inkPhysics

ANSWER BOOK

Mass-energy and binding energy

Nuclear physics · Year 13

AQA 3.8.1.6 · CIE 11.1, 23.1 · OCR A 6.4.4

10 questions · 30 marks

NAVY EDITION

SECTION A · Warm-up

A1 $E = mc^2$. The binding energy is the energy needed to separate a nucleus completely into its individual nucleons (equivalently, the energy released when the nucleus forms from them). [2]

A2 $E = mc^2 = 1.0 \times 10^{-28} \times (3.0 \times 10^8)^2 = 9.0 \times 10^{-12}$ J. [2]

A3 1 u is equivalent to about 931.5 MeV. [2]

SECTION B · Standard

B1 Mass defect = $(2 \times 1.00728 + 2 \times 1.00867) - 4.00150 = 0.03040$ u. Binding energy = $0.03040 \times 931.5 = 28.3$ MeV. [4]

B2 Binding energy per nucleon = $28.3/4 = 7.08$ MeV per nucleon. [3]

B3 $E = 28.3 \times 1.60 \times 10^{-13} = 4.53 \times 10^{-12}$ J. [3]

B4 $m = E/c^2 = (2.0 \times 10^{-11})/(3.0 \times 10^8)^2 = 2.22 \times 10^{-28}$ kg. [3]

SECTION C · Stretch

C1 Binding energy = $0.099 \times 931.5 = 92.2$ MeV. Binding energy per nucleon = $92.2/12 = 7.68$ MeV per nucleon. [4]

C2 The curve rises steeply for light nuclei to a broad maximum near iron-56 (about 8.8 MeV per nucleon), then falls slowly for heavier nuclei. Moving towards the peak raises the binding energy per nucleon: fusing light nuclei and splitting heavy nuclei both do this, so both release energy. [4]

C3 The peak (around iron-56) marks the most tightly bound, most stable nuclei. Nuclei on either side can release energy by moving towards it, but iron itself cannot release energy by fusion or fission, which is why it is an endpoint of energy-releasing nuclear processes in stars. [3]