A Level · OCR · Physics

32 mins · 4 questions

Structured Questions

Nuclear Fission & Fusion

Energy & Mass Equation / Particle-Antiparticle Pairs / Mass Defect & Binding Energy / Calculating Binding Energy / Nuclear Fission / Nuclear Fission Reactor & Waste / Nuclear Fusion / Balancing Nuclear Equations

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Total Marks **/32**

1 (a) Explain the function of the control rods and the moderator in a nuclear fission reactor.

[2]

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(2 marks)

(b) Some nuclear fission reactors use uranium-235 as fuel. In the future, there is possibility of using hydrogen-2 as fuel in fusion reactors.

Here is some information and data on fission and fusion reactions.

	Fission reactor	**Fusion reactor**
Typical reaction	${}^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{144}_{56}Ba + {}^{89}_{36}Kr + 3\,{}^{1}_{0}n$	${}^{2}_{1}H + {}^{2}_{1}H \rightarrow {}^{3}_{1}H + {}^{1}_{1}H$
Approximate energy produced in each reaction	200 MeV	4 MeV
Molar mass of fuel material	uranium-235: 0.235 kg mol^{-1}	hydrogen-2: 0.002 kg mol^{-1}

- Describe the similarities and the differences between fission and fusion reactions.
- Explain with the help of calculations, which fuel produces more energy per kilogram.

[6]

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(6 marks)

2 (a) A researcher is doing an experiment on a radioactive solution in a thin **glass** tube. The solution has two radioactive materials **X** and **Y**. The table below shows some data on these two materials.

	Material X	**Material Y**
Half-life	10 minutes	10 hours
Particles emitted	Alpha	Beta-minus
Daughter nuclei	Stable	Stable

The solution has the same number of nuclei of **X** and **Y** at the start.

i) State and explain which material has the greatest activity at the start.

[1]

ii) State why it is dangerous for the researcher to handle the test tube with bare hands.

[1]

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(2 marks)

(b) Carbon-14 $\left({}^{14}_{6}C\right)$ is produced in the upper atmosphere of the Earth by collisions between nitrogen nuclei and fast-moving neutrons. The nuclear transformation equation below shows the formation of a single carbon-14 nucleus.

$${}^{14}_{7}N + {}^{1}_{0}n \rightarrow {}^{14}_{6}C + X$$

i) State the proton number of particle **X**.

proton number = ... **[1]**

ii) Use the data below to determine the binding energy per nucleon of the 146C nucleus.

Write your answer to **3** significant figures.

- mass of neutron = 1.675×10^{-27} kg
- mass of proton = 1.673×10^{-27} kg
- mass of ${}^{14}_{6}C$ nucleus = 14.000 u
- 1 u = 1.66×10^{-27} kg

binding energy per nucleon = ... J per nucleon **[4]**

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(5 marks)

3 (a) Fig. 21 shows stable and unstable nuclei of some light elements plotted on a grid. This grid has number of neutrons *N* on the vertical axis and number of protons *Z* on the horizontal axis.

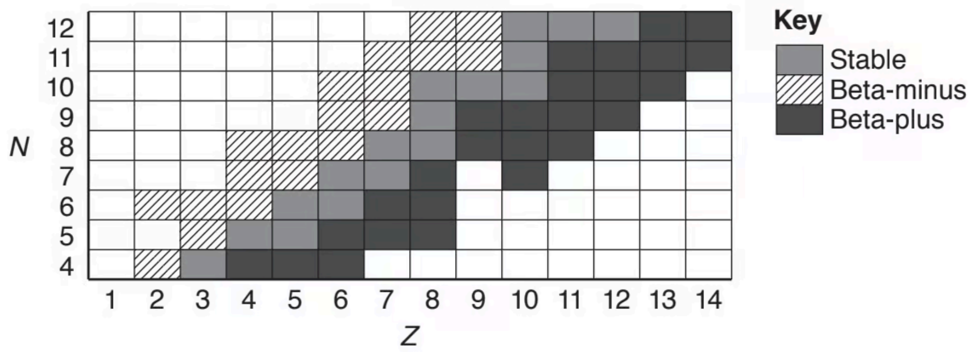

Fig. 21

The key on Fig. 21 shows whether a nucleus is stable, emits a beta-plus particle or emits a beta-minus particle to become stable. For $Z = 7$, suggest in terms of *N* why an isotope may emit

i) a beta-minus particle **[1]**

ii) a beta-plus particle. **[1]**

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(2 marks)

(b) Inside a nuclear reactor, fission reactions are controlled and **chain reactions** are prevented. A typical fission reaction of the uranium-235 nucleus ($^{235}_{92}\mathrm{U}$) is illustrated below.

$$^{1}_{0}\mathrm{n} + ^{235}_{92}\mathrm{U} \rightarrow ^{141}_{55}\mathrm{Cs} + ^{93}_{37}\mathrm{Rb} + 2^{1}_{0}\mathrm{n}$$

The neutron triggering the fission reaction moves slowly. The neutrons produced in the fission reaction move fast.

i) Describe what is meant by **chain reaction**.

[2]

ii) Explain how chain reactions are prevented inside a nuclear reactor.

[2]

iii) The energy released in each fission reaction is equivalent to a decrease in mass of 0.19u.

A fuel rod in a nuclear reactor contains 3.0% of uranium-235 by mass. Estimate the total energy produced from 1.0 kg of fuel rod. molar mass of uranium-235 = 0.235 kg mol^{-1} 1u = 1.66×10^{-27} kg

energy = ... J **[4]**

(8 marks)

4 (a) Stars produce energy by nuclear fusion. One particular fusion reaction between two protons (^1_1H) is shown below.

$$^1_1H + ^1_1H \rightarrow ^2_1H + ^{0}_{+1}e + v$$

In this reaction 2.2 MeV of energy is released.

Only one of the particles shown in the reaction has binding energy. Determine the binding energy per nucleon of this particle. Explain your answer.

[2]

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(2 marks)

(b) Explain why high temperatures are necessary for fusion reactions to occur in stars.

[2]

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(2 marks)

(c) A gamma photon in a star can spontaneously create an electron-positron pair. Calculate the **maximum** wavelength of a gamma photon for this creation event.

maximum wavelength = ... m **[3]**

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(3 marks)