Binding energies in Relativity, and Nuclear Fusion:

Accepted conversion values:
\[ c = 299\,792\,458 \text{ m s}^{-1} \text{ (defined as exact)} \]
\[ 1 \text{ eV} = 1.602\,176\,53(14) \times 10^{-19} \text{ J} \]
\[ 1 \text{ u} = 1.66053886(28) \times 10^{-27} \text{ kg} \text{ (u is “amu” or atomic mass unit)} \]
So \[ 1 \text{ u} \times c^2 = 931.494 \text{ MeV} \text{ or } 1.4924 \times 10^{-10} \text{ J} \]

Standard masses:
- proton = 1.007276 u = 938.27 MeV
- neutron = 1.008665 u = 939.57 MeV
- electron = 0.000549 u = 0.5110 MeV

reference: NIST (from website)

So the following combination can be made:

4 protons + 4 electrons = 4.0313 u
compare \(^4\text{He}\) atom = 4.0026 u

Difference is 0.0287 u = 26.7 MeV (per \(^4\text{He}\) atom)

This is (roughly) the fusion reaction that occurs in the Sun, where hydrogen is combined to give helium, producing energy in the process. Mass-energy conversion allows the resulting energies to be understood quantitatively.
e.g. converting to 1 kg of \(^4\text{He}\), which is 250 moles:

\[ 26.7 \text{ MeV} \times 250 \times N_A = 4.02 \times 10^{27} \text{ MeV} \text{ or } 6.4 \times 10^{14} \text{ J} \text{ obtained in this process.} \]
\((N_A \text{ is Avogadro constant})\)

For comparison, approximately \(48 \times 10^6 \text{ J/kg}\) is obtained from burning gasoline.
Fusion result is \(10^7\) times larger!

Notes:

1. In reality H and He exist as ionized species (bare nuclei) in the sun. The process envisioned above might better be described as:

\[ 4 \, ^1\text{H} + 2 \, e \rightarrow ^4\text{He} + 2 \, \text{neutrinos} + 6 \, \text{photons.} \]

The resulting 27 MeV would be distributed among the photons and neutrinos. (Neutrino rest mass is very small, so effectively all of the energy is released as kinetic energy.)

2. A simultaneous collision between 5 particles is actually extremely unlikely. See ch. 14 for a description of the actual processes going on in the sun. These involve neutrons as well as small nuclei, however the above analysis gives a good picture of how large nuclear interaction energies manifest themselves as mass differences.