Applying Inquiry Skills

8. **Prediction**

(a) $2\ Li_2O_{(s)} \rightarrow 4\ Li_{(s)} + O_{2(g)}$
$2\ MgO_{(s)} \rightarrow 2\ Mg_{(s)} + O2_{(g)}$
$ZnCl_{2(s)} \rightarrow Zn_{(s)} + Cl_{2(g)}$

Making Connections

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

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

(b) Catalytic converters help to reduce the amounts of carbon monoxide, hydrocarbons, and nitrogen oxides in car exhaust, which are responsible for smog, acid rain, and pollution. A catalytic converter is shaped like a honeycomb and is attached to a car's exhaust pipe. It is coated with platinum and palladium, which act as catalysts (substances that speed up a chemical reaction but are recovered at the end) in the decomposition reactions of hydrocarbons to water and carbon monoxide, of carbon monoxide to carbon dioxide, and of nitrogen oxides to nitrogen and oxygen. Since the products of these reactions do not contribute to air pollution, catalytic converters are effective tools in reducing air contaminants from cars.

10. (a) Student answers will vary depending on the metal they have chosen. Copper is a metal that is rarely found in elemental form. Most copper is mined as a carbonate or oxide ore.

(b) Copper carbonate and copper oxide are treated with dilute sulfuric acid to leach the copper out as copper(II) sulfate solution. For copper oxide, the reaction is
$CuO_{(s)} + H_2SO_{4(aq)} \rightarrow CuSO_{4(aq)} + H_2O_{(l)}$
If the copper(II) sulfate solution reacts with iron, the copper is displaced, according to the following reaction equation:
$CuSO_{4(aq)} + Fe_{(s)} \rightarrow FeSO_{4(aq)} + Cu_{(s)}$
The copper has now been recovered in its elemental state.

(c) The types of reactions used to purify copper are a double displacement reaction,
$CuO_{(s)} + H_2SO_{4(aq)} \rightarrow CuSO_{4(aq)} + H_2O_{(l)}$
and a single displacement reaction,
$CuSO_{4(s)} + Fe_{(s)} \rightarrow FeSO_{4(aq)} + Cu_{(s)}$

(d) Copper mine tailings (leftover earth) are usually piled up or spread around a copper mine site. These tailings have essentially no organic matter, are highly acidic, and represent an environmental threat from blowing dust, erosion, and runoff. Also, if they run into bodies of water, they can cause damage to marine or freshwater ecosystems.

1.15 USING SOLUBILITY RULES TO PREDICT PRECIPITATE FORMATION

PRACTICE

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Understanding Concepts

1. (a) lead(II) nitrate + sodium chloride → lead(II) chloride + sodium nitrate
lead(II) chloride—low solubility
sodium nitrate—soluble
aqueous lead(II) nitrate + aqueous sodium chloride → solid lead(II) chloride + aqueous sodium nitrate
$Pb(NO_3)_{2(aq)} + NaCl_{(aq)} \rightarrow PbCl_{2(s)} + NaNO_{3(aq)}$
$Pb(NO_3)_{2(aq)} + 2\ NaCl_{(aq)} \rightarrow PbCl_{2(s)} + 2\ NaNO_{3(aq)}$

(b) sodium sulfate + calcium chloride → calcium sulfate + sodium chloride
calcium sulfate—low solubility
sodium chloride—soluble
aqueous sodium sulfate + aqueous calcium chloride → solid calcium sulfate + aqueous sodium chloride

$Na_2SO_{4(aq)} + CaCl_{2(aq)} \rightarrow CaSO_{4(s)} + NaCl_{(aq)}$
$Na_2SO_{4(aq)} + CaCl_{2(aq)} \rightarrow CaSO_{4(s)} + 2\ NaCl_{(aq)}$

(c) magnesium acetate + silver nitrate $\rightarrow$ silver acetate + magnesium nitrate
silver acetate—low solubility
magnesium nitrate—soluble
aqueous magnesium acetate + aqueous silver nitrate $\rightarrow$ solid silver acetate + aqueous magnesium nitrate
$Mg(C_2H_3O_2)_{2(aq)} + AgNO_{3(aq)} \rightarrow AgC_2H_3O_{2(s)} + Mg(NO_3)_{2(aq)}$
$Mg(C_2H_3O_2)_{2(aq)} + 2\ AgNO_{3(aq)} \rightarrow 2\ AgC_2H_3O_{2(s)} + Mg(NO_3)_{2(aq)}$

(d) sodium acetate + potassium chloride $\rightarrow$ sodium chloride + potassium acetate
potassium acetate—soluble
sodium chloride—soluble
sodium acetate + potassium chloride $\rightarrow$ no reaction

