824.

Problem 54.15 (RHK)

We are asked to pick apart an α *particle* $\left({}^{4}\mathrm{He}\right)$ *by removing in sequence, a proton, a neutron, and a proton. We have to calculate* (a) *the work required for each step,* (b) *the total binding energy of the* α *particle, and* (c) *the binding energy per nucleon. Needed atomic masses are*

$^{4}\mathrm{He}$ 4.002603 u $^{2}\mathrm{H}$ 2.014102 u

$^{3}\mathrm{H}$ 3.016049 u $^{1}\mathrm{H}$ 1.007825 u

n 1.008665 u

Solution:

(a)

We will calculate the energy required for picking apart an α particle by removing in sequence, a proton, a neutron, and a proton.

Energy require for removing a proton from an α particle can be found by noting that we are considering the process

$$^{4}\mathrm{He} \rightarrow {}^{3}\mathrm{H} + \mathrm{p}.$$

The energy required for this process will be

$$\left(m\left({}^{3}\mathrm{H}\right)+m\left({}^{1}\mathrm{H}\right)-m\left({}^{4}\mathrm{He}\right)\right)c^{2}$$
$$=\left(3.016049+1.007825-4.002603\right)\ \mathrm{u}c^{2}$$
$$=\left(0.021271\right)\mathrm{u}c^{2}=0.021271\times 931.5\ \mathrm{MeV}$$
$$=19.81\ \mathrm{MeV}.$$

We next calculate the energy required for removing a neutron from ${}^{3}\mathrm{H}$ nucleus. That is we consider the process

$${}^{3}\mathrm{H}\rightarrow {}^{2}\mathrm{H}+\mathrm{n}.$$

The energy required for this process will be

$$\left(m\left({}^{3}\mathrm{H}\right)\rightarrow m\left({}^{2}\mathrm{H}\right)+\mathrm{m_n}\right)c^{2}$$
$$=\left(2.014102+1.008665-3.016049\right)\mathrm{u}c^{2}$$
$$=\left(0.006718\right)\mathrm{u}c^{2}=0.006718\times 931.5\ \mathrm{MeV}$$
$$=6.26\ \mathrm{MeV}.$$

We next calculate the energy required for removing a proton from ${}^{2}\mathrm{H}$. That is we consider the splitting of a deuteron ${}^{2}\mathrm{H}$ described by the process

$${}^{2}\mathrm{H}\rightarrow \mathrm{p}+\mathrm{n}.$$

The energy required for this process will be

$$\left(1.007825+1.008665-2.014102\right)\mathrm{u}c^{2}$$
$$=\left(0.002388\right)\mathrm{u}c^{2}$$
$$=2.22\ \mathrm{MeV}.$$

(b)

Therefore, the total energy required for splitting an α particle, which is its binding energy, is $(19.81 + 6.26 + 2.22)$ MeV $= 28.29$ MeV.

(c)

The binding energy per nucleon in an α particle, therefore, is $28.29 \text{ MeV}/4 = 7.07$ MeV.