inkPhysics

ANSWER BOOK

Fission and fusion

Nuclear physics · Year 13

AQA 3.8.1.6, 3.8.1.7 · CIE 23.1 · OCR A 6.4.4

10 questions · 31 marks

NAVY EDITION

SECTION A · Warm-up

A1 A heavy nucleus (such as uranium-235) absorbs a slow (thermal) neutron, becomes unstable and splits into two smaller nuclei, releasing two or three more neutrons and a large amount of energy. [2]

A2 Neutrons released by one fission go on to cause further fissions, each of which releases more neutrons, so the number of fissions can grow and the reaction sustains itself. [2]

A3 The critical mass is the minimum mass needed for a self-sustaining chain reaction, so that on average at least one neutron from each fission goes on to cause another fission rather than escaping. [2]

SECTION B · Standard

B1 Nucleon numbers: 235 + 1 = 141 + 92 + x, so 236 = 233 + x and x = 3 neutrons. Proton numbers: 92 + 0 = 56 + 36 + 0 = 92 ✓. [4]

B2 $E = mc^2 = 3.5 \times 10^{-28} \times (3.0 \times 10^8)^2 = 3.15 \times 10^{-11}$ J = 197 MeV. [4]

B3 Fusing nuclei must come extremely close together, but both are positively charged and repel strongly. Only at very high temperatures do nuclei move fast enough to overcome this electrostatic repulsion and get close enough for the strong nuclear force to bind them. [3]

B4 $E = 17.6 \times 10^6 \times 1.60 \times 10^{-19} = 2.82 \times 10^{-12}$ J. $m = E/c^2 = 3.13 \times 10^{-29}$ kg. [3]

SECTION C · Stretch

C1 Number of nuclei in 1.0 kg = $N_A \times 1000/235 = 2.56 \times 10^{24}$. Energy per fission = $200 \times 1.60 \times 10^{-13} = 3.20 \times 10^{-11}$ J. Total = $2.56 \times 10^{24} \times 3.20 \times 10^{-11} = 8.2 \times 10^{13}$ J. [4]

C2 Fission uses heavy nuclei (such as uranium-235), works with slow neutrons at ordinary temperatures, and produces radioactive fragments plus neutrons. Fusion uses light nuclei (such as hydrogen isotopes), needs extremely high temperatures and pressures, and produces helium with far less long-lived radioactive waste. [4]

C3 Both processes form products with a higher binding energy per nucleon than the starting material, moving nucleons towards the peak of the curve. The increase in binding energy per nucleon corresponds to a release of energy (and a loss of mass). [3]