ured directly. This is because there can be no transfer of electrons unless both the anode and the cathode are connected to form a complete circuit. A relative value for the potential of a half-reaction can be determined by connecting it to a standard half-cell as a reference. This standard half-cell, shown in **Figure 11,** is called a standard hydrogen electrode, or SHE. It consists of a platinum electrode dipped into a 1.00 M acid solution surrounded by hydrogen gas at 1 atm pressure and 25°C. Other electrodes are ranked according to their ability to reduce hydrogen under these conditions.

The anodic reaction for the standard hydrogen electrode is described by the forward half-reaction in the following equilibrium equation.

$$\overset{0}{H_2}(g) \rightleftarrows \overset{+1}{2H^+}(aq) + 2e^-$$

The cathodic half-reaction is the reverse. An arbitrary potential of 0.00 V is assigned to both of these half-reactions. *The potential of a half-cell under standard conditions measured relative to the standard hydrogen electrode is a* **standard electrode potential,** E^0. Electrode potentials are expressed as *potentials for reduction.* These reduction potentials provide a reliable indication of the tendency of a substance to be reduced. **Figure 12** shows how the SHE is used to find the electrode potentials of the zinc and copper half-cells. Half-reactions for some common electrodes and their standard electrode potentials are listed in **Table 1** on the next page.

Effective oxidizing agents, such as Cu^{2+} and F_2, have positive E^0 values. Half-reactions with negative reduction potentials prefer oxidation over reduction. Negative E^0 values indicate that the metal or other electrode is more willing to give up electrons than hydrogen. Effective reducing agents, such as Li and Zn, have negative E^0 values.

When a half-reaction is written as an oxidation reaction, the sign of its electrode potential is reversed, as shown for the oxidation and reduction half-reactions for zinc.

$$Zn^{2+} + 2e^- \longrightarrow Zn \qquad E^0 = -0.76 \text{ V}$$
$$Zn \longrightarrow Zn^{2+} + 2e^- \qquad E^0 = +0.76 \text{ V}$$

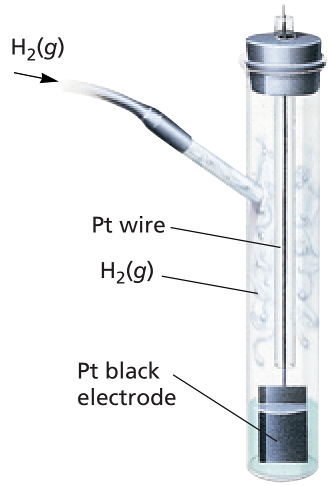

FIGURE 11 A hydrogen electrode is the standard reference electrode for measuring electrode potentials. The electrode surface in contact with the solution is actually a layer of hydrogen adsorbed onto the surface of the platinum.

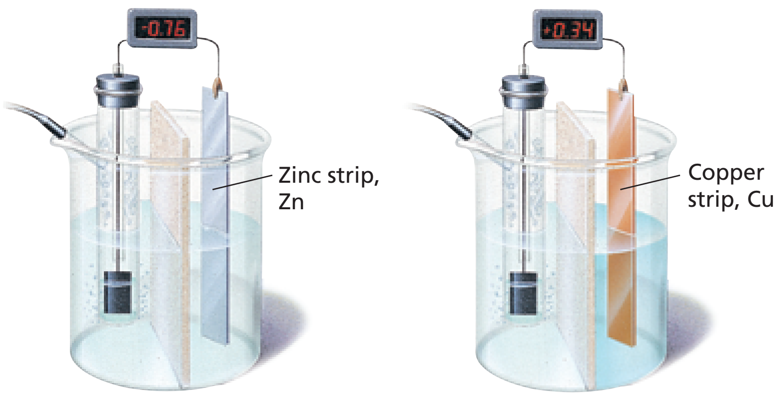

FIGURE 12 The electrode potentials of zinc and copper half-cells are measured by coupling them with a standard hydrogen electrode.