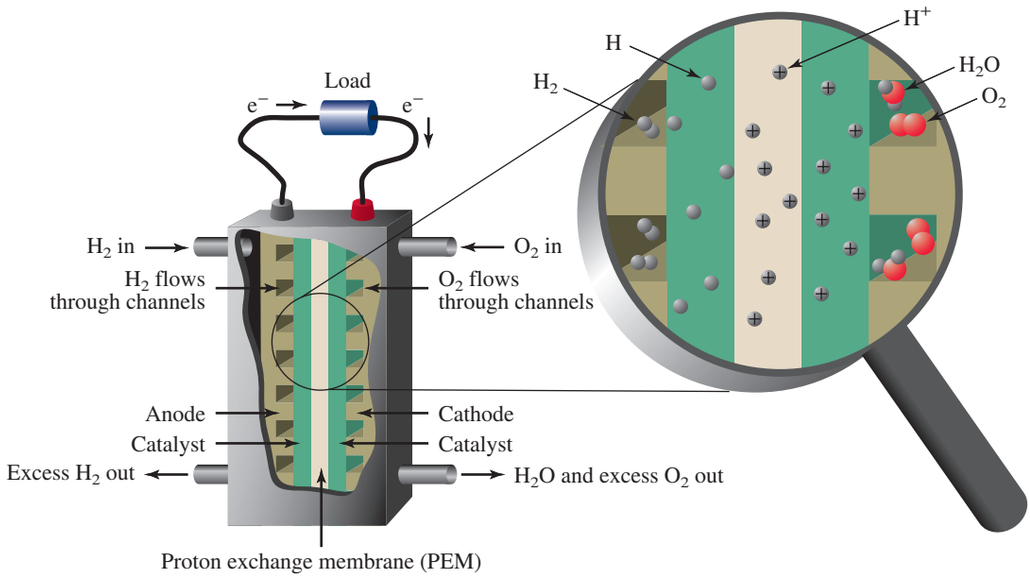

Figure 7.23

A PEM fuel cell in which H_2 and O_2 combine to form water without combustion.

As a molecule of hydrogen (H_2) passes through the membrane, it is oxidized and loses two electrons to form two hydrogen ions:

$$\text{oxidation half-reaction (anode)} \quad H_2(g) \longrightarrow 2\ H^+(aq) + 2\ e^- \qquad \textbf{[7.19]}$$

The hydrogen ions, H^+, flow through the proton exchange membrane and combine with oxygen (O_2). At the same time, they combine with two electrons to form water:

$$\text{reduction half-reaction (cathode)} \quad \tfrac{1}{2}\ O_2(g) + 2\ H^+(aq) + 2\ e^- \longrightarrow H_2O(g) \qquad \textbf{[7.20]}$$

As with galvanic cells, the overall cell equation is the sum of the two half-reactions:

$$H_2(g) + \tfrac{1}{2}\ O_2(g) + 2\ \cancel{H^+(aq)} + 2\ \cancel{e^-} \longrightarrow 2\ \cancel{H^+(aq)} + H_2O(g) + 2\ \cancel{e^-} \qquad \textbf{[7.21]}$$

The 2 e^- and 2 H^+ appearing on both sides of the arrow can be canceled:

$$H_2(g) + \tfrac{1}{2}\ O_2(g) \longrightarrow H_2O(g) \qquad \textbf{[7.22]}$$

In Section 5.5, we showed this chemical equation with whole-number coefficients as:

$2\ H_2(g) + O_2(g) \longrightarrow 2\ H_2O(g)$

The electrons flowing from the anode to the cathode of a fuel cell move through an external circuit to do work, which is the whole point of the device. Thus, in a fuel cell, a transfer of electrons occurs from H_2 to O_2. This occurs with no flame, with relatively little heat, and without producing any light. Because of these characteristics, the reaction is not classed as combustion. If only the energy-producing step is considered (admittedly omitting other parts of the energy picture), hydrogen fuel cells are considered a more environmentally friendly way to produce electricity than are coal-fired or nuclear power plants. No carbon-containing greenhouse gases are produced, no air pollutants are emitted, and no spent nuclear fuel needs to be disposed of. Water is the only chemical product if hydrogen is the fuel, an added benefit for the astronauts on the space shuttle, who relied on it as their source of water while in space.

The overall reaction (Equation 7.22) releases 249 kJ of energy per mole of water formed. But instead of liberating most of this energy in the form of heat, the fuel cell converts 45–55% of it to electric energy. This direct production of electricity eliminates the inefficiencies associated with using heat to do work to produce electricity. Internal combustion engines are only 20–30% efficient in deriving energy from fossil fuels. Table 7.4 shows a comparison of fuel combustion with fuel cell technology.