(c) The thin coating of titanium oxide isolates titanium atoms from their environment, preventing the titanium from corroding further.

7. **Table 1** Predictions for Reactions Between Metals and Their Ions

Metal \ Ion	$Ag^{+}_{(aq)}$	$Pb^{2+}_{(aq)}$	$Ni^{2+}_{(aq)}$	$Zn^{2+}_{(aq)}$)
$Ag_{(s)}$	NR	NR	NR	NR
$Pb_{(s)}$	R	NR	NR	NR
$Ni_{(s)}$	R	R	NR	NR
$Zn_{(s)}$	R	R	R	NR

NR = no reaction; R = reaction

8. (a) Steel wool is added to the copper(II) sulfate solution and allowed to react. Grains of copper metal are observed to form on the steel wool. Once the blue colour of the solution has completely disappeared, it is safe to assume that most of the copper(II) ions have been converted to copper atoms. The mixture then is filtered to separate the remaining solids from the solution.
   (b) $CuSO_{4(aq)} + Fe_{(s)} \rightarrow FeSO_{4(aq)} + Cu_{(s)}$
   (c) The copper ions could also be removed from the solution by precipitating them with a carbonate solution such as sodium carbonate. The solubility table (Appendix D4) suggests that copper(II) carbonate is insoluble in water and, as a result, should precipitate.
   (d) Student answers will vary. Removing copper(II) ions using steel wool is more effective because the solids left over at the end of the process are large enough to be filtered easily. Precipitation reactions, like the addition of sodium carbonate to copper(II) sulfate, often produce very fine precipitates that quickly clog the filter paper, making the separation cumbersome. Furthermore, steel wool is easier to obtain than is a compound to precipitate copper(II) ions.

Making Connections

9. (a) $2\ Al_{(s)} + Fe_2O_{3(s)} \rightarrow 2\ Fe_{(s)} + Al_2O_{3(s)}$
   (b) Student answers may vary. http://www.ilpi.com/genchem/demo/thermite/#demo
   (c) The Thermite process has been used to weld sections of railroad track together.

Extension

10. **Analysis**
   (a) The activity series of the three halogens is
   chlorine (most reactive)
   bromine
   iodine (least reactive)
   (b) Fluorine should be at the top of the halogen activity series since the observed reactivity of the other halogens follows the order of the halogens in the periodic table.

5.5 INVESTIGATION: TESTING THE ACTIVITY SERIES

(Pages 391–392)

Prediction

(a) According to the activity series, the following combinations of metals and solutions should react:

$Mg_{(s)}$ with $AgNO_{3(aq)}$
$Mg_{(s)}$ with $CuSO_{4(aq)}$
$Mg_{(s)}$ with $FeSO_{4(aq)}$
$Mg_{(s)}$ with $ZnSO_{4(aq)}$

$Zn_{(s)}$ with $AgNO_{3(aq)}$
$Zn_{(s)}$ with $CuSO_{4(aq)}$
$Zn_{(s)}$ with $FeSO_{4(aq)}$

$Fe_{(s)}$ with $AgNO_{3(aq)}$

$Fe_{(s)}$ with $CuSO_{4(aq)}$

$Cu_{(s)}$ with $AgNO_{3(aq)}$

Hypothesis

(b) The prediction is based on the fact that each of the metals listed in (a) is above the metal in the compound on the activity series.

Observations and Analysis

(c), (d), (e)

Table 1 Reactions of Metals in Metal Ion Solutions

		Metals				
		$Ag_{(s)}$	$Cu_{(s)}$	$Fe_{(s)}$	$Zn_{(s)}$	$Mg_{(s)}$
Metal ion solutions	$AgNO_{3(aq)}$	NR	R fuzzy silvery black deposit on the metal	R fuzzy silvery black deposit on the metal	R fuzzy silvery black deposit on the metal	R fuzzy silvery black deposit on the metal
	$CuSO_{4(aq)}$	NR	NR	R reddish deposit on the metal; solution turns green	R reddish and black deposits on the metal; some bubbles	R reddish deposit on the metal; some bubbles
	$FeSO_{4(aq)}$	NR	NR	NR	R zinc surface darkens	R bubbles on metal surface; black deposit on metal
	$ZnSO_{4(aq)}$	NR	NR	NR	NR	R grey deposit forming on the metal
	$Mg(NO_3)_{2(aq)}$	NR	NR	NR	NR	NR

(f) The metal–solution combinations that resulted in reactions are:

$Mg_{(s)}$ with $AgNO_{3(aq)}$
$Mg_{(s)}$ with $CuSO_{4(aq)}$
$Mg_{(s)}$ with $FeSO_{4(aq)}$
$Mg_{(s)}$ with $ZnSO_{4(aq)}$

$Zn_{(s)}$ with $AgNO_{3(aq)}$
$Zn_{(s)}$ with $CuSO_{4(aq)}$
$Zn_{(s)}$ with $FeSO_{4(aq)}$

$Fe_{(s)}$ with $AgNO_{3(aq)}$
$Fe_{(s)}$ with $CuSO_{4(aq)}$

$Cu_{(s)}$ with $AgNO_{3(aq)}$

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

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

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

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

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

(Page 393)

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