

824.

Problem 54.15 (RHK)

We are asked to pick apart an α particle (${}^4\text{He}$) 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

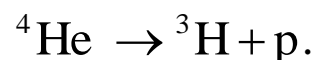
${}^4\text{He}$	4.002603 u	${}^2\text{H}$	2.014102 u
${}^3\text{H}$	3.016049 u	${}^1\text{H}$	1.007825 u
n	1.008665 u		

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.

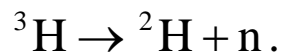
Energy require for removing a proton from an α particle can be found by noting that we are considering the process



The energy required for this process will be

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

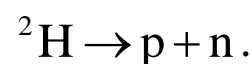
We next calculate the energy required for removing a neutron from ^3H nucleus. That is we consider the process



The energy required for this process will be

$$\begin{aligned}
& \left(m(^3\text{H}) - m(^2\text{H}) - m_{\text{n}} \right) c^2 \\
&= (3.016049 - 2.014102 - 1.008665) \text{ u} c^2 \\
&= (-0.006718) \text{ u} c^2 = -0.006718 \times 931.5 \text{ MeV} \\
&= -6.26 \text{ MeV}.
\end{aligned}$$

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



The energy required for this process will be

$$\begin{aligned}
& (1.007825 + 1.008665 - 2.014102) \text{ u} c^2 \\
&= (0.002388) \text{ u} c^2 \\
&= 2.22 \text{ MeV}.
\end{aligned}$$

(b)

Therefore, the total energy required for splitting an α particle, which is its binding energy, is

$$(19.81 + 6.26 + 2.22) \text{ MeV} = 28.29 \text{ MeV}.$$

(c)

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

