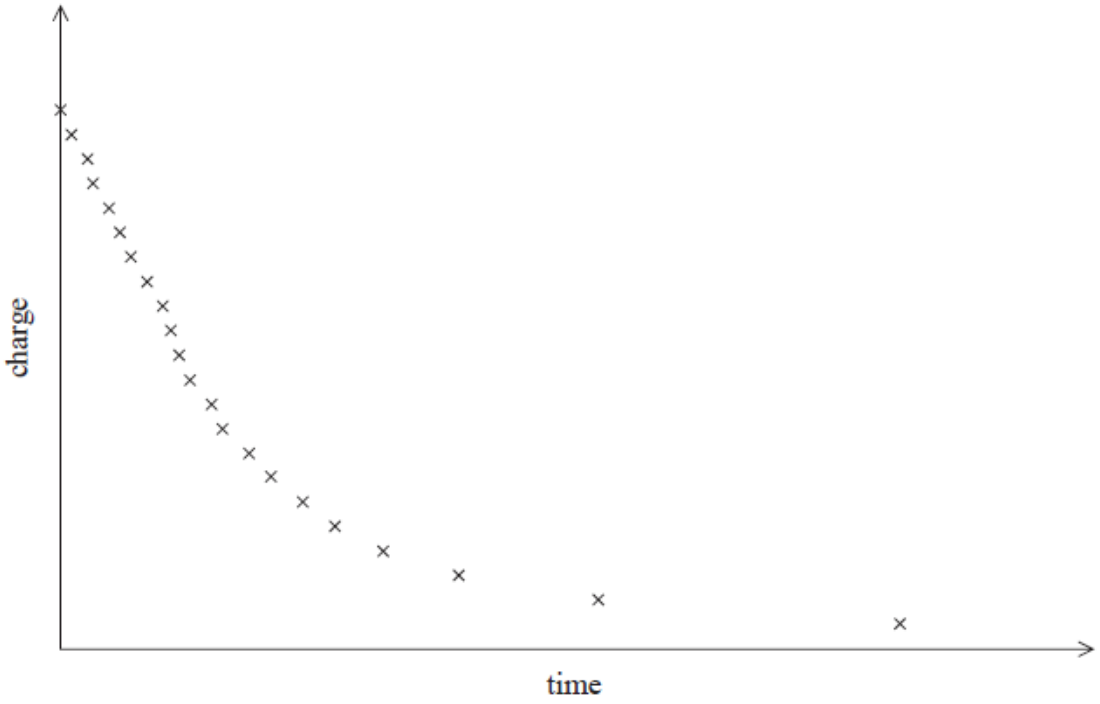
Q16.

A coulombmeter is used to measure charge.

In a laboratory demonstration of the photoelectric effect, a sheet of zinc was placed on top of a coulombmeter and the zinc was given a negative charge.

For one sheet of zinc, the charge at different times was measured.

The following graph was obtained.



A student suggests that this is an exponential decay curve.
Explain how this suggestion could be tested.

(3)

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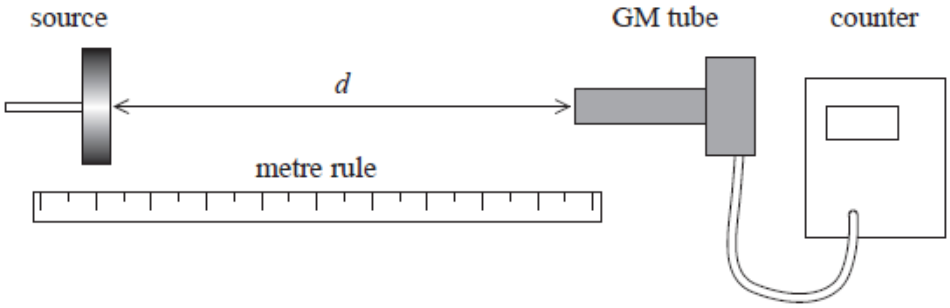
(Total for question = 3 marks)

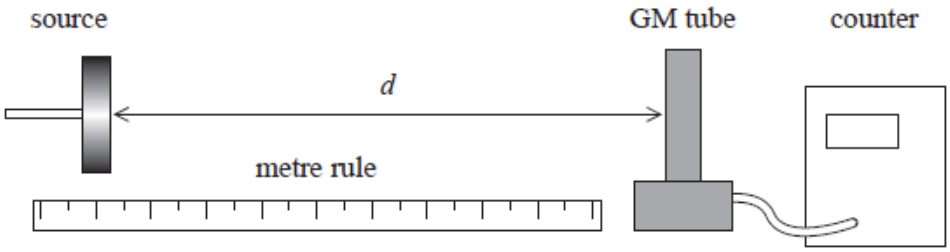
Q17.

