Q1.(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.

....

....

(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.

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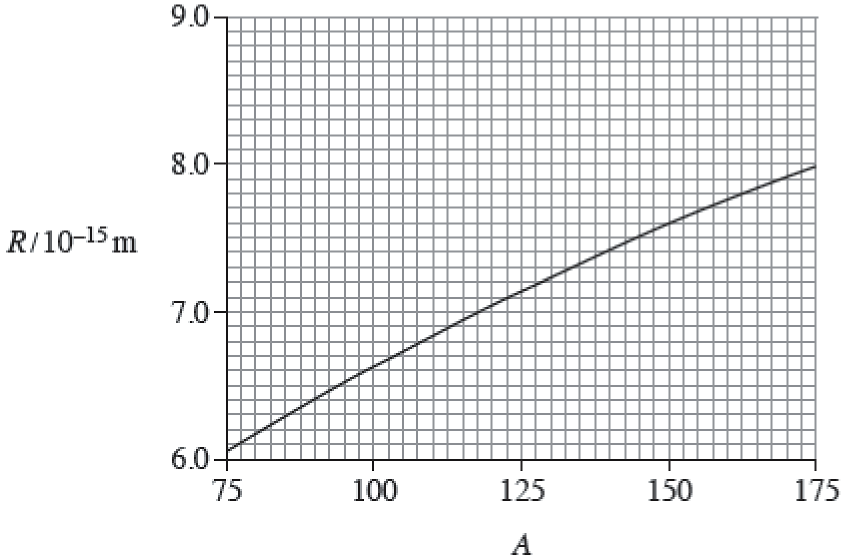
....

....

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



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

(1)

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

(2)

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

State an appropriate unit for your answer.

density .... unit ....

(3)
(Total 8 marks)

Q2. In stars, helium-3 and helium-4 are formed by the fusion of hydrogen nuclei. As the temperature rises, a helium-3 nucleus and a helium-4 nucleus can fuse to produce beryllium-7 with the release of energy in the form of gamma radiation.

The table below shows the masses of these nuclei.

Nucleus	Mass / u
Helium-3	3.01493
Helium-4	4.00151
Beryllium-7	7.01473

(a) (i) Calculate the energy released, in J, when a helium-3 nucleus fuses with a helium-4 nucleus.

energy released .... J

(4)

(ii) Assume that in each interaction the energy is released as a single gamma-ray photon.

Calculate the wavelength of the gamma radiation.

wavelength .... m

(3)

(b) For a helium-3 nucleus and a helium-4 nucleus to fuse they need to be separated by no more than 3.5×10^{-15} m.

(i) Calculate the minimum total kinetic energy of the nuclei required for them to reach a separation of 3.5×10^{-15} m.

total kinetic energy .... J

(3)

(ii) Calculate the temperature at which two nuclei with the average kinetic energy for that temperature would be able to fuse.
Assume that the two nuclei have equal kinetic energy.

temperature .... K

(3)

(c) Scientists continue to try to produce a viable fusion reactor to generate energy on Earth using reactors like the Joint European Torus (JET). The method requires a plasma that has to be raised to a suitable temperature for fusion to take place.

(i) State **two** nuclei that are most likely to be used to form the plasma of a fusion reactor.

1 ....

2 ....

(2)

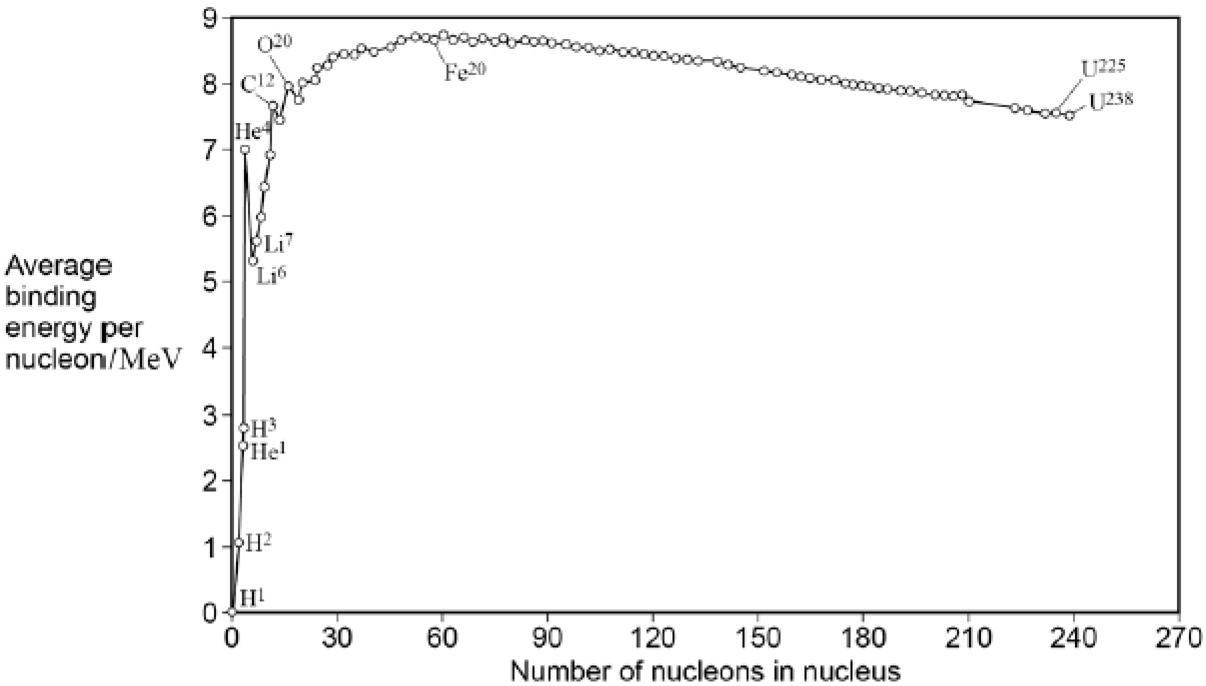
(ii) State **one** method which can be used to raise the temperature of the plasma to a suitable temperature.

