Activity and Half Life Questions

Q1.

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.

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(Total for question = 1 mark)

Q2.

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 ☒.

Carbon-14 is a radioactive isotope with a decay constant of 1.2×10^{-4} year^{-1}.

The fossil of a plant contains 24% of the amount of carbon-14 that would have been present when the plant was alive.

Which of the following expressions gives the age of the fossil in years?

☐ **A** $1.2 \times 10^{-4} \times \ln \frac{1}{0.24}$

☐ **B** $1.2 \times 10^{-4} \times \ln \frac{0.76}{0.24}$

☐ **C** $\frac{1}{1.2 \times 10^{-4}} \times \ln \frac{1}{0.24}$

☐ **D** $\frac{1}{1.2 \times 10^{-4}} \times \ln \frac{0.76}{0.24}$

(Total for question = 1 mark)

Q3.

A hundred years ago, a method to determine the age of certain rocks was developed. An unstable isotope of rubidium is present in some rocks when they form. Over time the rubidium decays to a stable isotope of strontium.

Give a reason why the half-life of the rubidium isotope is hard to determine.

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(Total for question = 1 mark)

Q4.

Astronauts on the 1971 Apollo 14 mission to the Moon brought back many rock samples. It is now believed that one of these contains a piece of rock that originated on Earth about 4 billion years (4×10^9 years) ago.

The piece of rock is believed to have been launched into space when an asteroid struck the Earth.

The rock sample contains uranium. The radioactive decay of uranium allows it to be used to determine the time since the rock was formed on the Earth.

(ii) The half-life of $^{238}_{92}U$ is 4.47×10^9 years.

The half-lives of the other stages in the decay to $^{206}_{82}Pb$ are relatively so short that they can be ignored.

There was no lead in the rock when it formed, so all the $^{206}_{82}Pb$ in the sample is a product of $^{238}_{92}U$ decay. In the sample, for every 103 uranium nuclei present at the start, 50 are now lead nuclei. Show that the age of the sample is about 4×10^9 years.

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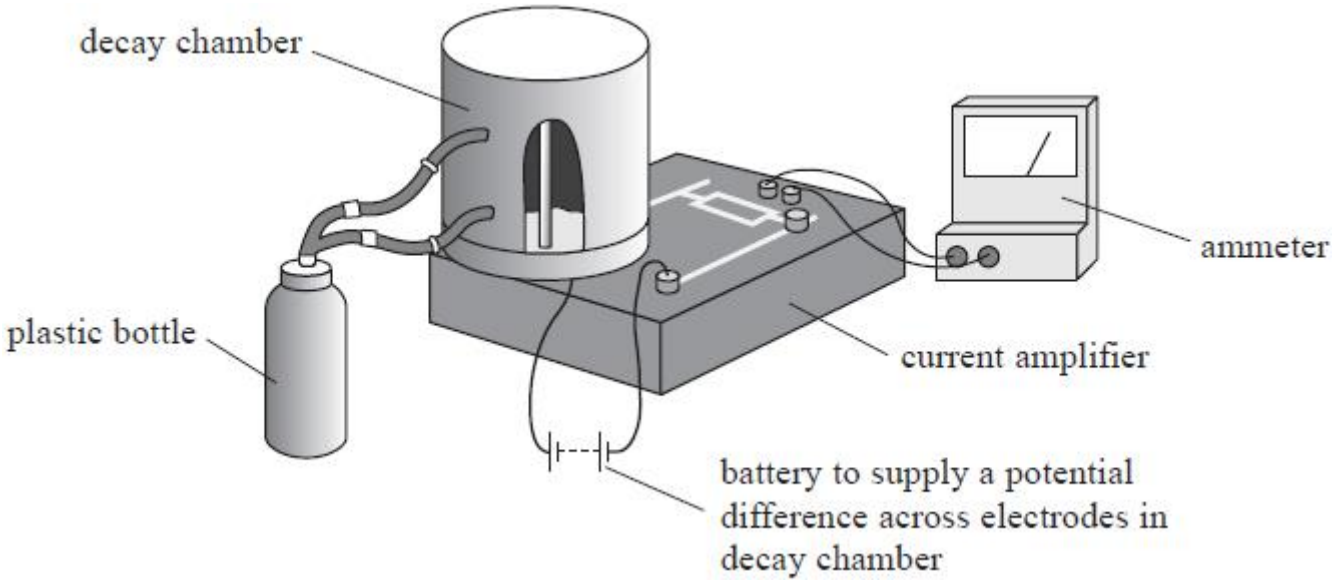
(Total for question = 5 marks)

