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.

GO TO www.science.nelson.com, Chemistry 11, Teacher Centre

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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## PRACTICE

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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

## PRACTICE

**(Page 138)**

### 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) $CaCO_{3(aq)}$

## PRACTICE

**(Page 141)**

### 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) $(NH_4)_2S_{(aq)} + FeSO_{4(aq)} \rightarrow (NH_4)_2SO_{4(aq)} + FeS_{(s)}$

 

6. $AB + CD \rightarrow AD + CB$
As the equation above shows, the ions “change partners” to form products. This type of reaction commonly occurs in aqueous solutions.
7. (a) $KNO_{3(aq)}$
(b) $CaCl_{2(aq)}$
(c) $Mg(OH)_{2(s)}$
(d) $Al_2(SO_4)_{3(aq)}$
(e) $PbI_{2(s)}$
(f) $Ca_3(PO_4)_{2(s)}$
(g) $(NH_4)_2CO_{3(aq)}$
8. (a) $2\ KCl_{(aq)} + Cu(NO_3)_{2\ (aq)} \rightarrow 2\ KNO_{3(aq)} + CuCl_{2(s)}$
(b) $MgCl_{2(aq)} + Ca(OH)_{2(aq)} \rightarrow Mg(OH)_{2(s)} + CaCl_{2(aq)}$
(c) $MgCl_{2(aq)} + Ca(OH)_{2(aq)} \rightarrow CaCl_{2(aq)} + Mg(OH)_{2(s)}$
(d) $3\ K_2SO_{4(aq)} + 2\ AlCl_{3(aq)} \rightarrow 6\ KCl_{(aq)} + Al_2(SO_4)_{3(aq)}$
(e) $CuI_{2(s)} + PbSO_{4(s)} \rightarrow CuSO_{4(aq)} + PbI_{2(s)}$
(f) $3\ CaI_{2(aq)} + Pb_3(PO_4)_{2(s)} \rightarrow 3\ PbI_{2(s)} + Ca_3(PO_4)_{2(s)}$
(g) $(NH_4)_2S_{(aq)} + CaCO_{3(s)} \rightarrow CaS_{(aq)} + (NH_4)_2CO_{3(aq)}$
9. (a) single displacement
(b) double displacement
10. (a) $Cl_{2(g)} + 2\ NaBr_{(aq)} \rightarrow 2\ NaCl_{(aq)} + Br_{2(g)}$ single displacement
(b) $H_2SO_{4(aq)} + 2\ NaOH_{(aq)} \rightarrow 2\ H_2O_{(l)} + Na_2SO_{4(aq)}$ double displacement
(c) $3\ Ca(NO_3)_{2(aq)} + 2\ Na_3PO_{4(aq)} \rightarrow Ca_3(PO_4)_{2(s)} + 6\ NaNO_{3(aq)}$ double displacement
11. (a) $Al_{(s)} + 3\ AgNO_{3(aq)} \rightarrow 3\ Ag_{(s)} + Al(NO)_{3(aq)}$ single displacement
(b) $Cl_{2(g)} + 2\ NaBr_{(aq)} \rightarrow 2\ NaCl_{(aq)} + Br_{2(g)}$ single displacement
(c) $Zn_{(s)} + H_2SO_{4(aq)} \rightarrow H_{2(g)} + ZnSO_{4(aq)}$ single displacement
(d) $2\ AgNO_{3(aq)} + MgCl_{2(aq)} \rightarrow 2\ AgCl_{(s)} + Mg(NO_3)_{2(aq)}$ double displacement
(e) $Na_2C_2O_{4(aq)} + CaCl_{2(aq)} \rightarrow CaC_2O_{4(aq)} + 2\ NaCl_{(aq)}$ double displacement
(f) $2\ Na_{(s)} + 2\ H_2O_{(l)} \rightarrow H_{2(g)} + 2\ NaOH_{(aq)}$ single displacement
(g) $3\ KOH_{(aq)} + FeCl_{3(aq)} \rightarrow 3\ KCl_{(aq)} + Fe(OH)_{3(s)}$ double displacement
12. (a) $Ca_3(PO_4)_{2(s)}$ calcium phosphate
(b) $3\ H_2SO_{4(aq)} + Ca_3(PO_4)_{2(s)} \rightarrow 2\ H_3PO_{4(aq)} + 3\ CaSO_{4(s)}$
(c) The simple procedure of “filtering” could be employed to isolate aqueous phosphoric acid from the solid calcium phosphate.
(d) If sodium phosphate is used in place of calcium phosphate as a reactant, the products of the reaction would be aqueous phosphoric acid and aqueous sodium sulfate. Sodium sulfate is highly soluble at SATP, and would pass through a simple filter. Thus the simple procedure of filtering would not be sufficient to isolate the phosphoric acid. The fertilizer manufacturer would prefer to avoid the additional costs that would be associated with a more involved process of isolating the phosphoric acid.

