Question (1550001)

Change in rest energy resulting from the fusion of hydrogen into helium.

In one type of fusion reaction, 6 hydrogen nuclei (each nuclei is one proton) eventually, after many steps, form 1 atom of helium (2 neutrons and 2 protons) and two atoms of hydrogen. (Read more about the proton-proton cycle to learn about the process.) The mass of hydrogen is \( 1.007825 \text{ MeV}/c^2 \). The mass of helium is \( 4.002603 \text{ MeV}/c^2 \). What is the change in the rest energy of the system during this reaction?

Solution

Define the system as the 6 hydrogen atoms. Its initial rest energy consists of the rest energy of 6 hydrogen atoms.

\[
E_{\text{rest},i} = 6E_{\text{rest},H}
\]

After the fusion reaction, there is one atom of helium and two hydrogen atoms. Their rest energies are the final rest energy of the system.

\[
E_{\text{rest},f} = 2E_{\text{rest},H} + E_{\text{rest},He}
\]

The change in rest energy of the system is

\[
\Delta E_{\text{rest}} = E_{\text{rest},f} - E_{\text{rest},i}
\]
\[
= (2E_{\text{rest},H} + E_{\text{rest},He}) - 6E_{\text{rest},H}
\]
\[
= E_{\text{rest},He} - 4E_{\text{rest},H}
\]
\[
= m_{He}c^2 - 4m_{H}c^2
\]
\[
= (4.002603 \text{ MeV}/c^2)c^2 - 4(1.007825 \text{ MeV}/c^2)c^2
\]
\[
= 4.002603 \text{ MeV} - 4(1.007825 \text{ MeV})
\]
\[
= -0.028697 \text{ MeV}
\]

(Note: all of the figures in the answer are significant.) It makes sense that rest energy is lost because this loss of rest energy results in gains of other types of energy, according to the Energy Principle. Where does the energy radiated from Sun come from? Ultimately, it comes from the loss of rest energy during the fusion reactions that occur within Sun.