inkPhysics

ANSWER BOOK

Nuclear radius and density

Nuclear physics · Year 13

AQA 3.8.1.5 · OCR A 6.4.1

10 questions · 30 marks

NAVY EDITION

SECTION A · Warm-up

A1 $R = R_0A^{1/3}$, where A is the nucleon number and $R_0 \approx 1.2 \times 10^{-15}$ m (1.2 fm). [2]

A2 $R = R_0A^{1/3} = 1.2 \times 10^{-15} \times 64^{1/3} = 1.2 \times 10^{-15} \times 4 = 4.8 \times 10^{-15}$ m. [2]

A3 Since volume $\propto R^3 \propto A$, and mass $\propto A$, the density (mass/volume) is the same for all nuclei: nuclear matter has an approximately constant density. [2]

SECTION B · Standard

B1 $R = R_0A^{1/3} = 1.2 \times 10^{-15} \times 27^{1/3} = 1.2 \times 10^{-15} \times 3 = 3.6 \times 10^{-15}$ m. [3]

B2 $\rho = u/((4/3)\pi R_0^3) = (1.66 \times 10^{-27})/((4/3)\pi \times (1.2 \times 10^{-15})^3) = 2.29 \times 10^{17}$ kg m^{-3}. [4]

B3 $R_{125}/R_8 = (125/8)^{1/3} = 2.5$. [3]

B4 If every nucleus has the same density, each nucleon occupies about the same volume regardless of the nucleus. This is what you expect if nucleons touch and are packed tightly, like closely packed spheres, rather than being spread out. [3]

SECTION C · Stretch

C1 At closest approach $E_k = kQ_\alpha Q_N/r$, with $Q_\alpha = 2e$ and $Q_N = 79e$. $E_k = 5.0 \times 10^6 \times 1.60 \times 10^{-19} = 8.0 \times 10^{-13}$ J. $r = k(2e)(79e)/E_k = 4.55 \times 10^{-14}$ m. [4]

C2 $R = 1.2 \times 10^{-15} \times 12^{1/3} = 2.75 \times 10^{-15}$ m. Mass $= 12 \times 1.66 \times 10^{-27} = 1.99 \times 10^{-26}$ kg. $\rho = m/((4/3)\pi R^3) = 2.29 \times 10^{17}$ kg m^{-3}, essentially the same as for any other nucleus. [4]

C3 A beam of high-energy electrons (whose de Broglie wavelength is comparable to the nuclear size) is fired at a thin sample. The electrons diffract around the nuclei, producing a pattern with minima; the angle of the first minimum depends on the nuclear diameter, allowing the radius to be calculated. [3]