 

## SECTIONS 3.3-3.4 QUESTIONS

**(Page 143)**

### Understanding Concepts

1. (a)-(e)

| | $Cl^-$ | $Br^-$ | $NO_3^-$ | $C_2H_3O_2^-$ | $PO_4^{3-}$ | $SO_4^{2-}$ | $OH^-$ | $SO_3^{2-}$ |
|---|---|---|---|---|---|---|---|---|
| $K^+$ | $KCl$ potassium chloride, binary ionic, sdr with zinc would not occur | $KBr$ potassium bromide, binary ionic, sdr with zinc would not occur | $KNO_3$ potassium nitrate, tertiary ionic, sdr with zinc would not occur | $KC_2H_3O_2$ potassium acetate, quaternary ionic, sdr with zinc would not occur | $K_3PO_4$ potassium phosphate, tertiary ionic, sdr with zinc would not occur | $K_2SO_4$ potassium sulfate, tertiary ionic, sdr with zinc would not occur | $KOH$ potassium hydroxide, tertiary ionic, sdr with zinc would not occur | $K_2SO_3$ potassium sulfite, tertiary ionic, sdr with zinc would not occur |
| $Ca^{2+}$ | $CaCl_2$ calcium chloride, binary ionic, sdr with zinc would not occur | $CaBr_2$ calcium bromide, binary ionic, sdr with zinc would not occur | $Ca(NO_3)_2$ calcium nitrate, tertiary ionic, sdr with zinc would not occur | $Ca(C_2H_3O_2)_2$ calcium acetate, quaternary ionic, sdr with zinc would not occur | $Ca_3(PO_4)_2(s)$ calcium phosphate, tertiary ionic, sdr with zinc would not occur | $CaSO_4(s)$ calcium sulfate, tertiary ionic, sdr with zinc would not occur | $Ca(OH)_2(s)$ calcium hydroxide, tertiary ionic, sdr with zinc would not occur | $CaSO_3(s)$ calcium sulfite, tertiary ionic, sdr with zinc would not occur |
| $Al^{3+}$ | $AlCl_3$ aluminum chloride, binary ionic, sdr with zinc would not occur | $AlBr_3$ aluminum bromide, binary ionic, sdr with zinc would not occur | $Al(NO_3)_3$ aluminum nitrate, tertiary ionic, sdr with zinc would not occur | $Al(C_2H_3O_2)_3$ aluminum acetate, quaternary ionic, sdr with zinc would not occur | $AlPO_4(s)$ aluminum phosphate, tertiary ionic, sdr with zinc would not occur | $Al_2(SO_4)_3$ aluminum sulfate, tertiary ionic, sdr with zinc would not occur | $Al(OH)_3(s)$ aluminum hydroxide, tertiary ionic, sdr with zinc would not occur | $Al_2(SO_3)_3(s)$ aluminum sulfite, tertiary ionic, sdr with zinc would not occur |
| $Cu^+$ | $CuCl$ copper(I) chloride, binary ionic, sdr with zinc will occur | $CuBr$ copper(I) bromide, binary ionic, sdr with zinc will occur | $CuNO_3$ copper(I) nitrate, tertiary ionic, sdr with zinc will occur | $CuC_2H_3O_2$ copper(I) acetate, quaternary ionic, sdr with zinc will occur | $Cu_3PO_4(s)$ copper(I) phosphate, tertiary ionic, sdr with zinc will occur | $Cu_2SO_4$ copper(I) sulfate, tertiary ionic, sdr with zinc will occur | $CuOH(s)$ copper(I) hydroxide, tertiary ionic, sdr with zinc will occur | $Cu_2SO_3(s)$ copper(I) sulfite, tertiary ionic, sdr with zinc will occur |
