$Zn_{(s)} + 2\ Ag^{+}_{(aq)} \rightarrow 2\ Ag_{(s)} + Zn^{2+}_{(aq)}$
$Zn_{(s)} + Cu^{2+}_{(aq)} \rightarrow Cu_{(s)} + Zn^{2+}_{(aq)}$
$Zn_{(s)} + Fe^{2+}_{(aq)} \rightarrow Fe_{(s)} + Zn^{2+}_{(aq)}$

$Fe_{(s)} + 2\ Ag^{+}_{(aq)} \rightarrow 2\ Ag_{(s)} + Fe^{2+}_{(aq)}$
$Fe_{(s)} + Cu^{2+}_{(aq)} \rightarrow Cu_{(s)} + Fe^{2+}_{(aq)}$

$Cu_{(s)} + 2\ Ag^{+}_{(aq)} \rightarrow 2\ Ag_{(s)} + Cu^{2+}_{(aq)}$

Evaluation

(h) The reaction of $Mg_{(s)}$ with $ZnSO_{4(aq)}$ was particularly difficult to detect because the deposit (zinc) that formed on the magnesium was very similar in colour to magnesium.
(i) The observed reactions are identical to the predictions made in (b).
(j) Because of its success in predicting reactions in (a), it can be concluded that the activity series is a reliable tool for predicting the reactivity of metals.

Synthesis

(k) Mg Zn Fe Cu Ag
most reactive ⟶ least reactive
(l) $Mg^{2+}_{(aq)}$ $Zn^{2+}_{(aq)}$ $Fe^{2+}_{(aq)}$ $Cu^{2+}_{(aq)}$ $Ag^{+}_{(aq)}$
least reactive ⟶ most reactive
(m) The reactivity order of the metals and their ions is opposite. The least reactive metal yields the most reactive ion, and vice versa.

5.6 INVESTIGATION: CONDUCTORS AND NONCONDUCTORS

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Prediction

(a) 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)
Students might predict that tap water is a nonconductor, or (because graphite is a conductor) that charcoal is a conductor.

Observations

Substance	Conductivity	pH
sodium hydroxide solution, $NaOH_{(aq)}$	good	13
sodium carbonate solution, $Na_2CO_{3(aq)}$	good	10
sulfuric acid, $H_2SO_{4(aq)}$	good	1
sodium chloride solution, $NaCl_{(aq)}$	good	7
potassium nitrate solution, $KNO_{3(aq)}$	good	7
glucose solution, $C_6H_{12}O_{6(aq)}$	none	7
distilled water, $H_2O_{(l)}$	poor	7
tap water	fair	7
battery paste	good	11
sulfur, $S_{(s)}$	none	n/a
copper, $Cu_{(s)}$	good	n/a
zinc, $Zn_{(s)}$	good	n/a
charcoal (carbon), $C_{(s)}$	none	n/a

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

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(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.