***4** Radium is a radioactive element. The most common isotope of radium has a half-life of almost two thousand years. A sample of radium can remain at a higher temperature than its surroundings for a long period of time.

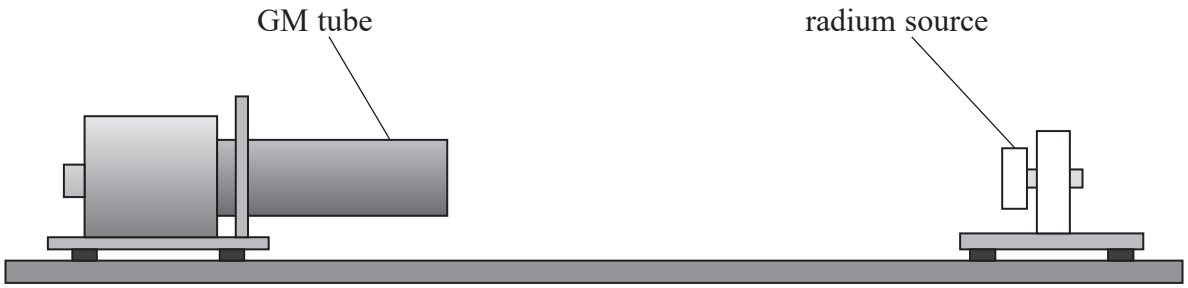
Explain how a sample of radium is able to release significant amounts of energy over a long period of time.

(6)

(Total for Question 4 = 6 marks)

2 A student used a Geiger-Müller (GM) tube to determine the activity of a radium source. Radium emits α, β, and γ radiation.

He positioned the source 20 cm from the GM tube, as shown, and recorded the count for 1 minute. He repeated the measurement and calculated a mean count.



The student recorded the following results.

Count 1	Count 2	Mean count
183	178	181

(a) Criticise the student's method for determining the count at this position.

(3)

(b) From his results the student determined that the activity of the source was 3.0 Bq.

Comment on his value for the activity of the source.

(5)

(Total for Question 2 = 8 marks)

4 Radioactive decay is often described in textbooks as a spontaneous, random process.

(a) State what is meant by spontaneous decay.

(1)

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*(b) Explain why there is an exponential decrease in the rate of decay for a sample containing a large number of unstable nuclei.

(6)

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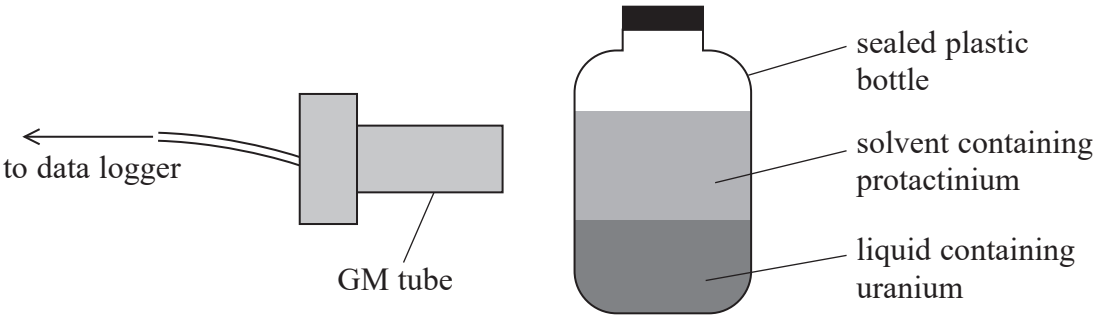
(Total for Question 4 = 7 marks)

8 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.



(a) Deduce whether alpha radiation or beta radiation from the inside of the bottle is detected by the GM tube.

(2)