| $Pb^{2+}$ | $PbCl_2(s)$ lead(II) chloride, binary ionic, sdr with zinc will occur | $PbBr_2(s)$ lead(II) bromide, binary ionic, sdr with zinc will occur | $Pb(NO_3)_2$ lead(II) nitrate, tertiary ionic, sdr with zinc will occur | $Pb(C_2H_3O_2)_2$ lead(II) acetate, quaternary ionic, sdr with zinc will occur | $Pb_3(PO_4)_2(s)$ lead(II) phosphate, tertiary ionic, sdr with zinc will occur | $PbSO_4(s)$ lead(II) sulfate, tertiary ionic, sdr with zinc will occur | $Pb(OH)_2(s)$ lead(II) hydroxide, tertiary ionic, sdr with zinc will occur | $PbSO_3(s)$ lead(II) sulfite, tertiary ionic, sdr with zinc will occur |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **$Fe^{3+}$** | $FeCl_3$ iron(III) chloride, binary ionic, sdr with zinc will occur | $FeBr_3$ iron(III) bromide, binary ionic, sdr with zinc will occur | $Fe(NO_3)_3$ iron(III) nitrate, tertiary ionic, sdr with zinc will occur | $Fe(C_2H_3O_2)_3$ iron(III) acetate, quaternary ionic, sdr with zinc will occur | $FePO_{4(s)}$ iron(III) phosphate, tertiary ionic, sdr with zinc will occur | $Fe_2(SO_4)_3$ iron(III) sulfate, tertiary ionic, sdr with zinc will occur | $Fe(OH)_{3(s)}$ iron(III) hydroxide, tertiary ionic, sdr with zinc will occur | $Fe_2(SO_3)_{3(s)}$ iron(III) sulfite, tertiary ionic, sdr with zinc will occur |
| **$Mg^{2+}$** | $MgCl_2$ magnesium chloride, binary ionic, sdr with zinc will occur | $MgBr_2$ magnesium bromide, binary ionic, sdr with zinc will occur | $Mg(NO_3)_2$ magnesium nitrate, tertiary ionic, sdr with zinc will occur | $Mg(C_2H_3O_2)_2$ magnesium acetate, quaternary ionic, sdr with zinc will occur | $Mg_3(PO_4)_{2(s)}$ magnesium phosphate, tertiary ionic, sdr with zinc will occur | $MgSO_4$ magnesium sulfate, tertiary ionic, sdr with zinc will occur | $Mg(OH)_{2(s)}$ magnesium hydroxide, tertiary ionic, sdr with zinc will occur | $MgSO_{3(s)}$ magnesium sulfite, tertiary ionic, sdr with zinc will occur |
| **$NH_4^+$** | $NH_4Cl$ ammonium chloride, tertiary ionic, sdr with zinc will occur | $NH_4Br$ ammonium bromide, tertiary ionic, sdr with zinc will occur | $NH_4NO_3$ ammonium nitrate, tertiary ionic, sdr with zinc will occur | $NH_4C_2H_3O_2$ ammonium acetate, quaternary ionic, sdr with zinc will occur | $(NH_4)_3PO_4$ ammonium phosphate, quaternary ionic, sdr with zinc will occur | $(NH_4)_2SO_4$ ammonium sulfate, quaternary ionic, sdr with zinc will occur | $NH_4OH$ ammonium hydroxide, tertiary ionic, sdr with zinc will occur | $(NH_4)_2SO_3$ ammonium sulfite, quaternary ionic, sdr with zinc will occur |

NOTE: All substances aqueous (aq), unless noted otherwise.
sdr stands for “single displacement reaction.”