Q5.

Radon is a radioactive gas. One isotope of radon, $^{220}_{86}Rn$, decays to polonium, Po, by emitting an alpha particle.

The diagram shows apparatus for monitoring the decay of radon in the laboratory.
Radon gas is produced in the plastic bottle from the decay of radium. A small amount of radon is then inserted into the decay chamber by squeezing the plastic bottle.
A current is produced between two electrodes inside the chamber. This current is amplified and recorded by the ammeter.



(ii) A teacher is demonstrating the operation of the decay chamber to her class. She squeezes the bottle to introduce radon into the chamber.

She claims that within 450 s the activity of the radon in the chamber will be less than 1% of its initial value.
Assess whether her claim is correct.
half-life of radon = 55.6 s

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(Total for question = 5 marks)

Q6.

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.

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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.

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(Total for question = 6 marks)

Q7.

In 2011, a tsunami was caused by a massive earthquake centred some distance off the coast of Japan. The tsunami caused a cooling system failure at the Fukushima Nuclear Power Plant. This resulted in a nuclear meltdown and radioactive materials were released into the surroundings.

A reservoir beside one of the reactor buildings contained a large volume of water. In 2013, this water was found to have an extremely high concentration of caesium-137.

Caesium-137 is a radioactive isotope of caesium.

(ii) An activity of 2.35×10^{12} Bq per m^3 of water in the reservoir was measured. It is suggested that a safe level for the activity of all water in the reservoir would be 100 Bq.

Calculate the time in years for the caesium-137 to decay to a safe level.

volume of water in reservoir = 5000 m^3

half-life of caesium-137 = 30 years

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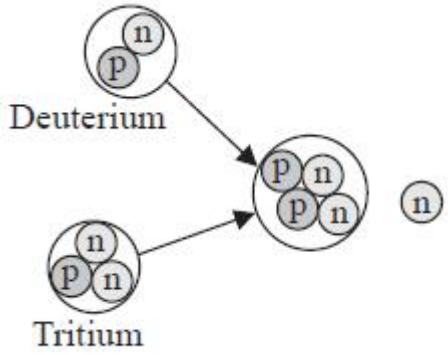
Time = ... years

(Total for question = 4 marks)

Q8.

(a) The latest proposed fusion reactor will fuse deuterium and tritium, which are isotopes of hydrogen. This fusion reaction is illustrated below.



(b) A sample of tritium is produced. Tritium is unstable and decays by β^- emission with a half-life of 12.3 years.

Calculate the time taken, in years, for the activity of the sample to fall to 10% of its initial value.

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Time taken = ... years

(Total for question = 3 marks)

Q9.

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}

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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

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(Total for question = 5 marks)

Q10.

The photograph shows the containers of two radioactive sources kept in a school.

The sources are tested every year and a record of the activity of the sources has to be kept.

The school has incomplete records. The table shows the test entries for cobalt for 2015 and for a year X, which is the year the source was purchased.

Year	Background: counts in 60 s	Source: counts in 60 s
X	22	12227
2015	15	322

The school records show that sources were purchased in 1980, 1987 and 1995, but there is no record of which source was purchased in which year.

(i) Determine the age of the cobalt source in order to establish in which year the school purchased this source.

half-life of Co 60 = 5.3 years

(5)

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Year = ...

