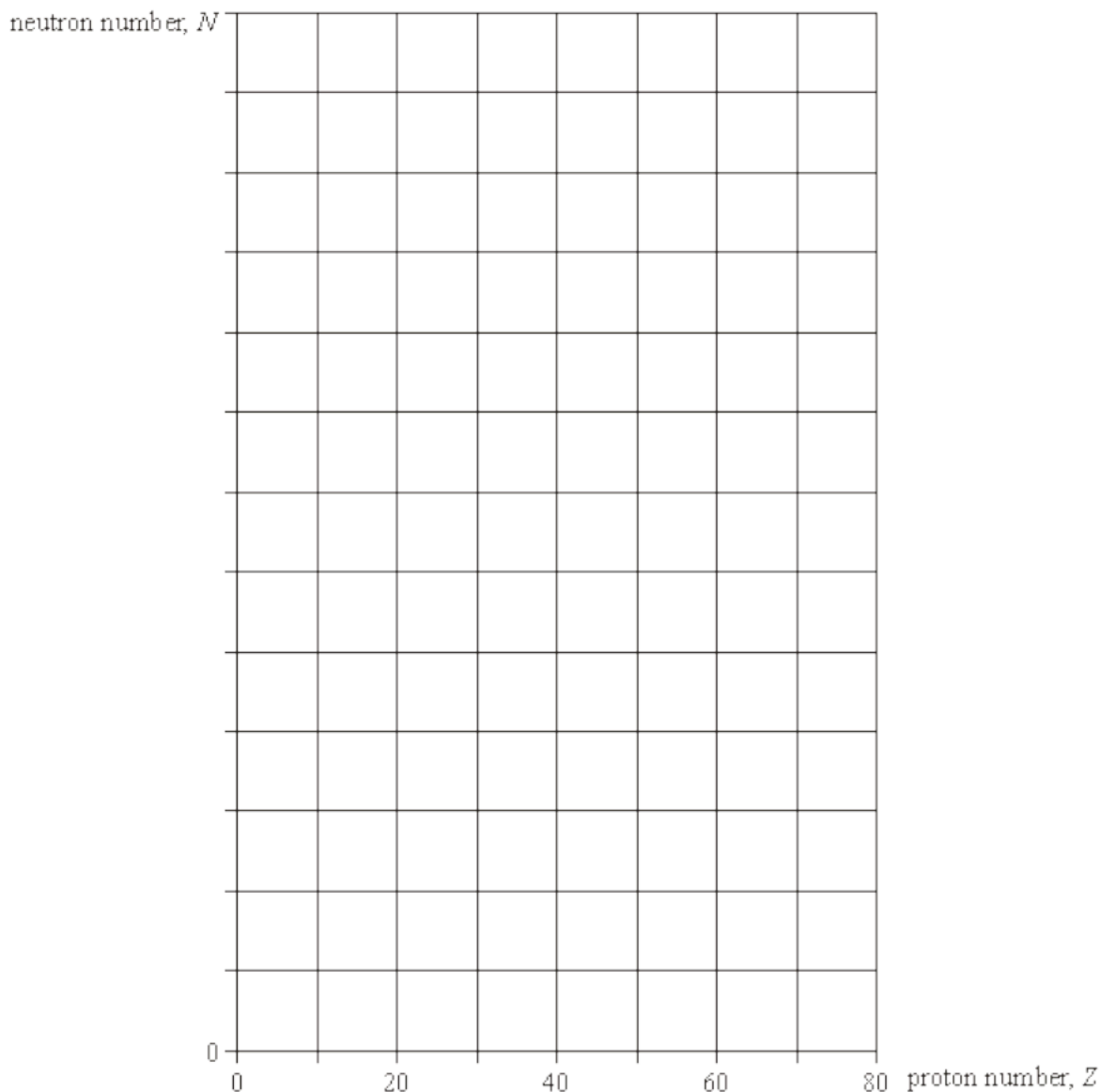


1

- (a) Sketch, using the axes provided, a graph of neutron number, N , against proton number, Z , for stable nuclei over the range $Z = 0$ to $Z = 80$. Show suitable numerical values on the N axis.

**(2)**

- (b) On the graph indicate, for each of the following, a possible position of a nuclide that may decay by
- (i) α emission, labelling the position with **W**,
 - (ii) β^- emission, labelling the position with **X**,
 - (iii) β^+ emission, labelling the position with **Y**.

(3)

- (c) The isotope $^{222}_{86}\text{Rn}$ decays sequentially by emitting α particles and β^- particles, eventually forming the isotope $^{206}_{82}\text{Pb}$. Four α particles are emitted in the sequence.

Calculate the number of β^- particles in the sequence.

(2)

- (d) A particular nuclide is described as proton-rich. Discuss **two** ways in which the nuclide may decay. You may be awarded marks for the quality of written communication in your answer.

(3)

(Total 10 marks)

2

- (a) (i) Sketch a graph to show how the neutron number, N , varies with the proton number, Z , for naturally occurring stable nuclei over the range $Z = 0$ to $Z = 90$. Show values of N and Z on the axes of your graph and draw the $N = Z$ line.



- (ii) On your graph mark points, one for each, to indicate the position of an unstable nuclide which would be likely to be

an α emitter, labelling it A,

a β^- emitter, labelling it B.

(5)

- (b) State the changes in N and Z which are produced in the emission of

- (i) an α particle,

- (ii) a β^- particle.

