Additional Example

EXAMPLE 30–7 KE of the α in $^{232}_{92}U$ decay. For the $^{232}_{92}U$ decay of Example 30–6, how much of the 5.4-MeV disintegration energy will be carried off by the α particle?

APPROACH In any reaction, momentum must be conserved as well as energy.

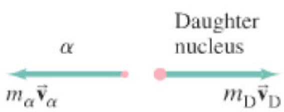

FIGURE 30–6 Momentum conservation in Example 30–7.

SOLUTION Before disintegation, the nucleus can be assumed to be at rest, so the total momentum was zero. After disintegration, the total vector momentum must still be zero so the magnitude of the α particle's momentum must equal the magnitude of the daughter's momentum (Fig. 30–6):

$$m_\alpha v_\alpha = m_D v_D.$$

Thus $v_\alpha = m_D v_D / m_\alpha$ and the α's kinetic energy is

$$\text{KE}_\alpha = \tfrac{1}{2} m_\alpha v_\alpha^2 = \tfrac{1}{2} m_\alpha \left(\frac{m_D v_D}{m_\alpha}\right)^2 = \tfrac{1}{2} m_D v_D^2 \left(\frac{m_D}{m_\alpha}\right) = \left(\frac{m_D}{m_\alpha}\right) \text{KE}_D$$

$$= \left(\frac{228.028731\ \text{u}}{4.002603\ \text{u}}\right) \text{KE}_D = 57\text{KE}_D.$$

The total disintegration energy is $Q = \text{KE}_\alpha + \text{KE}_D = 57\text{KE}_D + \text{KE}_D = 58\text{KE}_D$. Hence

$$\text{KE}_\alpha = \frac{57}{58} Q = 5.3\ \text{MeV}.$$

The lighter α particle carries off (57/58) or 98% of the total KE.

Why α particles?

Why, you may wonder, do nuclei emit this combination of four nucleons called an α particle? Why not just four separate nucleons, or even one? The answer is that the α particle is very strongly bound, so that its mass is significantly less than that of four separate nucleons. As we saw in Example 30–3, two protons and two neutrons separately have a total mass of about 4.032980 u (electrons included). The total mass of $^{228}_{90}Th$ plus four separate nucleons is 232.061711 u, which is greater than the mass of the parent (232.037146). Such a decay could not occur because it would violate the conservation of energy. Similarly, it is almost always true that the emission of a single nucleon is energetically not possible.

Smoke Detectors—An Application

PHYSICS APPLIED
Smoke detector

One widespread application of nuclear physics is present in nearly every home in the form of an ordinary **smoke detector**. The most common type of detector contains about 0.2 mg of the radioactive americium isotope, $^{241}_{95}Am$, in the form of AmO_2. The radiation continually ionizes the nitrogen and oxygen molecules in the air space between two oppositely charged plates. The resulting conductivity allows a small steady current. If smoke enters, the radiation is absorbed by the smoke particles rather than by the air molecules, thus reducing the current. The current drop is detected by the device's electronics and sets off the alarm. The radiation dose that escapes from an intact americium smoke detector is much less than the natural radioactive background, and so can be considered relatively harmless. There is no question that smoke detectors save lives and reduce property damage.