(ii) Explain a factor that may affect the reliability of this date.

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Q11.

An old type of camping lamp used a 'gas mantle'. The gas mantle is heated by the gas flame on the lamp and emits a bright white light. Gas mantles used to contain thorium-230.

Thorium-230 decays by alpha emission to form an isotope of radium. A student keeps a radioactive gas mantle in a sealed polythene bag. The student suggests that over a period of a year a significant volume of helium gas will be collected, since an alpha particle is a helium nucleus.

A particular gas mantle contains 5.18×10^{-5} g of thorium-230.

(i) Show that the activity of the thorium-230 in the mantle is about 4.0×10^{4} Bq.

230 g of thorium-230 contains 6.02×10^{23} atoms
half-life of thorium-230 = 75 400 years
number of seconds in 1 year = 3.15×10^{7}

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(Total for question = 4 marks)

Q12.

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.

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Fraction decayed = ...

(Total for Question = 7 marks)

Q13.

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.

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Time = ... years

(Total for question = 6 marks)

Q14.

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.

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

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(Total for question = 8 marks)

Q15.

Actinium-225 and bismuth-210 are radioactive isotopes. A sample of each isotope is prepared so that each sample has the same number of nuclei initially.

Explain why the activity of each sample would be the same after 10 days.

half-life of actinium-225 = 10 days
half-life of bismuth-210 = 5 days

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(Total for question = 4 marks)

Q16.

The Sun is believed to be about 4.5 billion years old. To determine this, scientists measure the ratios of the lead isotopes found in meteorites. Since uranium undergoes radioactive decay in a chain to eventually become an isotope of lead, the ratios of lead isotopes can be used to find the age of a meteorite.

(ii) One isotope produced in the chain is thorium-230, which decays to an isotope of radium with a half-life of 75,000 years.

Calculate the time in years it would take for 90% of an initial sample of thorium to have decayed.

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Time taken = ... years

(Total for question = 6 marks)

Q17.

A hundred years ago, a method to determine the age of certain rocks was developed. An unstable isotope of rubidium is present in some rocks when they form. Over time the rubidium decays to a stable isotope of strontium.

A sample of Moon rock from the Apollo 11 mission was analysed to determine the age of the rock. When the sample was analysed the number of rubidium atoms was N_R and the number of strontium atoms was N_S.

As strontium atoms have all been produced from the decay of rubidium, the original number of rubidium atoms in the sample was (N_R + N_S).

From the analysis of the sample, it was determined that $\frac{N_S}{N_R} = 0.0532$

Deduce whether this ratio is consistent with the Earth and the Moon forming at the same time.

age of Earth = 4.5×10^9 years
half-life of rubidium isotope = 4.88×10^{10} years

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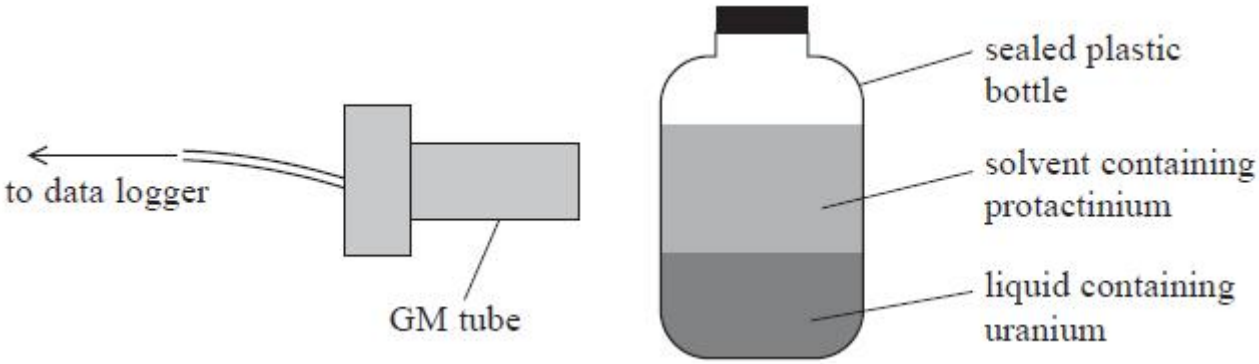
(Total for question = 5 marks)