(2)

- (c) The results of electron scattering experiments using different target elements show that

$$R = r_0 A^{\frac{1}{3}}$$

where A is the nucleon number and r_0 is a constant.

Use this equation to show that the density of a nucleus is independent of its mass.

(3)

(Total 10 marks)

3

- (a) (i) Explain why, despite the electrostatic repulsion between protons, the nuclei of most atoms of low nucleon number are stable.

- (ii) Suggest why stable nuclei of higher nucleon number have greater numbers of neutrons than protons.

- (iii) All nuclei have approximately the same density. State and explain what this suggests about the nature of the strong nuclear force.

- (b) (i) Compare the electrostatic repulsion and the gravitational attraction between a pair of protons the centres of which are separated by 1.2×10^{-15} m.

proton charge	=	1.6×10^{-19} C
proton mass	=	1.7×10^{-27} kg
gravitational constant	=	6.7×10^{-11} N m ² kg ⁻²
permittivity of free space	=	8.9×10^{-12} F m ⁻¹

- (ii) Comment on the relative roles of gravitational attraction and electrostatic repulsion in nuclear structure.

(5)

(Total 11 marks)

Mark schemes

1

- (a) graph passes through $N = 10/11$ when $Z = 10$ and N increases as Z increases (1)
 $N = 115 \rightarrow 125$ when $Z = 80$ and graph must bend upwards (1)

2

- (b) (i) **W** at $Z > 60$ just (within one diagonal of a square) below line (1)
 (ii) **X** just (within one diagonal of a square) above line (1)
 (iii) **Y** just (within one diagonal of a square) below line (1)

3

- (c) working showing the change due to emission of four α particles (1)
 four β^- particles (1)

1

- (d) Any **two** from the following list of processes:

β^+

describe the changes to N (up by 1) and Z (down by 1)
 [or allow p change to n]

α

move closer to line of stability
 [or state the proton to neutron ratio is reduced]

p

only if nuclide is **very** proton rich
 [or electrostatic repulsion has to overcome the strong nuclear force]
 [or highly unstable]
 [or rare process]

e^- capture

describe the changes to N (up by 1) and Z (down by 1)
 allow p changes to n

marking: listing **two** processes (1)

discussing **each** of the two processes (1) (1)

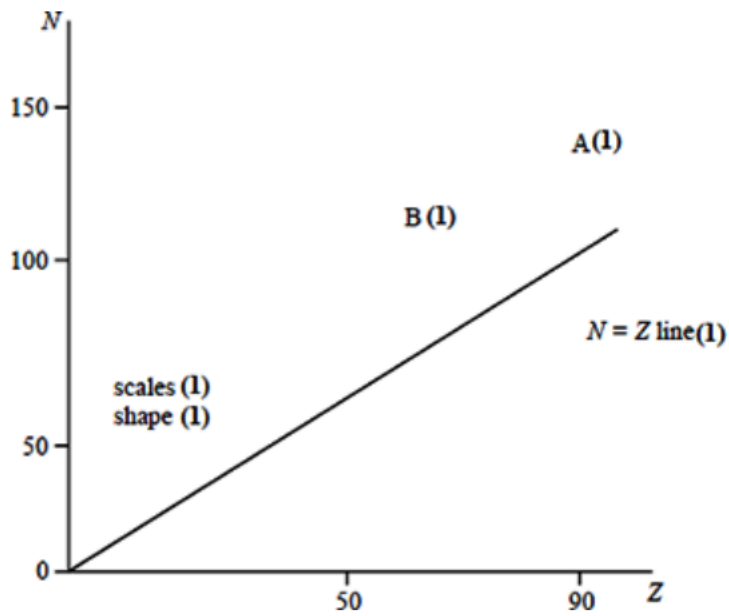
3

QWC 1

[10]

2

(a)



(5)

(b) (i) α emitter: $N \downarrow 2$, $Z \downarrow 2$ (1)(ii) β^- emitter: $N \downarrow 1$, $Z \uparrow 1$ (1)

(2)

(c) density = $\frac{\text{mass}}{\text{volume}}$ (1)mass $\propto A$ volume $\propto R^3$ and $R \propto A^{\frac{1}{3}}$ hence volume $\propto A$ (1)hence density = $\frac{\text{mass}}{\text{volume}}$ is independent of A (1)

(3)

[10]

3

- (a) (i) strong nuclear force acts on all nucleons/both forces act on protons/mention of gluons as force carrier

B1

strong nuclear force > electrostatic repulsion

B1

- (ii) neutrons spread the protons out/neutrons reduce electrostatic repulsion

B1

- (iii) strong nuclear force has short range

M1

if snf fell off more gradually bigger nuclei would have lower densities/...more rapidly still higher densities

A1

strong nuclear force acts on all nucleons

M1

attractive nature of snf means all nucleons in contact/close packed

A1

strong nuclear force becomes repulsive at very small separations

M1

prevents nuclei from becoming denser

A1

needs minimum of two M1s to score all three here

max 6

(b) (i) $F_E \frac{Q_1 Q_2}{4\pi\epsilon_0 r^2}$ or $F_E \propto k \frac{Q_1 Q_2}{r^2}$ with k defined

C1

$$1.59 \times 10^2 \text{N}$$

A1

$$F_G = G \frac{m_1 m_2}{r^2}$$

C1

$$1.3 \times 10^{-34} \text{N}$$

A1

- (ii) can ignore gravitation when considering nuclear forces **or**
gravitational force is much weaker than electrostatic force **not** e.c.f.

B1