A student investigated the way in which gamma radiation spreads out from a source.
He placed a cobalt-60 source in a source holder and set up a Geiger-Müller (GM) tube a short distance *d* away. He connected the GM tube to a counter as shown.



The student recorded the count for 2 minutes.

His teacher turned the GM tube through 90° so that the side of the tube faced the source as shown below.



(i) Explain why this arrangement could lead to more accurate data.

(2)

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(ii) Explain another modification to the experimental method which would improve the accuracy of the data.

(2)

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(Total for question = 4 marks)

Q18.

All living organisms contain ^{12}C and radioactive ^{14}C. The concentration of ^{14}C in the organism is maintained whilst the organism is alive, but starts to fall once death has occured.

(a) The count rate obtained from wood from an old Viking ship is 14.7 min^{-1} per gram of wood, after being corrected for background radiation. The corrected count rate from similar living wood is 16.5 min^{-1} per gram of wood

Calculate the age of the ship in years.

^{14}C. has a half life of 5700 years.

(4)

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Age of ship = ...years

(b) The concentration of ^{14}C in living organisms might have been greater in the past.

Explain how this would affect the age that you have calculated.

(2)

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(Total for question = 6 marks)

Q19.

Phosphogypsum is a by-product in the manufacture of fertiliser. It is slightly radioactive because of the presence of radium-226, a radioisotope with a half-life of 1600 years.

It must be stored securely as long as the activity of the radium-226 it contains is greater than 0.4 Bq per gram of phosphogypsum.

(i) In a sample of 1.0 g of phosphogypsum, the activity of radium-226 is 1.3 Bq.

Calculate the number of nuclei of radium-226 in this sample.

(3)

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Number of nuclei = ...

(ii) Calculate the time in years it would take before this sample reached the permitted level of decay rate.

(3)

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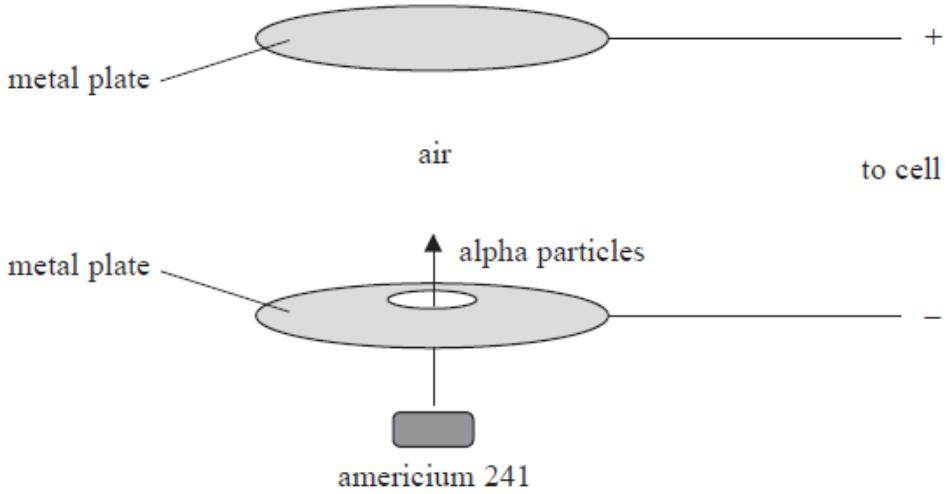
Time = ... years

(Total for question = 6 marks)

Q20.

Some types of smoke detector contain a radioactive isotope of americium, ^{241}Am. The nuclei of ^{241}Am decay by emitting an alpha particle.

The diagram shows part of a smoke detector.
The detectors use a small amount of ^{241}Am to make the air between two metal plates conduct charge.



(a) (i) Explain why a stream of alpha particles will cause charge to flow between the metal plates.

(2)

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(ii) Suggest how smoke particles entering the space between the plates will cause the current to decrease.

(1)

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(b) (i) The decay of ^{241}Am is said to be random and spontaneous.
State what is meant by random and spontaneous.

(2)

Random

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.....

Spontaneous

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(ii) Complete the equation for the decay of ^{241}Am.

