

- 1 The neutron–proton model of the nucleus was first put forward by Rutherford to explain the general composition of the nucleus. The existence of the neutron was not proved experimentally until some years later.
- (a) Give **two** reasons why Rutherford’s neutron–proton model was considered more than an untested hypothesis when it was first put forward. (3 marks)
- (b) The α particles from any α -emitting isotope have the same initial kinetic energy and a well-defined range in air at atmospheric pressure. The table below shows the range R in air and the initial kinetic energy E of α particles from several α -emitting isotopes.

R/mm	39	48	53	57	66	78
E/MeV	5.3	6.0	6.5	6.8	7.4	8.3

Plot a suitable graph to find out if the relationship between R and E is of the form $R = kE^n$, where k and n are constants, and determine a value for n . Explain your choice of graph. (10 marks)

- 2 **Figure 1** shows the apparatus in which α particles are directed at a metal foil in order to investigate the structure of the atom.

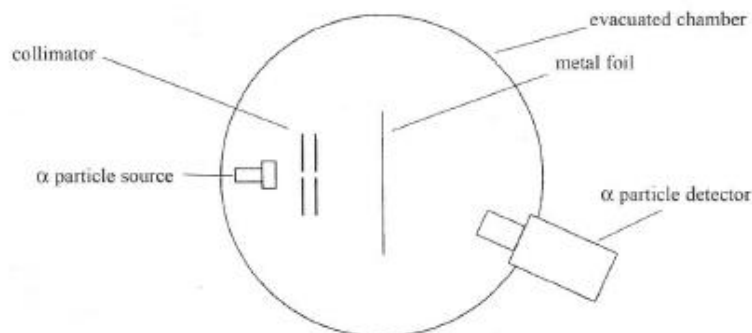


Figure 1

- (a) (i) Give **two** reasons why the metal foil should be thin. (3 marks)
- (ii) Explain why the incident beam of α particles should be narrow. (2 marks)
- (b) Describe and explain **one** feature of the distribution of the scattered α particles that suggests the nucleus contains most of the mass of an atom. (2 marks)
- (c) **Figure 2** shows three α particles with the same constant velocity incident on an atom in the metal foil. They all approach the nucleus close enough to be deflected by at least 10° .



Figure 2

Draw the paths followed by the three α particles whose initial directions are shown by the arrows.

(3 marks)

AQA, 2007

- 3 A radioactive nucleus decays with the emission of an alpha particle and a gamma-ray photon.
- (a) Describe the changes that occur in the proton number and the nucleon number of the nucleus. (2 marks)
- (b) Comment on the relative penetrating powers of the two types of ionising radiation. (1 mark)
- (c) Gamma rays from a point source are travelling towards a detector. The distance from the source to the detector is changed from 1.0 m to 3.0 m.

Calculate:

$$\frac{\text{intensity of radiation at 3.0 m}}{\text{intensity of radiation at 1.0 m}}$$

(2 marks)

AQA, 2006

- 4 (a) A radioactive source gives an initial count rate of 110 counts per second. After 10 minutes the count rate is 84 counts per second.
background radiation = 3 counts per second
- (i) Give **three** origins of the radiation that contributes to this background radiation.
- (ii) Calculate the decay constant of the radioactive source in s^{-1} .
- (iii) Calculate the number of radioactive nuclei in the initial sample assuming that the detector counts all the radiation emitted from the source. (7 marks)
- (b) Discuss the dangers of exposing the human body to a source of α radiation. In particular compare the dangers when the α source is held outside, but in contact with the body, with those when the source is placed inside the body. (3 marks)

AQA, 2004

- 5 The radioactive isotope of sodium ${}_{11}^{22}\text{Na}$ has a half-life of 2.6 years. A particular sample of this isotope has an initial activity of $5.5 \times 10^5 \text{ Bq}$.
- (a) Explain what is meant by the *random nature* of radioactive decay. (2 marks)
- (b) Sketch a graph of the activity of the sample of sodium over a period of 6 years. (2 marks)
- (c) Calculate:
- (i) the decay constant, in s^{-1} , of ${}_{11}^{22}\text{Na}$,
1 year = $3.15 \times 10^7 \text{ s}$
- (ii) the number of atoms of ${}_{11}^{22}\text{Na}$ in the sample initially,
- (iii) the time taken, in s, for the activity of the sample to fall from $1.0 \times 10^5 \text{ Bq}$ to $0.75 \times 10^5 \text{ Bq}$. (6 marks)

AQA, 2003

- 6 Iodine-123 is a radioisotope used medically as a tracer to monitor thyroid and kidney functions. The decay of an iodine-123 nucleus produces a gamma ray which, when emitted from inside the body of a patient, can be detected externally.
- (a) Why are gamma rays the most suitable type of nuclear radiation for this application? (2 marks)
- (b) In a laboratory experiment on a sample of iodine-123 the following data were collected.

time/h	0	4	8	12	16	20	24	28	32
count rate/counts s^{-1}	512	401	338	279	217	191	143	119	91