Word and chemical equation examples:

zinc + potassium chloride → NR

$Zn_{(s)} + KCl(aq) \rightarrow NR$

zinc + iron(III) acetate → iron + zinc acetate

$3\ Zn_{(s)} + 2\ Fe(C_2H_3O_2)_{3(aq)} \rightarrow 2\ Fe_{(s)} + 3\ Zn(C_2H_3O_2)_{2(aq)}$

2.

1. octane + oxygen → carbon dioxide + water combustion

$2\ C_8H_{18(g)} + 25\ O_{2(g)} \rightarrow 16\ CO_{2(g)} + 18\ H_2O_{(g)}$

Rain becomes slightly acidic due to the presence of carbon dioxide, which dissolves in atmospheric moisture and reacts to form very dilute carbonic acid, $H_2CO_{3(aq)}$. Carbon dioxide gas also contributes to the greenhouse effect, which may lead to global warming and dramatic climate changes.

2. sulfur + oxygen → sulfur dioxide synthesis (combustion)

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

Sulfur dioxide joins the naturally produced oxides in the atmosphere, and reacts with water vapour to form acids, and is responsible for the increased acidity of precipitation known as acid rain.

3. nitrogen + oxygen → nitrogen monoxide synthesis (combustion)

$N_{2(s)} + O_{2(g)} \rightarrow 2\ NO_{(g)}$

Nitrogen monoxide joins the naturally produced oxides in the atmosphere, and reacts with water vapour to form acids, and is responsible for the increased acidity of precipitation known as acid rain.

4. nitrogen monoxide + oxygen → nitrogen dioxide synthesis

$2\ NO_{(s)} + O_{2(g)} \xrightarrow{Pt} 2\ NO_{(g)}$

Nitrogen dioxide joins the naturally produced oxides in the atmosphere, and reacts with water vapour to form acids, and is responsible for the increased acidity of precipitation known as acid rain.

5. sulfur trioxide + water → sulfuric acid synthesis

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

Sulfur trioxide reacts with water vapour to form sulfuric acid, and is responsible for the increased acidity of precipitation known as acid rain.

6. nitrogen monoxide → nitrogen + oxygen decomposition

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

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.

## Applying Inquiry Skills

3. **Analysis**

(a) Y would be highest in the activity series, followed by Z, and then X, as indicated below:

Y
Z
X

(b) Y and Z would be located higher in the activity series than hydrogen. X would be located lower in the activity series than hydrogen, unless in fact it is actually hydrogen.

Using empirical evidence gathered in many experiments, scientists have been able to list the elements in order of their reactivity. The empirical evidence has shown that the more reactive element will replace the less reactive element. Since Y and Z showed evidence of reaction in water and acid - bubbles were observed - it is evident that Y and Z have reacted with the water and the acid to displace hydrogen and produce hydrogen gas. And since Y and Z displaced hydrogen, they cannot be hydrogen. The only possible choice for hydrogen would be X.

**Synthesis**

(c) X would appear higher in order than Y, as you descend the group.

For metals, the lower the electronegativity value, the more reactive the metal should be. As the evidence showed Y to be more reactive than X, it would be expected to have a lower electronegativity value than X. And since electronegativity values decrease as you move down a group, it makes sense that X would appear higher in order than Y, as you descend the group.

Y would appear to be further to the left in order than Z, as you move from left to right within the same period.

