1 (a) Suggest, with a reason, which type of radiation is likely to be the most appropriate for the sterilisation of metallic surgical instruments.

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(1)

(b) Explain why the public need not worry that irradiated surgical instruments become radioactive once sterilised.

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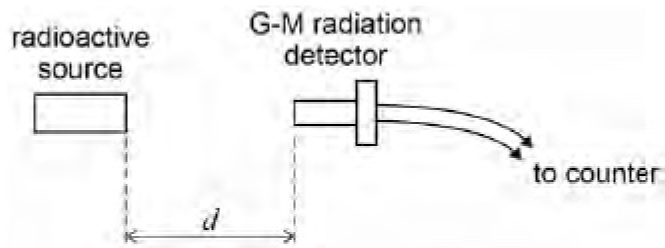
(1)

(c) A student detects the counts from a radioactive source using a G-M radiation detector as shown in the diagram.



The student measures the count rate for three different distances d. The table shows the count rate, in counts per minute, corrected for background for each of these distances.

d/m	Corrected count rate / counts per minute			
0.20	9013			
0.50	1395			
1.00	242			

Explain, with the aid of suitable calculations, why the data in the table are **not** consistent with an inverse-square law. You may use the blank columns for your working.

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(2)

(d) State **two** possible reasons why the results do **not** follow the expected inverse-square law.

Reason 1 ____

____

Reason 2 ____

____

(2)

(Total 6 marks)

2 During a single fission event of uranium-235 in a nuclear reactor the total mass lost is 0.23 u. The reactor is 25% efficient.

How many events per second are required to generate 900 MW of power?

A 1.1×10^{14} ☐

B 6.6×10^{18} ☐

C 1.1×10^{20} ☐

D 4.4×10^{20} ☐

(Total 1 mark)

3 An ancient sealed flask contains a liquid, assumed to be water. An archaeologist asks a scientist to determine the volume of liquid in the flask without opening the flask. The scientist decides to use a radioactive isotope of sodium ($^{24}_{11}Na$) that decays with a half-life of 14.8 h.

(a) She first mixes a compound that contains 3.0×10^{-10} g of sodium-24 with 1500 cm^3 of water. She then injects 15 cm^3 of the solution into the flask through the seal.
Show that initially about 7.5×10^{10} atoms of sodium-24 are injected into the flask.

(1)

(b) Show that the initial activity of the solution that is injected into the flask is about 1×10^6 Bq.

activity = ______________Bq

(3)

(c) She waits for 3.5 h to allow the injected solution to mix thoroughly with the liquid in the flask. She then extracts 15 cm^3 of the liquid from the flask and measures its activity which is found to be 3600 Bq.

Calculate the total activity of the sodium-24 in the flask after 3.5 h and hence determine the volume of liquid in the flask.

(3)

(d) The archaeologist obtained an estimate of the volume knowing that similar empty flasks have an average mass of 1.5 kg and that mass of the flask and liquid was 5.2 kg. Compare the estimate that the archaeologist could obtain from these masses with the volume calculated in part 4.3 and account for any difference.

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(2)

(Total 9 marks)

4 The Rutherford scattering experiment led to

A the discovery of the electron. ⬭

B the quark model of hadrons. ⬭

C the discovery of the nucleus. ⬭

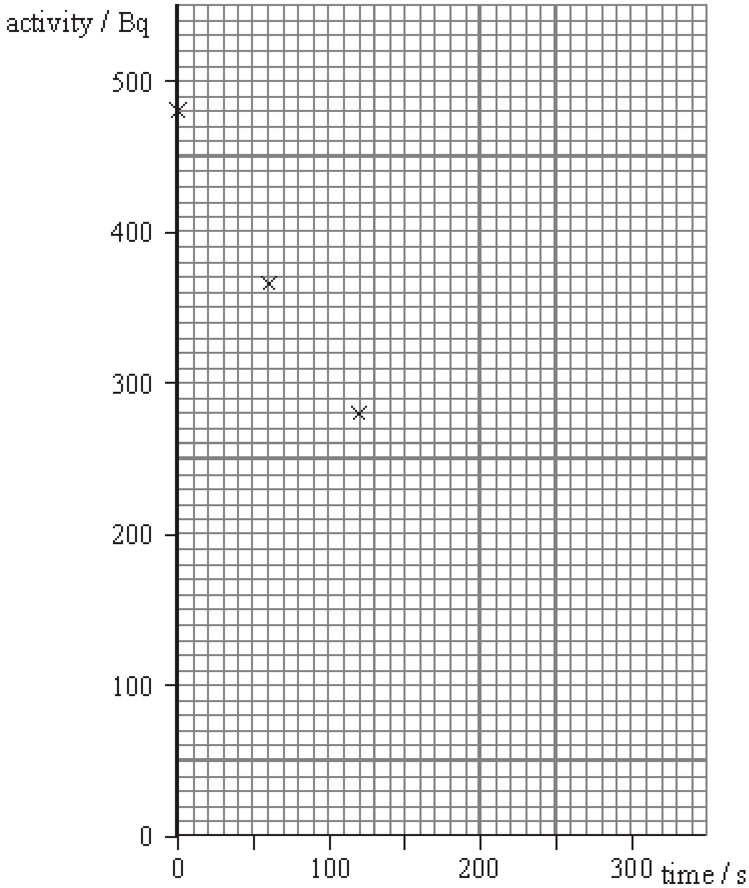
D evidence for wave-particle duality. ⬭

(Total 1 mark)

5 The table below gives the values for the activity of a radioactive isotope over a period of a few minutes.

time/s	0	60	120	180	240	300
activity/Bq	480	366	280	214	163	124

(a) Complete the graph below by plotting the remaining points and drawing an appropriate curve.



(3)

(b) Use the graph to determine the half-life of the isotope.

half-life ____________________

(3)

(c) Initially there were 1.1×10^5 atoms of the isotope present. Calculate the decay probability of the isotope.

decay probability ____________________

(2)

(Total 8 marks)

6 A Geiger counter is placed near a radioactive source and different materials are placed between the source and the Geiger counter.

The results of the tests are shown in the table.

Material	**Count rate of Geiger counter / s^{-1}**
None	1000
Paper	1000
Aluminium foil	250
Thick steel	50

What is the radiation emitted by the source?

A α only ☐

B α and γ ☐

C α and β ☐

D β and γ ☐

(Total 1 mark)

7 A nucleus of plutonium ($^{240}_{94}\text{Pu}$) decays to form uranium (U) and an alpha-particle (α).

(a) Complete the equation that describes this decay:

$$^{240}_{94}\text{Pu} \rightarrow$$

(2)

(b) (i) Show that about 1 pJ of energy is released when one nucleus decays.

mass of plutonium nucleus = 3.98626×10^{-25} kg
mass of uranium nucleus = 3.91970×10^{-25} kg
mass of alpha particle = 6.64251×10^{-27} kg
speed of electromagnetic radiation = 2.99792×10^{8} m s^{-1}

(3)

(ii) The plutonium isotope has a half-life of 2.1×10^{11} s. Show that the decay constant of the plutonium is about 3×10^{-12} s^{-1}.

(2)

(iii) A radioactive source in a school laboratory contains 3.2×10^{21} atoms of plutonium. Calculate the energy that will be released in one second by the decay of the plutonium described in part (b)(i).

(3)

(iv) Comment on whether the energy release due to the plutonium decay is likely to change by more than 5% during 100 years. Support your answer with a calculation.

(4)

(Total 14 marks)