Analysis

(b) (i) The acid ($H_2SO_{4(aq)}$), bases ($NaOH_{(aq)}$, $Na_2CO_{3(aq)}$), and solutions of neutral ionic compounds ($NaCl_{(aq)}$, $KNO_{3(aq)}$) were all conductors. The solution of a molecular compound ($C_6H_{12}O_{6(aq)}$) was a nonconductor.

(ii) Distilled water was a nonconductor, while tap water was a fair conductor. The battery paste was a very good conductor.

(iii) The metals (copper and zinc) were good conductors, while the nonmetals (sulfur and charcoal) were nonconductors.

(c) Conductors: $NaOH_{(aq)}$, $Na_2CO_{3(aq)}$, $H_2SO_{4(aq)}$, $NaCl_{(aq)}$, $KNO_{3(aq)}$, tap water, battery paste, copper, zinc
Nonconductors: $C_6H_{12}O_{6(aq)}$, distilled water, sulfur, charcoal (carbon)

Evaluation

(d) Student answers will vary, but students should find general agreement between their predictions and observations. The observations matched the predictions. [Students may have had some difficulty in predicting the conductivity of tap water and charcoal.]

(e) Sources of error will vary, but may include the use of an insufficiently accurate conductivity tester and contamination of the samples. Preparing fresh solutions from pure solids might ensure that the solutions are pure.

Synthesis

(f) The nonconducting liquids in this activity (distilled water and glucose solution) are molecular substances.

(g) The elements that are conductors are all metals; they are found on the left and in the centre of the periodic table (left of the staircase line).

5.7 GALVANIC CELLS

TRY THIS ACTIVITY: ELECTROCHEMICAL GIZMOS

(Page 344)

(a) The combination of tap water and two different electrodes made the clock turn on.

(b) Student answers may vary. The strips must be different metals, so that one metal attracts electrons more strongly than the other, making electrons flow along the wire.

(c) Distilled water is pure H_2O. Tap water is a mixture of water and various dissolved substances, including electrolytes. The presence of ions in tap water should enhance the conductivity of the solution.

PRACTICE

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Understanding Concepts

(a) anode half-reaction: $Zn_{(s)} \rightarrow Zn^{2+}_{(aq)} + 2\ e^-$
cathode half-reaction: $Pb^{2+}_{(aq)} + 2\ e^- \rightarrow Pb_{(s)}$
overall cell reaction: $Pb^{2+}_{(aq)} + Zn_{(s)} \rightarrow Pb_{(s)} + Zn^{2+}_{(aq)}$

(b) anode half-reaction: $Mg_{(s)} \rightarrow Mg^{2+}_{(aq)} + 2\ e^-$
cathode half-reaction: $2\ Ag^{+}_{(aq)} + 2\ e^- \rightarrow 2\ Ag_{(s)}$
overall cell reaction: $2\ Ag^{+}_{(aq)} + Mg_{(s)} \rightarrow 2\ Ag_{(s)} + Mg^{2+}_{(aq)}$

SECTION 5.7 QUESTIONS

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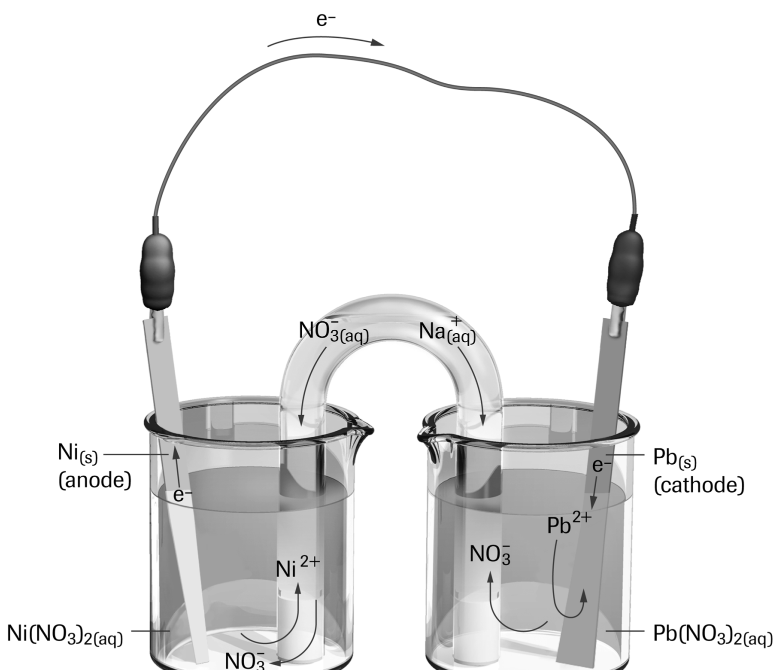
Understanding Concepts

