$S_{(s)} + O_{2(g)} \rightarrow SO_{2(g)}$ synthesis (combustion)

$2\ SO_{2(g)} + O_{2(g)} \rightarrow 2\ SO_{3(g)}$ synthesis (combustion)

$SO_{3(g)} + H_2O_{(l)} \rightarrow H_2SO_{4(aq)}$ synthesis

(b) Sulfur trioxide is a byproduct of the combustion of gasoline in car engines. In the atmosphere it reacts with condensed water on dust particles, producing sulfuric acid. Atmospheric sulfuric acid is one of the acids that is responsible for the increased acidity of precipitation known as acid rain.

4. (a) Nitrogen monoxide decomposes into nitrogen and oxygen.

$$2\ NO_{(g)} \xrightarrow{Pt/Pd} N_{2(g)} + O_{2(g)}$$

(b) The platinum/palladium catalytic converter built into today's automobiles catalyzes the decomposition of nitrogen monoxide — which is a combustion engine exhaust pollutant — into harmless nitrogen and oxygen.

3.3 SINGLE DISPLACEMENT REACTIONS

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Understanding Concepts

1. In single displacement reactions, like displaces like – a metallic element takes the place of a metal in a compound; a nonmetallic element takes the place of a nonmetal in a compound.
2. An "activity series" is a list of elements arranged in order of their reactivity, based upon empirical evidence gathered from single displacement reactions.
3. (a) $Zn_{(s)} + CuCl_{2(aq)} \rightarrow Cu_{(s)} + ZnCl_{2(aq)}$

   (b) $Br_{2(aq)} + CaCl_{2(aq)} \rightarrow NR$

   (c) $Pb_{(s)} + 2\ HCl_{(aq)} \rightarrow H_{2(g)} + PbCl_{2(aq)}$

   (d) $Cl_{2(aq)} + 2\ NaI_{(aq)} \rightarrow 2\ NaCl_{(aq)} + I_{2(s)}$

   (e) $Ca_{(s)} + 2\ H_2O_{(l)} \rightarrow H_{2(g)} + Ca(OH)_{2(aq)}$

   (f) $Au_{(s)} + ZnSO_{4(aq)} \rightarrow NR$

   (g) $Sn_{(s)} + 2\ AgNO_{3(aq)} \rightarrow 2\ Ag_{(s)} + Sn(NO_3)_{2(aq)}$

   (h) $2\ Al_{(s)} + 3\ H_2O_{(l)} \rightarrow 3\ H_{2(g)} + Al_2O_{3(aq)}$

   (i) $Br_{2(aq)} + MgI_{2(aq)} \rightarrow MgBr_{2(aq)} + I_{2(s)}$

   (j) $2\ Al_{(s)} + 3\ ZnSO_{4(aq)} \rightarrow 3\ Zn_{(s)} + Al_2(SO_4)_{3(aq)}$

4. Generally speaking, the more reactive elements will replace the less reactive elements. Thus, within the metal group, the more reactive metal elements are the ones with low electronegativity values and they will replace metal elements with higher electronegativity values. For example, lithium has an electronegativity value of 1.0 and will replace potassium, which has an electronegativity value of 0.8. (It should be noted that there are a number of exceptions to this generalization.)

   Within the nonmetal group, the more reactive nonmetal elements are the ones with high electronegativity values and they will replace nonmetal elements with lower electronegativity values. For example, fluorine has an electronegativity value of 4.0 and will replace chlorine, which has an electronegativity value of 3.0. (Again, it should be noted that there are a number of exceptions to this generalization.)
5. As you move from left to right within the same period, the elements of the periodic table show a general increase in electronegativity values. The most reactive metals are the ones with lower electronegativity values and are positioned at the left of a period. Thus, as you move from left to right within the same period, the metals become more electronegative and therefore less reactive. However, the most reactive nonmetals are the ones with high electronegativity values and are positioned at the right of a period. Thus, as you move from left to right within the same period, the nonmetals become more electronegative and therefore more reactive.

6. (a) The Goldschmidt process is a single displacement reaction.
   (b) $CrO_{(s)}$ or $Cr_2O_{3(s)}$, $MnO_{(s)}$, $BaO_{(s)}$
   (c) $2\ Al_{(s)} + Cr_2O_{3(s)} \rightarrow 2\ Cr_{(s)} + Al_2O_{3(s)}$

   $2\ Al_{(s)} + 3\ MnO_{(s)} \rightarrow 3\ Mn_{(s)} + Al_2O_{3(s)}$

   $2\ Al_{(s)} + 3\ BaO_{(s)} \rightarrow NR$

   (According to the activity series, aluminum is less reactive than barium and should not displace it from barium oxide. There should be no reaction.)
   (d) The more reactive aluminum displaces the chromium and manganese from their oxides, producing the pure metals of chromium and manganese, along with aluminum oxide.
7. (a) titanium dioxide + carbon + chlorine → titanium tetrachloride + carbon dioxide
   magnesium + titanium tetrachloride → titanium + magnesium chloride
   (b) $2\ Mg_{(s)} + TiCl_{4(s)} \rightarrow Ti_{(s)} + 2\ MgCl_{2(s)}$ single displacement reaction
   (c) For the metals, the lower the electronegativity, the more reactive the metal should be.
   Magnesium has a lower electronegativity value than titanium and is more reactive than titanium. Therefore magnesium displaces titanium, producing pure titanium along with magnesium chloride.