Why was it unnecessary to correct these values for background radiation? (2 marks)

- (c) Draw a graph of count rate against time. (2 marks)
- (d) Use your graph to find an accurate value for the half-life of iodine-123.
Show clearly the method you use. (3 marks)
- (e) Give **two** reasons why radioisotopes with short half-lives are particularly suitable for use as a medical tracer. (2 marks)

AQA, 2004

- 7 (a) Sodium-21 ($^{21}_{11}\text{Na}$) decays to neon-21 ($^{21}_{10}\text{Ne}$). A nucleus of neon-21 is stable.
- State the names of the particles emitted when a sodium-21 nucleus decays.
 - How many neutrons are there in a nucleus of neon-21?
- (3 marks)
- (b) Figure 2 shows how the activity A of a freshly prepared sample of sodium-21 varies as it decays. Figure 3 shows how N , the number of sodium-21 nuclei, varies with time t during the same time interval.

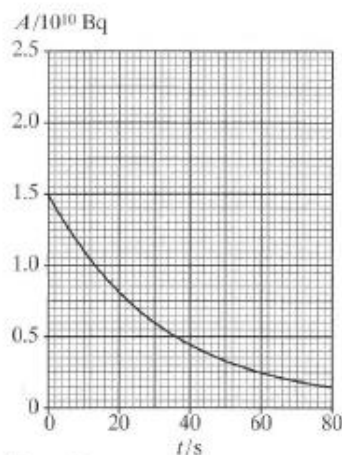


Figure 3

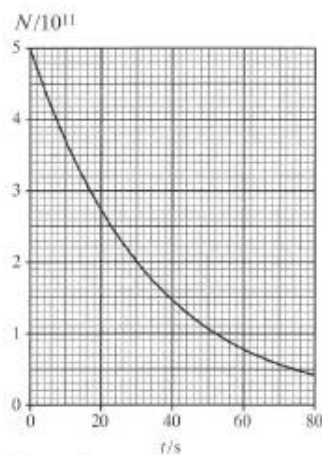


Figure 4

- Use the graphs to find the number of active sodium nuclei and the corresponding activity one half-life after $t = 0$. Hence find the probability of decay of a sodium-21 nucleus.
 - The total energy produced when a sodium-21 nucleus decays is $5.7 \times 10^{-13}\text{J}$. Calculate the number of radioactive atoms in a sample that is producing 2.6 mJ of energy each second.
- (6 marks)
AQA, 2003
- 8 (a) Calculate the radius of the $^{238}_{92}\text{U}$ nucleus.
 $r_1 = 1.3 \times 10^{-15}\text{m}$ (2 marks)
- (b) At a distance of 30 mm from a point source of γ rays the corrected count rate is C . Calculate the distance from the source at which the corrected count rate is $0.10C$, assuming that there is no absorption. (2 marks)
- (c) The activity of a source of β particles falls to 85% of its initial value in 52 s. Calculate the decay constant of the source. (3 marks)
- (d) Explain why the isotope of technetium, $^{99}_{43}\text{Tc}_m$, is often chosen as a suitable source of radiation for use in medical diagnosis. (3 marks)
AQA, 2006

- 9 The high-energy electron diffraction apparatus represented in **Figure 3** can be used to determine nuclear radii. The intensity of the electron beam received by the detector is measured at various diffraction angles, θ .

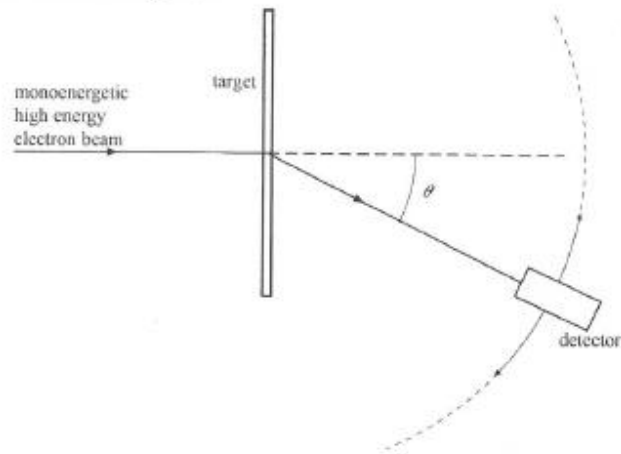


Figure 5

- (a) Sketch a graph to show how, in such an electron diffraction experiment, the electron intensity varies with the angle of diffraction, θ . (2 marks)
- (b) (i) Use the data in the table to plot a straight line graph that confirms the relationship

$$R = r_0 A^{1/3}$$

element	radius of nucleus, $R/10^{-15}\text{ m}$	nucleon number, A
lead	6.66	208
tin	5.49	120
iron	4.35	56
silicon	3.43	28
carbon	2.66	12

- (ii) Estimate the value of r_0 from the graph. (5 marks)
- (c) Discuss the merits of using high-energy electrons to determine nuclear radii rather than using α particles. (3 marks)

AQA, 2005