1 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)

2 Uranium-236 undergoes nuclear fission to produce barium-144, krypton-89 and three free neutrons.

What is the energy released in this process?

Nuclide	Binding energy per nucleon / MeV
$^{236}_{92}U$	7.5
$^{144}_{56}Ba$	8.3
$^{89}_{36}Kr$	8.6

A 84 MeV ⬭

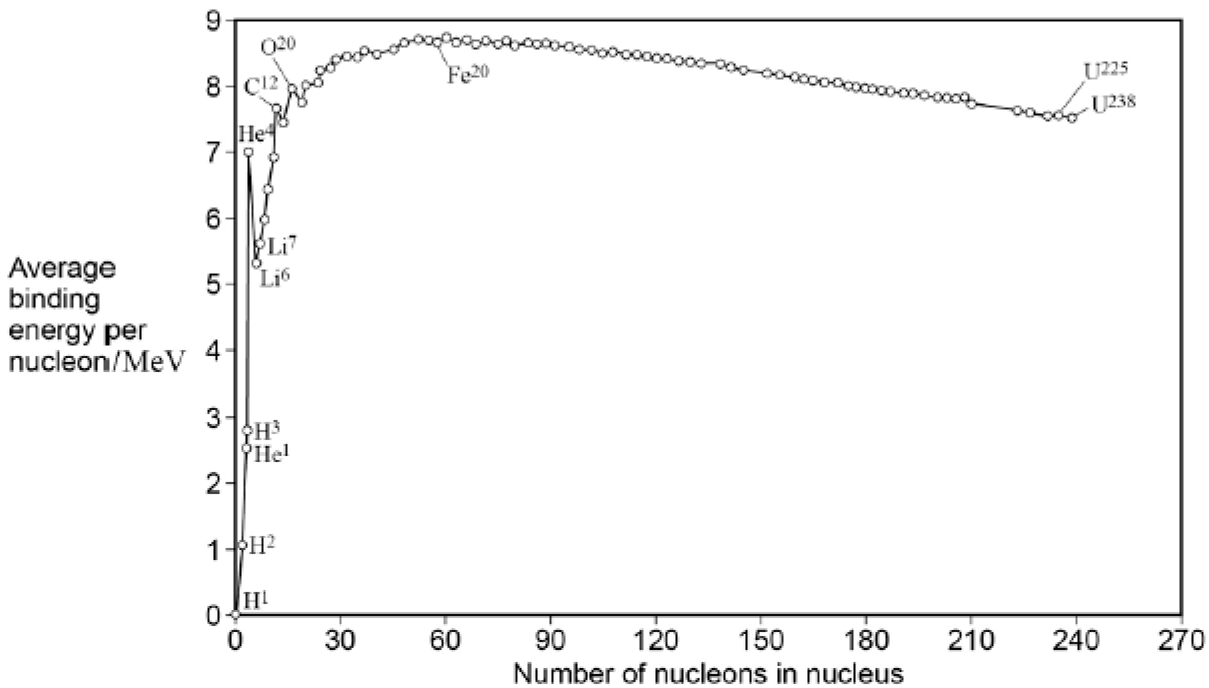
B 106 MeV ⬭

C 191 MeV ⬭

D 3730 MeV ⬭

(Total 1 mark)

3 The graph shows how the binding energy per nucleon varies with the nucleon number for stable nuclei.



What is the approximate total binding energy for a nucleus of $^{184}_{74}\mathrm{W}$?

A	1.28 pJ	⬭
B	94.7 pJ	⬭
C	103 pJ	⬭
D	230 pJ	⬭

8 MeV/nucleon

so $8 \times 10^6 \times 184 \times 1.6 \times 10^{-19}$

(Total 1 mark)

4 (a) Scattering experiments are used to investigate the nuclei of gold atoms.
In one experiment, alpha particles, all of the same energy (monoenergetic), are incident on a foil made from a single isotope of gold.

(i) State the main interaction when an alpha particle is scattered by a gold nucleus.

electrostatic

(1)

(ii) The gold foil is replaced with another foil of the same size made from a mixture of isotopes of gold. Nothing else in the experiment is changed.

Explain whether or not the scattering distribution of the monoenergetic alpha particles remains the same.

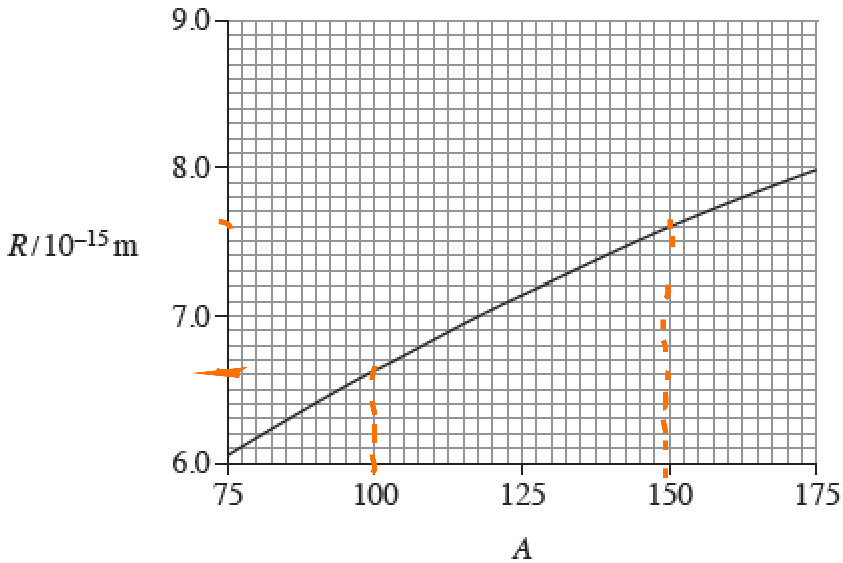
depends!

