Alternatively, the mass of the nucleus is often expressed in terms of rest energy. A particle has a certain amount of energy, called *rest energy,* associated with its mass. The following equation expresses the relationship between mass and rest energy mathematically:

ADVANCED TOPICS

See "The Equivalence of Mass and Energy" in **Appendix J: Advanced Topics** to learn more about rest energy.

RELATIONSHIP BETWEEN REST ENERGY AND MASS

$$E_R = mc^2$$

$$\textbf{rest energy} = \textbf{(mass)(speed of light)}^2$$

This expression is often used because mass is not conserved in many nuclear processes, as we will see. Because the rest energy of a particle is given by $E_R = mc^2$, it is convenient to express a particle's mass in terms of its energy equivalent. The equation that follows is for the rest energy of a particle with a mass of exactly 1 u.

$$E_R = mc^2 = \frac{(1.660\ 538\ 782 \times 10^{-27}\ \text{kg})(299\ 792\ 458\ \text{m/s})^2}{1.602\ 176\ 53 \times 10^{-19}\ \text{J/eV}} \approx 931.49\ \text{MeV}$$

Thus, the conversion of 1 u of mass into energy would produce about 931.49 MeV. This book will use the value 931.49 MeV for calculations. (Recall that M is an abbreviation for the SI prefix *mega-*, which indicates 10^6.)

The masses and energy equivalent of the proton, neutron, and electron are summarized in **Table 2.** Notice that in order to distinguish between the mass of the proton and the mass of the neutron, you must know their masses to at least four significant figures. The masses and some other properties of selected isotopes are given in Appendix H.

Did you know?

The equivalence between mass and energy is predicted by Einstein's special theory of relativity. Another aspect of this theory is that time and length are relative. That is, they depend on an observer's frame of reference, while the speed of light is absolute.

Table 2 Mass and Rest Energy of Atomic Particles

Particle	*m* (kg)	*m* (u)	E_R (MeV)
proton	1.673×10^{-27}	1.007 276	938.3
neutron	1.675×10^{-27}	1.008 665	939.6
electron	9.109×10^{-31}	0.000 549	0.5110

NUCLEAR STABILITY

Given that the nucleus consists of a closely packed collection of protons and neutrons, you might be surprised that it can exist. It seems that the Coulomb repulsion between protons would cause a nucleus to fly apart. There must be some attractive force to overcome this repulsive force. This force is called the *nuclear force,* or the **strong force.**

strong force

the interaction that binds nucleons together in a nucleus