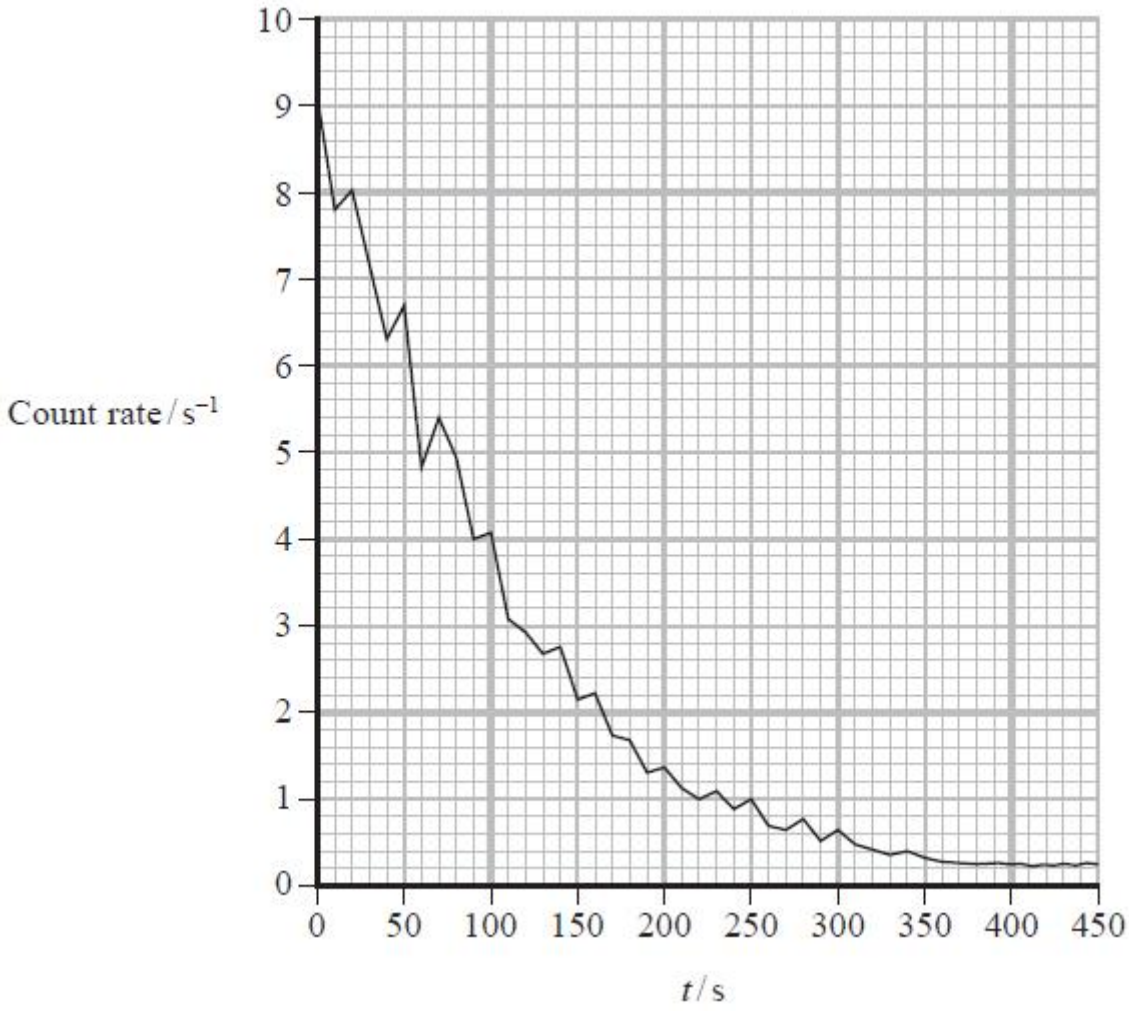
Q18.