→ no change ∵ same charge on nucleus

→ but slightly differing mass which means the recoil of heavy nucleus will slightly less.

(1)

(b) Data from alpha−particle scattering experiments using elements other than gold allow scientists to relate the radius R, of a nucleus, to its nucleon number, A.
The graph shows the relationship obtained from the data in a graphical form, which obeys the relationship $R = r_0 A^{\frac{1}{3}}$



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

(i) Use information from the graph to show that r_0 is about 1.4×10^{-15} m.

r_0 is gradient

$\frac{\Delta R}{\Delta A^{1/3}} = \frac{7.6 - 6.6 \times 10^{-15}}{150^{1/3} - 100^{1/3}}$

$\approx 1.49 \times 10^{-15}$

(1)

(ii) Show that the radius of a $^{51}_{23}V$ nucleus is about 5×10^{-15} m.

$R = R_0 A^{1/3} = 5.2 \times 10^{-15}$ m

r_0 : 1.4×10^{-15} A : 51

(2)

(c) Calculate the density of a $^{51}_{23}\mathrm{V}$ nucleus.

$r = 5\times10^{-15}$ $\rho = \frac{m}{V}$

State an appropriate unit for your answer.

$$\frac{(23\times m_p + 28\,m_n)}{\frac{4}{3}\pi\,(5\times10^{-15})^2} = 8.5\times10^{-26}$$

density 1.6×10^{17} unit kg/m^3

(3)

(Total 8 marks)

Mark schemes

1 **C**

[1]

2 **C**

[1]

3 D

[1]

4 (a) (i) electromagnetic / electrostatic / Coulomb (repulsion between the alpha particles and the nuclei) ✓

The interaction must be named not just described.

1

(ii) the scattering distribution remains the same (because the alpha particles interact with a nucleus) whose charge / proton number / atomic number remains the same or the (repulsive) force remains the same

The mark requires a described distribution <u>and the reason</u> for it.

Or
the scattering distribution changes / becomes less distinct because there is a mixture of nuclear <u>masses</u> (which gives a mixture of nuclear recoils) ✓
(owtte)

A reference must be made to mass and not density or size.

1

(b) (i) use of graph to find r_0
e.g. $r_0 = 6.0 \times 10^{-15} / 75^{1/3}$ ✓
(or $8.0 \times 10^{-15} / 175^{1/3}$)
($r_0 = 1.43 \times 10^{-15}$ m)

Substitution and calculation t must be shown.

Condone a gradient calculation on <u>R against $A^{1/3}$</u> graph (not graph in question) as $R \propto A^{1/3}$

1

(ii) **Escalate if clip shows $^{27}_{13}$Al in the question giving R ≈ 4 × 10^{-15} m.**

(using $R = r_0 A^{1/3}$)
$R = 1.43 \times 10^{-15} \times 51^{1/3}$ ✓
$R = 5.3 \times 10^{-15}$ (m) ✓
($R = 5.2 \times 10^{-15}$ m from
$r_0 = 1.4 \times 10^{-15}$ m)

First mark for working.

Second mark for evaluation which must be 2 or more sig figs allow CE from (i) R = 3.71 × (i).

***Possible escalation**.*

2

(c) **Escalate if clip shows $^{27}_{13}$ in the question and / or the use of 27 in the working.**

density = mass / volume

m = 51 × 1.67 × 10^{-27}

(= 8.5 × 10^{-26} kg)

Give the first mark for substitution of data into the top line or bottom line of the calculation of density.

v = 4/3π (5.3 × 10^{-15})^3

(6.2(4) × 10^{-43} m^3)

In the second alternative the mark for the substitution is only given if the working equation is given as well.

Or

density = A × u / 4/3π (r_0 $A^{1/3}$)^3

= u /4/3π (r_0)^3

51 × 1.67 × 10^{-27} would gain a mark on its own but 1.66 × 10^{-27} would need u / 4/3 π(r_0)^3 as well to gain the mark.

top line = 1.66 × 10^{-27}

bottom line = 4/3π (1.43 × 10^{-15})^3

✓ for one substitution

density = 1.4 × 10^{17} ✓

(1.37 × 10^{17})

kg m^{-3} ✓

Expect a large spread of possible answers. For example
If R = 5 × 10^{-15} V = 5.24 × 10^{-43} and density = 1.63 × 10^{17}.

***Possible escalation**.*

3

[8]