....

....

(1)
(Total 16 marks)

Q3. 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 $^{184}_{74}W$?

A 1.28 pJ ☐

B 94.7 pJ ☐

C 103 pJ ☐

D 230 pJ ☐

(Total 1 mark)

Q4.(a) State what is meant by the binding energy of a nucleus.

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....

(2)

(b) (i) When a ${}^{235}_{92}\mathrm{U}$ nucleus absorbs a slow-moving neutron and undergoes fission one possible pair of fission fragments is technetium ${}^{112}_{43}\mathrm{Tc}$ and indium ${}^{122}_{49}\mathrm{In}$.

Complete the following equation to represent this fission process.

$${}^{1}_{0}\mathrm{n} + {}^{235}_{92}\mathrm{U} \rightarrow {}^{112}_{43}\mathrm{Tc} + {}^{122}_{49}\mathrm{In} + \ldots\ldots\ldots\ldots$$

(1)

(ii) Calculate the energy released, in MeV, when a single ${}^{235}_{92}\mathrm{U}$ nucleus undergoes fission in this way.

binding energy per nucleon of ${}^{235}_{92}\mathrm{U}$ = 7.59 MeV

binding energy per nucleon of ${}^{112}_{43}\mathrm{Tc}$ = 8.36 MeV

binding energy per nucleon of ${}^{122}_{49}\mathrm{In}$ = 8.51 MeV

energy released .... MeV

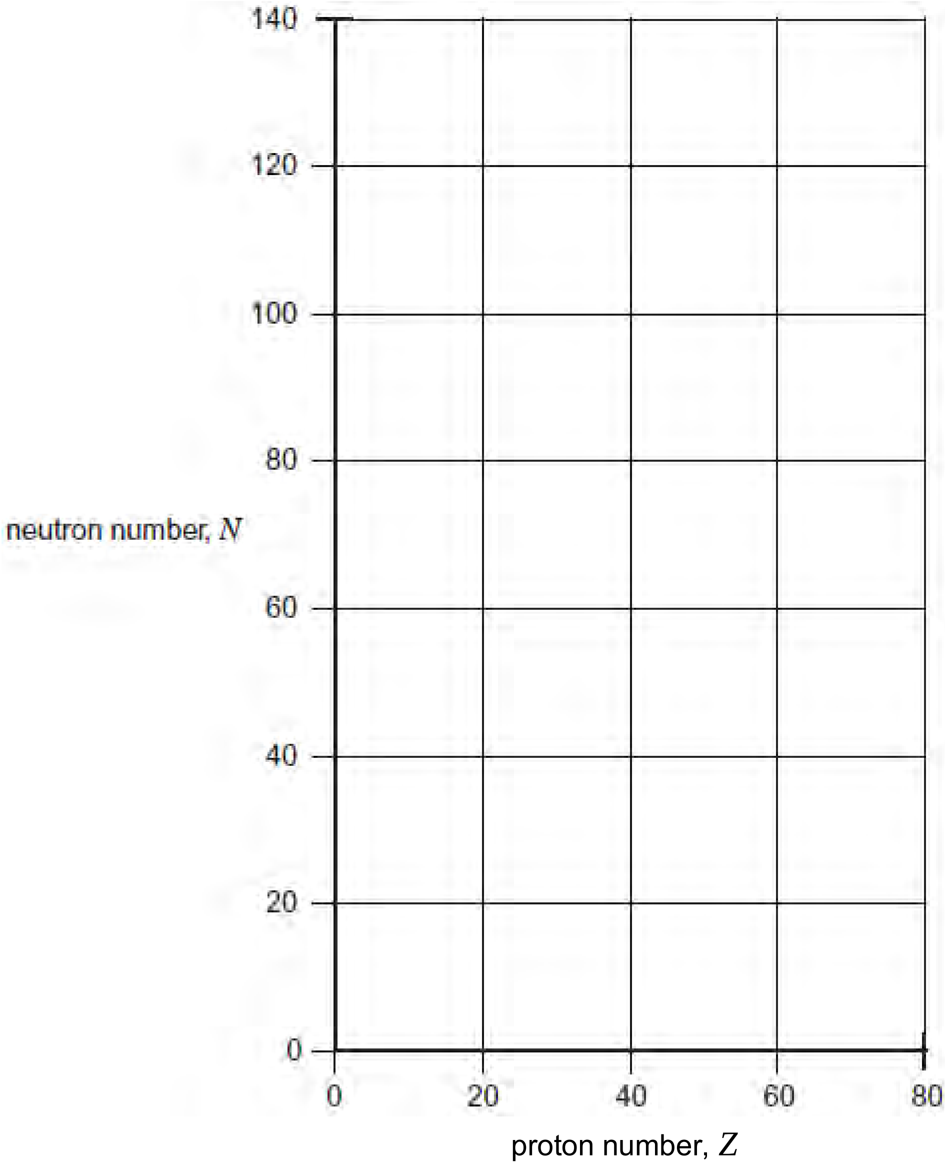
(3)

(iii) Calculate the loss of mass when a $^{235}_{92}U$ nucleus undergoes fission in this way.

loss of mass .... kg

(2)

(c) (i) On the figure below sketch a graph of neutron number, N, against proton number, Z, for stable nuclei.



(1)

(ii) With reference to the figure, explain why fission fragments are unstable and explain what type of radiation they are likely to emit initially.

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(3)
(Total 12 marks)