For metals, the lower the electronegativity value, the more reactive the metal should be. As the evidence showed Y to be more reactive than Z, it would be expected to have a lower electronegativity value than Z. And since electronegativity values increase as you move from left to right within the same period, it makes sense that Y would appear further to the left in order than Z, as you move from left to right within the same period.

(d) Assign the following element identities:

X = Li

Y = Na

Z = Mg

$2\ Li_{(s)} + 2\ H_2O_{(l)} \rightarrow H_{2(g)} + 2\ LiOH_{(aq)}$

$2\ Li_{(s)} + 2\ HCl_{(aq)} \rightarrow H_{2(g)} + 2\ LiCl_{(aq)}$

$2\ Na_{(s)} + 2\ H_2O_{(l)} \rightarrow H_{2(g)} + 2\ NaOH_{(aq)}$

$2\ Na_{(s)} + 2\ HCl_{(aq)} \rightarrow H_{2(g)} + 2\ NaCl_{(aq)}$

$Mg_{(s)} + 2\ H_2O_{(l)} \rightarrow H_{2(g)} + Mg(OH)_{2(s)}$

$Mg_{(s)} + 2\ HCl_{(aq)} \rightarrow H_{2(g)} + MgCl_{2(aq)}$

(e) All reactions are single displacement reactions.

With respect to the reaction with water:

Use a lighted splint to ignite the gas produced. A "pop" sound when ignited indicates hydrogen gas. The aqueous solution could be tested with pH paper to determine if it is basic. These tests would indicate that the reaction was a single displacement type, with the metal displacing hydrogen in the water ($H_2O_{(l)}$) to produce hydrogen gas and a metal hydroxide.

With respect to the reaction with acid:

Use a lighted splint to ignite the gas produced. A "pop" sound when ignited indicates hydrogen gas. The aqueous solution could be evaporated and the remaining compound analyzed to determine if it is a metal chloride. These tests would indicate that the reaction was a single displacement type, with the metal displacing hydrogen in the acid ($HCl_{(aq)}$) to produce hydrogen gas and a metal chloride.

### Making Connections

4. (a) $2K_{(s)} + BeCl_{2(s)} \xrightarrow{Pt} Be_{(s)} + 2\ KCl_{(l)}$ single displacement

   (b) Beryllium chloride should be stored dry within air and water vapour tight sealed containers. The substance should only be handled in environmentally enclosed and controlled areas, and all required protective equipment such as gas masks, protective clothing, and protective gloves should be worn.

5. (a) $C_{(s)} + SiO_{2(l)} \rightarrow Si_{(l)} + CO_{2(g)}$ single displacement

   $Si_{(s)} + 2\ Cl_{2(g)} \rightarrow SiCl_{4(l)}$ synthesis

   $2\ Mg_{(s)} + SiCl_{4(l)} \rightarrow Si_{(s)} + 2\ MgCl_{2(aq)}$ single displacement

   (b) Emissions of carbon dioxide gas (a product of the first reaction) cause rain to become slightly acidic. Carbon dioxide gas also contributes to the greenhouse effect, which may lead to global warming and dramatic climate changes.

## CHAPTER 3 REVIEW

**(Page 146)**

### Understanding Concepts

1. The kinetic molecular theory states that all matter is made up of particles in continuous random motion.

   A gas has widely separated molecules in constant, chaotic motion. The average kinetic energy of the molecules is much larger than the energy associated with the attractive forces between them.

   With liquids, the attractive forces between molecules have energies comparable to the kinetic energies of the molecules. The attractive forces are able to hold the molecules close to each other. However, the attractive forces are not strong enough to hold the molecules rigidly in place. In fact, molecules within a liquid are able to move in a more or less chaotic fashion, allowing liquids to be poured, and to flow to take the shape of their container.

   With solids, the intermolecular attractions are sufficiently strong enough to hold the molecules rigidly in place. The average kinetic energy of the molecules is much smaller than the energy associated with the attractive forces between them. The particles of a solid are not free to move. However, the molecules within a solid may undergo vibrational motion.

 