A teacher demonstrated the decay of protactinium using a Geiger-Müller (GM) tube connected to a data logger.

A sealed plastic bottle contains a solvent floating above a liquid containing a uranium salt. Protactinium is produced from the decay of uranium and is present in the solvent as shown.



The data logger output is shown below.



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

(4)

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Half-life of protactinium = ...

(ii) Explain why the count rate doesn't reach zero.

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(Total for question = 6 marks)

Q19.

A hundred years ago, a method to determine the age of certain rocks was developed. An unstable isotope of rubidium is present in some rocks when they form. Over time the rubidium decays to a stable isotope of strontium.

Recent investigations suggest that the half-life of the rubidium isotope may be larger than the traditionally accepted value.

Explain how this would affect the ages obtained by this dating method.

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(Total for question = 2 marks)

Q20.

Nuclear decay is described as being spontaneous and random.

Americium-241 is used in schools as a source of alpha radiation.
A pure americium-241 source was bought 34 years ago by a school.

(i) Determine the percentage of the initial activity that would be expected today for the americium-241 source.

half-life of americium-241 = 432 years

(3)

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Expected percentage of initial activity = ...

(ii) The decay products of americium are unstable and undergo a series of further decays.

The table shows the first three decays in this sequence.

Isotope	Decay product	Emission	Half-life
americium-241	neptunium-237	alpha	432 years
neptunium-237	protactinium-233	alpha	2 100 000 years
protactinium-233	uranium-233	beta	27 days

A student states, "Protactinium-233 emits beta particles when it decays, so by now the americium-241 source bought 34 years ago will be emitting a significant amount of beta radiation."
Discuss the student's statement.

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(Total for question = 6 marks)

Q21.

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

(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

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New corrected count rate = ...

(Total for question = 4 marks)

Q22.

In 2011, a tsunami was caused by a massive earthquake centred some distance off the coast of Japan. The tsunami caused a cooling system failure at the Fukushima Nuclear Power Plant. This resulted in a nuclear meltdown and radioactive materials were released into the surroundings.

A reservoir beside one of the reactor buildings contained a large volume of water. In 2013, this water was found to have an extremely high concentration of caesium-137.

Caesium-137 is a radioactive isotope of caesium.

The most common radionuclide amongst the fission products in the fuel was iodine-131, which decays with a half-life of 8.0 days to form a stable isotope of the gas xenon.

Deduce whether enough xenon would have collected in 32 days to exert a pressure of 1.0×10^5 Pa in a volume of 450 m^3. Assume that no gas escapes.

temperature = 20 °C

initial number of iodine nuclei = 1.25×10^{28}

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(Total for question = 6 marks)

Q23.

The photograph shows a vase made of uranium glass. Uranium glass is radioactive.

Uranium glass usually contains a maximum of 2% uranium. Uranium glass made in the early part of the 20th century can contain up to 25% uranium.

A student carried out an investigation to determine the percentage of uranium in the glass.

The student measured the count rate by placing a Geiger Muller (GM) tube against the vase at a single position. This value was used to calculate the decay rate for the whole vase.

(i) Show that the decay constant for uranium is about 5×10^{-18} s^{-1}

half-life of uranium = 1.41×10^{17} s

(2)

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(ii) Calculate the percentage of uranium, by mass, in the glass.

area of GM tube window = 6.36×10^{-5} m^2
surface area of vase = 0.0177 m^2
background count rate = 525 counts in 10 minutes
count rate when GM tube next to vase = 3623 counts in 5 minutes
mass of vase = 149 g
mass of uranium atom = 238 u

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Percentage of uranium = ...

(Total for question = 10 marks)