1. Nov/2023/Paper_9702/41/No.9

(a) State what is meant by nuclear fusion.

....

....

.... [2]

(b) On Fig. 9.1, sketch the variation of binding energy per nucleon with nucleon number *A* for values of *A* between 1 and 250.

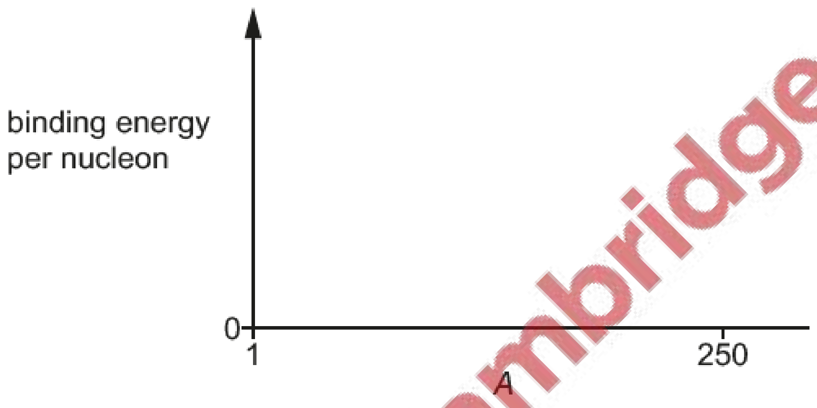

Fig. 9.1

[2]

(c) On your line in Fig. 9.1, label:

(i) a point X that could represent a nucleus that undergoes alpha-decay [1]

(ii) a point Y that could represent a nucleus that undergoes nuclear fusion. [1]

(d) A nucleus Z undergoes nuclear fission to form strontium-93 ($^{93}_{38}Sr$) and xenon-139 ($^{139}_{54}Xe$) according to

$$^{1}_{0}n + Z \longrightarrow {}^{93}_{38}Sr + {}^{139}_{54}Xe + 2{}^{1}_{0}n.$$

Table 9.1 shows the binding energies of the strontium-93 and xenon-139 nuclei.

Table 9.1

nucleus	binding energy / J
$^{93}_{38}Sr$	1.25×10^{-10}
$^{139}_{54}Xe$	1.81×10^{-10}

The fission of 1.00 mol of Z releases 1.77×10^{13} J of energy.

Determine the binding energy per nucleon, in MeV, of Z.

binding energy per nucleon = ... MeV [4]

[Total: 10]

2. June/2023/Paper_9702/41/No.9

Carbon-11 is radioactive and decays by β^+ emission to form boron-11. Carbon-11 has a half-life of 20 minutes. Boron-11 is stable.

(a) Define half-life.

....

.... [1]

(b) A sample contains N_0 nuclei of carbon-11 and no other nuclei at time $t = 0$.

On Fig. 9.1, sketch the variation with t of the number of nuclei of **boron-11** in the sample.

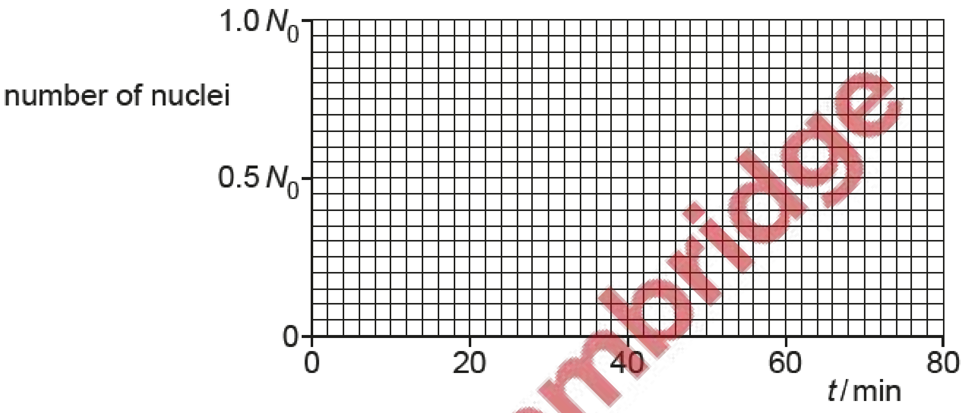

Fig. 9.1

[3]

(c) **(i)** Explain, with reference to the random nature of radioactive decay, why the activity of the carbon-11 sample in **(b)** decreases with time.

....

....

.... [2]

(ii) State, with reasons, whether a radiation detector placed near to the sample of carbon-11 indicates a measured count rate from the sample that is less than, the same as or greater than the activity of the sample.

....

....

....

....

.... [3]

[Total: 9]

3. June/2023/Paper_9702/42/No.9

(a) Define mass defect.

....

....

.... [2]

(b) Table 9.1 shows the mass defects of three nuclei.

Table 9.1

nucleus	mass defect / u
$^{2}_{1}H$	0.002 388
$^{3}_{1}H$	0.009 105
$^{4}_{2}He$	0.030 377

The nuclear fusion process in a particular star is described by

$$^{2}_{1}H + ^{3}_{1}H \rightarrow ^{4}_{2}He + X$$

where X is a particle that has no mass defect.

(i) State the name of particle X.

.... [1]

(ii) Show that the energy released when one nucleus of $^{4}_{2}He$ is formed in this fusion reaction is 2.8×10^{-12} J.

[3]

(c) The star in **(b)** has a radius of 2.3×10^9 m and a luminosity of 1.4×10^{28} W.
All the energy released from the formation of ${}^4_2He$ is radiated away from the star.
All the energy that is radiated from the star has been released in the formation of ${}^4_2He$.

Determine:

(i) the mass of ${}^4_2He$ produced per unit time by the fusion process

mass per unit time = ... $kg\,s^{-1}$ [3]

(ii) the surface temperature of the star.

temperature = ... K [2]

[Total: 11]

4. March/2023/Paper_9702/42/No.8

Plutonium-238 ($^{238}_{94}Pu$) is unstable and undergoes alpha decay.

(a) Complete the equation to show the decay of plutonium-238.

$$^{238}_{94}Pu \rightarrow \;^{\dots\dots}_{\dots\dots}U + \;^{\dots\dots}_{\dots\dots}\alpha$$

[2]

(b) The power source in a space probe contains 0.874 kg of plutonium-238. Each nucleus of plutonium-238 that decays emits 5.59 MeV of energy. The half-life of plutonium-238 is 87.7 years.

(i) Calculate the initial number N_o of nuclei of plutonium-238 in the power source.

N_o = ... [1]

(ii) Determine the initial activity of the source. Give a unit with your answer.

activity = ... unit .... [2]

(iii) Use your answer in **(b)(ii)** to determine the initial power output from the source due to the decay of plutonium-238.

power output = ... W [2]

(iv) The space probe will continue to function until the power output from the plutonium in the source decreases to 65.3% of its initial value.

Calculate the time, in years, for which the space probe will function.

time = ... years [2]

(c) An alternative power source uses energy generated from the radioactive decay of polonium-210. This isotope has a half-life of 0.378 years. The mass of the isotope needed for the same initial power output as in **(b)** is 3.37 g.

Suggest **one** advantage and **one** disadvantage of using polonium-210 as the source of energy.

advantage ....

....

disadvantage ....

....

[2]

[Total: 11]