(2)

$$\text{.....}^{241}\text{Am} \rightarrow \text{.....}_{93}\text{Np} + \text{.....}\alpha$$

(Total for question = 7 marks)

Q21.

When a photographic film that is not exposed to light is placed near to a source of ionising radiation the film darkens.

(a) (i) State what is meant by ionising radiation.

(1)

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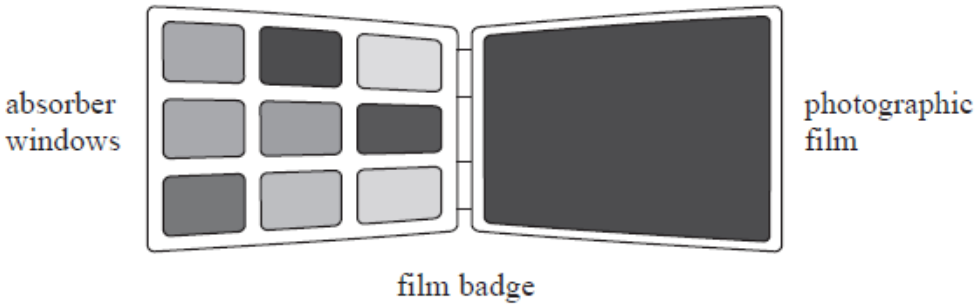
(ii) Complete the table to show α, β, and γ radiations in order of increasing ionising power.

(1)

Least ionising → Most ionising		

(b) In a physics lesson some students are learning about the use of a film badge to monitor exposure to ionising radiation.

Each absorber window is made from a different material and the type of radiation can be determined from the extent to which the film is darkened.



film badge

The students are asked to predict what would happen if α, β, and γ radiations were incident upon absorber windows made from paper, aluminium and lead.

(i) Complete the table to show the penetration of α, β, and γ radiations through each material.

Use the words "passes through" or "stopped".

(3)

	Paper	0.5 cm aluminium	0.5 cm lead
α radiation		stopped	
β radiation			stopped
γ radiation	passes through		

(ii) In a nuclear power plant there may be other radiation present which would **not** be detected by a film badge.

Suggest what type of radiation this is and why it would not be detected by a film badge.

(2)

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(Total for question = 7 marks)

Q22.

Radioactive isotopes are often used as markers, so that chemical substances can be traced around the body. In one medical procedure tritium is used as a means of studying protein absorption by the intestine.

A patient was given a sample containing the tritium to drink and then monitored. The initial activity of the sample was 3450 Bq.

Tritium is a beta-emitter with a half-life of 3.89×10^{8} s.

(a) State what is meant by the activity of a radioactive source.

(1)

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(b) Show that the decay constant of the tritium is about 1.8×10^{-9} s^{-1} and hence calculate the number of tritium nuclei in the initial sample.

(3)

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Number of nuclei = ...

(c) (i) Show that the time taken for the activity of the sample to fall to 10% of its initial value is about 40 years.

(3)

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(ii) Comment on the time given in (c) (i).

(1)

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(Total for question = 8 marks)

Q23.

In March 2011, a nuclear meltdown occurred at the Fukushima Nuclear Power Plant and radioactive materials were released into the environment.

A month later, seaweed off the coast near Long Beach, California was found to be contaminated with iodine-131, a radioisotope that decays by emitting β particles. In one sample the activity was found to be 2.5 Bq per gram of dry seaweed.

(a) State what is meant by the activity of a radioactive source.

(1)

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(b) A Geiger counter is used to measure the count from a sample of seaweed over a period of 10 minutes. The corrected readings obtained are shown in the table below.

Corrected count 1	Corrected count 2	Corrected count 3	Corrected count rate / Bq
3820	3830	3825	6.38

(i) State why the readings obtained from the Geiger counter have to be corrected.

(1)

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(ii) Explain why the radioactive count is repeated.

(2)

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(iii) The measurements were repeated with the same sample of seaweed 30 days later. Calculate the new corrected count rate of the sample.

half-life of iodine-131 = 8.0 days

(3)

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New corrected count rate = ...

(iv) There is a moderate risk to the public from the accumulation of iodine-131 in the seaweed. Explain why.

