Masses are often specified using the electron-volt energy unit. This can be done because mass and energy are related, and the precise relationship is given by Einstein's equation $E = mc^2$ (Chapter 26). Since the mass of a proton is 1.67262×10^{-27} kg, or 1.007276 u, then

$$1.0000\text{ u} = \left(\frac{1.0000\text{ u}}{1.007276\text{ u}}\right)\left(1.67262 \times 10^{-27}\text{ kg}\right) = 1.66054 \times 10^{-27}\text{ kg};$$

this is equivalent to an energy (see Table inside front cover) in MeV ($= 10^6$ eV) of

$$E = mc^2 = \frac{\left(1.66054 \times 10^{-27}\text{ kg}\right)\left(2.9979 \times 10^8\text{ m/s}\right)^2}{\left(1.6022 \times 10^{-19}\text{ J/eV}\right)} = 931.5\text{ MeV}.$$

Thus

Atomic mass unit and MeV

$$1\text{ u} = 1.6605 \times 10^{-27}\text{ kg} = 931.5\text{ MeV}/c^2.$$

The rest masses of some of the basic particles are given in Table 30–1.

TABLE 30–1
Rest Masses in Kilograms, Unified Atomic Mass Units, and MeV/c^2

	Mass		
Object	**kg**	**u**	**MeV/c^2**
Electron	9.1094×10^{-31}	0.00054858	0.51100
Proton	1.67262×10^{-27}	1.007276	938.27
$^1_1$H atom	1.67353×10^{-27}	1.007825	938.78
Neutron	1.67493×10^{-27}	1.008665	939.57

Just as an electron has intrinsic spin and angular momentum quantum numbers, so too do nuclei and their constituents, the proton and neutron. Both the proton and the neutron are spin $\frac{1}{2}$ particles. A nucleus, made up of protons and neutrons, has a **nuclear spin** quantum number, I, that can be either integer or half integer, depending on whether it is made up of an even or an odd number of nucleons.

30–2 Binding Energy and Nuclear Forces

Binding Energies

The total mass of a stable nucleus is always less than the sum of the masses of its separate protons and neutrons, as the following Example shows.

EXAMPLE 30–3 **$^4_2$He mass compared to its constituents.** Compare the mass of a $^4_2$He atom to the total mass of its constituent particles.

PROBLEM SOLVING *Keep track of electron masses*

APPROACH The $^4_2$He nucleus contains 2 protons and 2 neutrons. Tables normally give the masses of neutral atoms—that is, nucleus plus its Z electrons—since this is how masses are measured. We must therefore be sure to balance out the electrons when we compare masses. Thus we use the mass of $^1_1$H rather than that of a proton alone. We look up the mass of the $^4_2$He atom in Appendix B (it includes the mass of 2 electrons), as well as the mass for the 2 neutrons and 2 hydrogen atoms (= 2 protons + 2 electrons).

SOLUTION The mass of a neutral $^4_2$He atom, from Appendix B, is 4.002603 u. The mass of two neutrons and two H atoms (2 protons including the 2 electrons) is

$$2m_n = 2(1.008665\text{ u}) = 2.017330\text{ u}$$
$$2m(^1_1\text{H}) = 2(1.007825\text{ u}) = \underline{2.015650\text{ u}}$$
$$\text{sum} = 4.032980\text{ u}.$$