InkPhysics

QUESTION WORKBOOK

Mass-energy and binding energy

Nuclear physics · Year 13

AQA 3.8.1.6 · CIE 11.1.12, 23.1.1, 23.1.3, 23.1.4, 23.1.6, 23.1.7
OCR A 6.4.4(a), 6.4.4(b), 6.4.4(d), 6.4.4(e), 6.4.4(f)

18 questions · 48 marks

PRINT EDITION

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SECTION A · Warm-up

A1 State the equation linking mass and energy, and define the binding energy of a nucleus. [2]

A2 A mass of 1.0×10^{-28} kg is converted entirely into energy. Calculate the energy released.
$c = 3.0 \times 10^{8}$ m s^{-1} [2]

A3 State the energy equivalent of one atomic mass unit (u) in MeV. [1]

A4 Define the atomic mass unit, u, and state its value in kilograms. [2]

A5 The water in a kettle is heated, increasing its internal energy. State what happens to the mass of the water, and explain why the change cannot be detected by weighing. [2]

SECTION B · Standard

B1 A helium-4 nucleus has a mass of 4.00150 u. The mass of a proton is 1.00728 u and the mass of a neutron is 1.00867 u. Calculate the mass defect of the nucleus and its binding energy in MeV.
1 u = 931.5 MeV [4]

B2 The binding energy of helium-4 is 28.3 MeV. Calculate its binding energy per nucleon. [2]

B3 Express the binding energy of helium-4 (28.3 MeV) in joules.
1 MeV = 1.60×10^{-13} J [2]

B4 In a nuclear reaction, 2.0×10^{-11} J of energy is released. Calculate the mass converted into energy in the reaction. [2]

B5 The binding energy per nucleon of oxygen-16 is 7.98 MeV. Calculate the mass defect of an oxygen-16 nucleus, in u.
1 u = 931.5 MeV [3]

B6 Radium-226 decays by alpha emission: $^{226}_{88}Ra \rightarrow ^{222}_{86}Rn + ^{4}_{2}He$. The nuclear masses are 226.02540 u, 222.01757 u and 4.00260 u respectively. Calculate the energy released in one decay, in MeV.
1 u = 931.5 MeV [3]

B7 Nucleus X has a total binding energy of 1638 MeV and nucleon number 210. Nucleus Y has a total binding energy of 492 MeV and nucleon number 56. A student claims that X is the more stable nucleus because its binding energy is greater. Deduce whether the student is correct. [3]

SECTION C · Stretch

C1 A nucleus with nucleon number 12 has a mass defect of 0.099 u. Calculate its binding energy and its binding energy per nucleon. [3]

C2 Sketch the variation of binding energy per nucleon with nucleon number, and use your sketch to explain why fusion of light nuclei and fission of heavy nuclei both release energy. [4]

C3 Explain the significance of the peak of the binding energy per nucleon curve. [3]

C4 Show that the energy equivalent of one atomic mass unit is about 930 MeV.
1 u = 1.661×10^{-27} kg, c = 3.0×10^{8} m s^{-1}, 1 MeV = 1.60×10^{-13} J [3]

C5 A nucleus with nucleon number 240 and binding energy per nucleon 7.6 MeV splits into two equal fragments, each with binding energy per nucleon 8.5 MeV. The freed neutrons may be neglected. Estimate the energy released in the fission. [3]

C6 Calculate the minimum energy, in MeV, needed to remove one neutron from a carbon-13 nucleus, leaving carbon-12.
Nuclear masses: carbon-13 13.00006 u, carbon-12 11.99671 u, neutron 1.00867 u; 1 u = 931.5 MeV [4]