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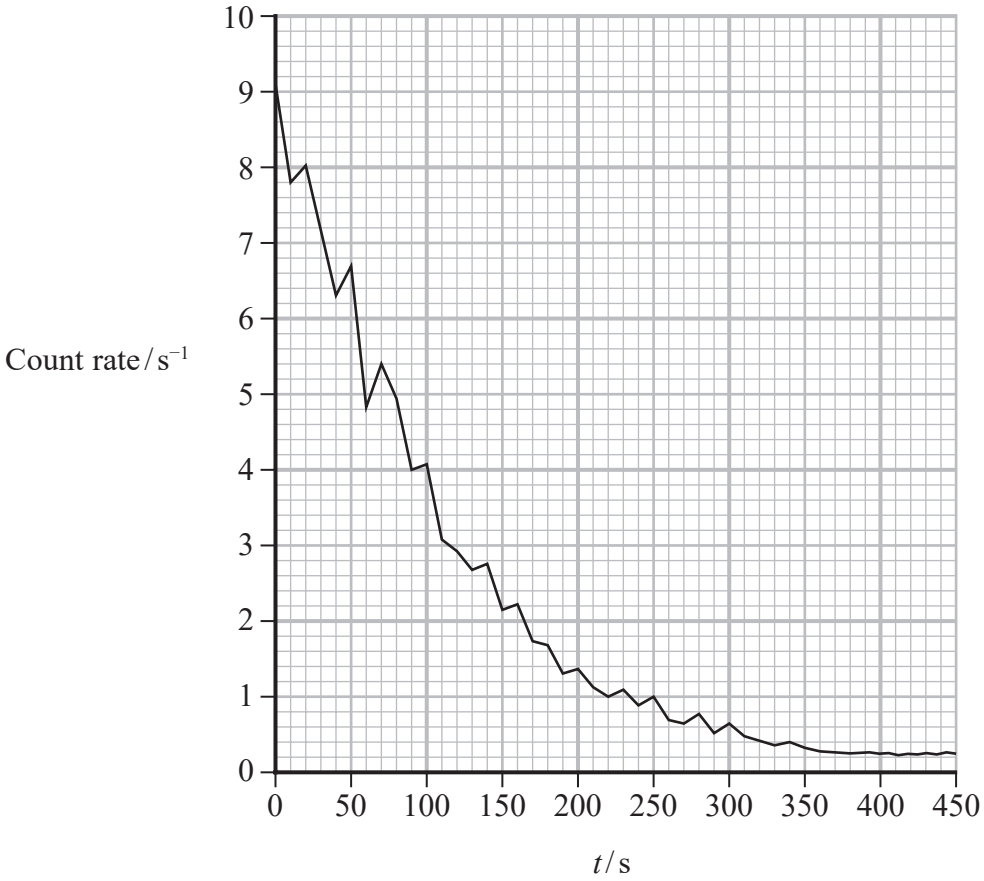
(b) The data logger output is shown below.



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

(4)

Half-life of protactinium = ...

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

(2)

(Total for Question 8 = 8 marks)

12 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) 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.

(i) Complete the nuclear equation for the decay of caesium-137.

$$^{137}_{55}\text{Cs} \rightarrow \text{.....}\,\text{Ba} + \text{.....}\,\beta^- + {}^{0}_{0}\overline{\nu}_{e}$$

(2)

(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

(4)

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Time = ... years

(b) 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.

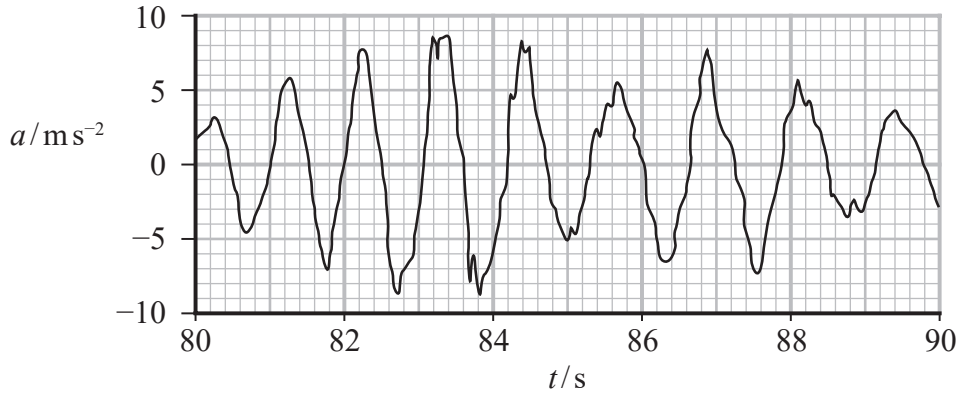
Deduce whether enough xenon would have collected in 32 days to exert a pressure of 1.0×10^5 Pa in a volume of 450 m^3. Assume that no gas escapes.

temperature = 20 °C
initial number of iodine nuclei = 1.25×10^{28}

(6)

(c) Buildings in nearby Tohoku University suffered structural damage during the 2011 earthquake.

The graph shows how the acceleration of one of the buildings, measured on the 9th floor, varied with time during the earthquake.



(Source: https://www.sciencedirect.com/science/article/pii/S0038080612001035)

At the time it was reported that during the earthquake the 9th floor of the building displaced by more than 30 cm from its normal position.

Assess the accuracy of this report.

(5)

(Total for Question 12 = 17 marks)