1. During the operation of a galvanic cell, stored chemical energy is converted to electrical energy.
2. The anode and cathode in galvanic cells are both solids and good conductors of electricity. They also provide a surface at which the cell reactions can occur. They are different in their reactivity: the degree to which they attract electrons. Oxidation occurs at the anode and reduction occurs at the cathode.
3. The two electrodes must be connected with an electrical conductor—a wire.
   The solutions must also be connected with a conducting solution—the salt bridge.

4. anode half-reaction: $Mg_{(s)} \rightarrow Mg^{2+}_{(aq)} + 2\ e^-$
   cathode half-reaction: $Zn^{2+}_{(aq)} + 2\ e^- \rightarrow Zn_{(s)}$
   overall cell reaction: $Zn^{2+}_{(aq)} + Mg_{(s)} \rightarrow Zn_{(s)} + Mg^{2+}_{(aq)}$
5. The cell potential measures the difference in electrical potential energy between the two electrodes of the cell.
6. Removing the salt bridge breaks the electrolyte connection in the cell. There is no longer a continuous path for the electric charges to flow along, so the cell potential drops to zero.
7. (a) anode: copper cathode: silver
   (b) anode half-reaction: $Cu_{(s)} \rightarrow Cu^{2+}_{(aq)} + 2\ e^-$
   cathode half-reaction: $2\ Ag^{+}_{(aq)} + 2\ e^- \rightarrow 2\ Ag_{(s)}$
   (c) overall cell reaction: $2\ Ag^{+}_{(aq)} + Cu_{(s)} \rightarrow 2\ Ag_{(s)} + Cu^{2+}_{(aq)}$
   (d) Electrons flow from anode (copper) to cathode (silver).
   (e) Negative ions (anions: $NO_3{}^-{}_{(aq)}$) flow towards the anode. Positive ions (cations: $Ag^{+}_{(aq)}$ and $Cu^{2+}_{(aq)}$) flow towards the cathode.
   (f) Since the copper electrode is the site of oxidation, the mass of the electrode is expected to decrease as copper solid is converted to copper(II) ions. Conversely, the mass of the silver electrode should increase due to the reduction of silver ions to silver metal.
   (g) Sodium nitrate is a suitable electrolyte because it will not react with the contents of the cell. If sodium chloride were used, a precipitate of silver chloride would form in the cathode half-cell.

Applying Inquiry Skills

8. (a) and (b)



Making Connections

9. Galvani believed that electricity was somehow stored in the muscle tissue in the frog. In fact, Galvani spent a considerable amount of time trying to prove the existence of what he termed “animal electricity.” Alessandro Volta, using sensitive galvanometers that he had developed, showed that the movement of the frog leg depended on the metals in contact with the fluid in the muscle tissue. Volta’s findings resulted in the invention of the first battery.

Extension

10. A pH meter measures potential difference between a pH-sensitive electrode and a reference electrode, and converts this measurement into a pH value. The potential difference increases as the hydrogen ion concentration in the solution being tested increases. The pH-sensitive electrode consists of a glass tube with a very thin bulb of pH-sensitive glass at one end. The glass in the bulb is thin enough to allow hydrogen ions from the test solution to migrate across it. The electrode detects the presence of the hydrogen ions and sends a signal along a silver wire to the meter.
    The reference electrode is similar in structure to the pH electrode, except that it lacks the pH-sensitive bulb.