(2)

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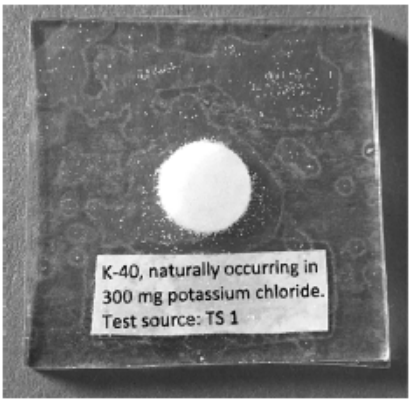
(Total for question = 9 marks)

Q24.

A school science department keeps a sample of potassium chloride to use as a test source for Geiger-Müller tubes.



Potassium contains 0.012% of the unstable isotope potassium-40.

A teacher makes some measurements using the potassium chloride test source to determine whether a Geiger-Müller tube is sufficiently efficient at detecting β radiation.

(i) The potassium chloride sample has a mass of 300 mg.

Show that the number of nuclei of potassium-40 in the sample is about 3×10^{17}.

number of potassium nuclei in 1 g of potassium chloride = 8.1×10^{21}

(2)

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(ii) Show that the activity of this sample is about 5 Bq.

half-life of potassium-40 = 1.25×10^{9} years

(3)

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(iii) With no sample in front of the Geiger-Müller tube, a count rate of 15 counts per minute is recorded. When the potassium chloride test sample is placed next to the Geiger-Müller tube 176 counts are recorded in a period of 10 minutes.

A detector is considered efficient if it detects at least 7.5% of beta emissions from the source.

Determine whether this Geiger-Müller tube can be considered efficient.

(3)

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(iv) Explain a possible reason why only a low proportion of the decays are detected.

(2)

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(Total for question = 10 marks)

Q25.

Positron emission tomography (PET) is a nuclear medicine imaging technique. Pairs of gamma rays, produced when positrons from a radioisotope annihilate with electrons, are detected to form the image.

Radioisotopes used in PET scanning are typically isotopes with short half-lives such as carbon-11. Carbon-11 has a half-life of 1220 s and decays by positron emission to stable boron-11. Positrons are the antiparticles to electrons.

(a) Explain what is meant by a radioactive atom.

(2)

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(b) Complete the equation for the decay of carbon-11.

$$^{11}_{6}C \rightarrow \text{\_\_\_\_}B + \text{\_\_\_\_}e^{+} + {}^{0}_{0}\nu_{e}$$

(2)

(c) Calculate the energy in joules released in a positron decay of carbon-11.

	Mass / MeV/c^2
positron	0.511
carbon	10 253.6
boron	10 252.2

(3)

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Energy = ... J

(d) Explain why carbon-11 is a relatively safe radioisotope to use within the body.

(2)

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(e) A patient was injected intravenously with a radioactive compound containing carbon-11 with an activity of 1.58×10^{6} Bq.

The sample was prepared 3600 s before it was administered to the patient.

Calculate the activity of the sample when it was prepared.

(4)

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Activity of the sample = ...

(Total for Question = 13 marks)

Q26. On 1st November 2006, the former Russian spy Alexander Litvinenko fell ill. Twenty one days later he died from the radiation effects of polonium-210. Experts suggest that as little as 0.89 μg of polonium-210 would be enough to kill, although Mr Litvinenko's death was linked to a much larger dose of the radioactive isotope. Traces of the isotope were later found in washrooms at five locations around London visited by the Russian.

Polonium-210 has a half life of 138 days.

(a) (i) In a 0.89 μg sample of polonium-210 there are 2.54×10^{15} atoms of polonium. Show that the decay constant for polonium-210 is about 6×10^{-8} s^{-1}, and hence calculate the activity of a sample of this size.

(4)

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Activity = ...

(ii) Calculate the fraction of polonium-210 nuclei that have decayed after a time of 21 days.

(3)

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Fraction decayed = ...

(b) Polonium-210 emits alpha particles. Explain why polonium-210 is virtually harmless unless it is taken into the body.

(2)

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(c) (i) Complete the equation below for the decay of polonium.

(2)

$$^{210}_{84}\text{Po} \rightarrow \text{\_\_\_\_}\text{Pb} + \text{\_\_\_\_}\alpha$$

(ii) State why the Pb nuclei would recoil from the alpha particles emitted during the decay.

(1)

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(d) Radioactive decay is said to occur spontaneously and randomly. Explain what is meant by spontaneous and random in this context.

(2)

Spontaneous

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Random

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(e) Suggest why traces of the isotope were found in locations visited by the Russian.

(2)

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(Total for Question = 16 marks)