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Understanding Concepts

8. As a result of their greater reactivity, calcium and sodium are most commonly found in compounds, ores, rather than as elements. In order to extract these two elements from their ores, they must be reacted with metals that are higher in the activity series. However, according to the activity series, calcium and sodium are high in the activity series and are two of the most reactive elements, so they would tend not to be displaced by other metals in an aqueous environment.

Making Connections

9. (a) The student is to use the Internet to carry out research on a metallic element that is mined in Canada, with respect to how and where it is mined, extracted, and purified, and the uses of the metal.
   (b) The findings are to be compiled in a table that lists the positive and negative aspects. The table is to be used to help the student decide on changes that could be made in the way we use the metal or the way we obtain it. The student is to report on the findings.


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Understanding Concepts

10. Yellow brass is an alloy that comprises 70% copper by mass, and 30% zinc by mass. It is harder and more resistant to corrosion than copper alone.

    Stainless steel is an alloy that comprises a number of metals, but mainly comprises 79.06 – 81.06% iron by mass, and 16–18% chromium by mass. It is more resistant to corrosion than iron alone.

Making Connections

11. (a) The higher acidic nature of women's skin causes some of the copper in the gold ring to dissolve, leaving deposits of dissolved copper. Women wear 18K gold rings because there is less copper content by mass in the 18K gold, thus reducing the amount of copper available to dissolve.
    (b) The 14K gold alloy is a solid solution that consists of gold, silver, copper, and zinc. The greenish stain that develops beneath a 14K gold bracelet is the result of acidic skin that has caused some of the copper in the gold bracelet to dissolve back into the liquid phase. The green copper stain becomes visible when the wearer's body dissolves the copper faster than it absorbs it. This happens when there is profuse perspiration, or when our sweat becomes more acidic.

12. The student is to use the Internet to research the composition of various steels and to choose one alloy and list its properties and its applications. The student is then to write a short "infomercial" advertising the benefits of this material to potential users and to include any precautions necessary for its safe use.

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13. The student is to use the Internet to research the applications of aluminum and its alloys and the environmental issues surrounding aluminum production. The student is to use the findings to comment on the following statement: Risks to the environment posed by mining and refining aluminum are outweighed by the technological benefits of aluminum alloys.

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Making Connections

14. The student is to research one of the careers listed on page 135 or a related career, and write a report that:
    (a) provides a general description of the nature of the work and how chemical reactions are involved;
    (b) describes the educational background and the length of study required to obtain employment in this field;
    (c) gives examples of programs offered by educational institutions leading to this career;
    (d) forecasts employment trends for this field; and
    (e) describes working conditions and salary.

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3.4 DOUBLE DISPLACEMENT REACTIONS

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Understanding Concepts

1. The following monatomic ions form compounds that have high solubility in water:

Group 1 monatomic ions that form compounds with Cl^-, Br^-, and I^-.

Group 1 and Group 2 monatomic ions that form compounds with S^{2-}.

2. NH_4^+ is the positive polyatomic ion that forms compounds that all have high solubility in water.

3. (a) $KCl_{(aq)}$
   (b) $Ca(NO_3)_{2(aq)}$
   (c) $Na_2SO_{4(aq)}$
   (d) $AgC_2H_3O_{2(s)}$
   (e) $NH_4Br_{(aq)}$
   (f) $BaS_{(aq)}$
   (g) $PbI_{2(s)}$
   (h) $Ca(OH)_{2(s)}$
   (i) $Fe(OH)_{3(s)}$
   (j) $PbSO_{4(s)}$
   (k) $Ca_3(PO_4)_{2(s)}$
   (l) $KMnO_{4(aq)}$
   (m) $NH_4NO_{3(aq)}$
   (n) $CoCl_{2(aq)}$
   (o) $CaCO_{3(aq)}$

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Understanding Concepts

4. The reaction involves two ionic compounds as reactants.

5. (a) $Cu(NO_3)_{2(aq)} + MgCl_{2(aq)} \rightarrow CuCl_{2(s)} + Mg(NO_3)_{2(aq)}$
   (b) $3\ Ba(OH)_{2(aq)} + Fe_2(SO_4)_{3(aq)} \rightarrow 3\ BaSO_{4(s)} + 2\ Fe(OH)_{3(s)}$
   (c) $Mg(OH)_{2(s)} + H_2SO_{4(aq)} \rightarrow MgSO_{4(aq)} + 2\ H_2O_{(l)}$
   (d) $(NH_4)_2S_{(aq)} + FeSO_{4(aq)} \rightarrow (NH_4)_2SO_{4(aq)} + FeS_{(s)}$