be the conservation of kinetic energy or the simpler Eq. 7–7 we derived from it:

$$v_A - v_B = v'_B - v'_A, \qquad \text{or} \qquad v = v'_B - v'_A$$

since $v_A = v$ and $v_B = 0$. We subtract $v = v'_B - v'_A$ from our momentum equation $(v = v'_A + v'_B)$ and obtain

$$0 = 2v'_A.$$

Hence $v'_A = 0$. We can now solve for the other unknown (v'_B) since $v = v'_B - v'_A$:

$$v'_B = v + v'_A = v + 0 = v.$$

To summarize, before the collision we have

$$v_A = v, \qquad v_B = 0$$

and after the collision

$$v'_A = 0, \qquad v'_B = v.$$

That is, ball A is brought to rest by the collision, whereas ball B acquires the original velocity of ball A. See Fig. 7–15.

NOTE Our result is often observed by billiard and pool players, and is valid only if the two balls have equal masses (and no spin is given to the balls).

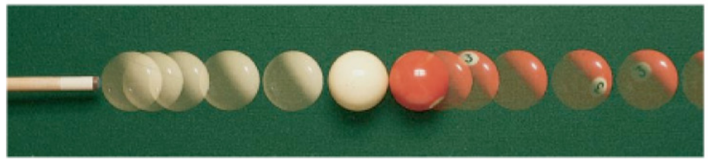

FIGURE 7–15 In this multiflash photo of a head-on collision between two balls of equal mass, the white cue ball is accelerated from rest by the cue stick and then strikes the red ball, initially at rest. The white ball stops in its tracks, and the (equal mass) red ball moves off with the same speed as the white ball had before the collision. See Example 7–7.

EXAMPLE 7–8 **A nuclear collision.** A proton (p) of mass 1.01 u (unified atomic mass units) traveling with a speed of $3.60 \times 10^4\,\text{m/s}$ has an elastic head-on collision with a helium (He) nucleus $(m_{He} = 4.00\,\text{u})$ initially at rest. What are the velocities of the proton and helium nucleus after the collision? (As mentioned in Chapter 1, $1\,\text{u} = 1.66 \times 10^{-27}\,\text{kg}$, but we won't need this fact.) Assume the collision takes place in nearly empty space.

APPROACH Like Example 7–7, this is an elastic head-on collision, but now the masses of our two-particle system are not equal. The only external force is Earth's gravity, but it is insignificant compared to the strong force during the collision. So again we use the conservation laws of momentum and of kinetic energy, and apply them to our system of two particles.

SOLUTION Let the proton (p) be particle A and the helium nucleus (He) be particle B. We have $v_B = v_{He} = 0$ and $v_A = v_p = 3.60 \times 10^4\,\text{m/s}$. We want to find the velocities v'_p and v'_{He} after the collision. From conservation of momentum,

$$m_p v_p + 0 = m_p v'_p + m_{He} v'_{He}.$$

Because the collision is elastic, the kinetic energy of our system of two particles is conserved and we can use Eq. 7–7, which becomes

$$v_p - 0 = v'_{He} - v'_p.$$

Thus

$$v'_p = v'_{He} - v_p,$$

and substituting this into our momentum equation displayed above, we get

$$m_p v_p = m_p v'_{He} - m_p v_p + m_{He} v'_{He}.$$

Solving for v'_{He}, we obtain

$$v'_{He} = \frac{2m_p v_p}{m_p + m_{He}} = \frac{2(1.01\,\text{u})(3.60 \times 10^4\,\text{m/s})}{5.01\,\text{u}} = 1.45 \times 10^4\,\text{m/s}.$$

The other unknown is v'_p, which we can now obtain from

$$v'_p = v'_{He} - v_p = (1.45 \times 10^4\,\text{m/s}) - (3.60 \times 10^4\,\text{m/s}) = -2.15 \times 10^4\,\text{m/s}.$$

The minus sign for v'_p tells us that the proton reverses direction upon collision, and we see that its speed is less than its initial speed (see Fig. 7–16).

NOTE This result makes sense: the lighter proton would be expected to "bounce back" from the more massive helium nucleus, but not with its full original velocity as from a rigid wall (which corresponds to extremely large, or infinite, mass).

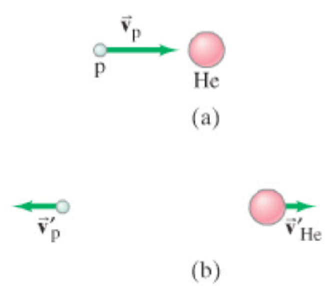

FIGURE 7–16 Example 7–8: (a) before collision, (b) after collision.