PRACTICE

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2. (a) barium chloride + silver nitrate $\rightarrow$ silver chloride + barium nitrate
silver chloride—low solubility
barium nitrate—soluble
aqueous barium chloride + aqueous silver nitrate $\rightarrow$ solid silver chloride + aqueous barium nitrate
$BaCl_{2(aq)} + AgNO_{3(aq)} \rightarrow AgCl_{(s)} + Ba(NO_3)_{2(aq)}$
$BaCl_{2(aq)} + 2\ AgNO_{3(aq)} \rightarrow 2\ AgCl_{(s)} + Ba(NO_3)_{2(aq)}$
$Ba^{2+}_{(aq)} + 2\ Cl^{-}_{(aq)} + 2\ Ag^{+}_{(aq)} + 2\ NO^{-}_{3(aq)} \rightarrow 2\ AgCl_{(s)} + Ba^{2+}_{(aq)} + 2\ NO^{-}_{3(aq)}$ (total ionic equation)
$\cancel{Ba^{2+}_{(aq)}} + 2\ Cl^{-}_{(aq)} + 2\ Ag^{+}_{(aq)} + \cancel{2\ NO^{-}_{3(aq)}} \rightarrow 2\ AgCl_{(s)} + \cancel{Ba^{2+}_{(aq)}} + \cancel{2\ NO^{-}_{3(aq)}}$
$\cancel{2}\ Ag^{+}_{(aq)} + \cancel{2}\ Cl^{-}_{(aq)} + \rightarrow \cancel{2}\ AgCl_{(s)}$
$Ag^{+}_{(aq)} + Cl^{-}_{(aq)} \rightarrow AgCl_{(s)}$ (net ionic equation)

(b) zinc chloride + lead(II) nitrate $\rightarrow$ lead(II) chloride + zinc nitrate
lead(II) chloride—low solubility
zinc nitrate—soluble
aqueous zinc chloride + aqueous lead(II) nitrate $\rightarrow$ solid lead(II) chloride + aqueous zinc nitrate
$ZnCl_{2(aq)} + Pb(NO_3)_{2(aq)} \rightarrow PbCl_{2(s)} + Zn(NO_3)_{2(aq)}$
$Zn^{2+}_{(aq)} + 2\ Cl^{-}_{(aq)} + Pb^{2+}_{(aq)} + 2\ NO^{-}_{3(aq)} \rightarrow PbCl_{2(s)} + Zn^{2+}_{(aq)} + 2\ NO^{-}_{3(aq)}$ (total ionic equation)
$\cancel{Zn^{2+}_{(aq)}} + 2\ Cl^{-}_{(aq)} + Pb^{2+}_{(aq)} + \cancel{2\ NO^{-}_{3(aq)}} \rightarrow PbCl_{2(s)} + \cancel{Zn^{2+}_{(aq)}} + \cancel{2\ NO^{-}_{3(aq)}}$
$Pb^{2+}_{(aq)} + 2\ Cl^{-}_{(aq)} \rightarrow PbCl_{2(s)}$ (net ionic equation)

SECTION 1.15 QUESTIONS

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Understanding Concepts

1. (a) $PbSO_4$—low solubility
(b) $(NH_4)_2S$—soluble
(c) $AgNO_3$—soluble
(d) AgCl—low solubility
(e) $CaCO_3$—low solubility
(f) NH_4OH—soluble
(g) $Ba(OH)_2$—soluble

2. (a) strontium nitrate + sodium sulfate $\rightarrow$ strontium sulfate + sodium nitrate
strontium sulfate—low solubility
sodium nitrate—soluble
Strontium sulfate, $SrSO_4$, precipitates.
(b) sodium acetate + silver nitrate $\rightarrow$ silver acetate + sodium nitrate
silver acetate—low solubility
sodium nitrate—soluble

Silver acetate, $AgC_2H_3O_2$, precipitates.

(c) barium nitrate + ammonium phosphate → barium phosphate + ammonium nitrate
barium phosphate—low solubility
ammonium nitrate—soluble
Barium phosphate, $Ba_3(PO_4)_2$, precipitates.

(d) sodium hydroxide + calcium nitrate → calcium hydroxide + sodium nitrate
calcium hydroxide—low solubility
sodium nitrate—soluble
Calcium hydroxide, $Ca(OH)_2$, precipitates.

3. (a) Sr(NO3)2(aq) + Na2SO4(aq) → SrSO4(s) + 2 NaNO3(aq)
$Sr^{2+}_{(aq)} + 2\ NO^{-}_{3(aq)} + 2\ Na^{+}_{(aq)} + SO^{2-}_{4(aq)} \rightarrow SrSO_{4(s)} + 2\ Na^{+}_{(aq)} + 2\ NO^{-}_{3(aq)}$ (total ionic equation)
$Sr^{2+}_{(aq)} + \cancel{2\ NO^{-}_{3(aq)}} + \cancel{2\ Na^{+}_{(aq)}} + SO^{2-}_{4(aq)} \rightarrow SrSO_{4(s)} + \cancel{2\ Na^{+}_{(aq)}} + \cancel{2\ NO^{-}_{3(aq)}}$
$Sr^{2+}_{(aq)} + SO^{2-}_{4(aq)} \rightarrow SrSO_{4(s)}$ (net ionic equation)

(b) $NaC_2H_3O_{2(aq)} + AgNO_{3(aq)} \rightarrow AgC_2H_3O_{2(s)} + NaNO_{3(aq)}$
$Na^{+}_{(aq)} + C_2H_3O_2{}^{-}_{(aq)} + Ag^{+}_{(aq)} + NO^{-}_{3(aq)} \rightarrow AgC_2H_3O_{2(s)} + Na^{+}_{(aq)} + NO^{-}_{3(aq)}$ (total ionic equation)
$\cancel{Na^{+}_{(aq)}} + C_2H_3O_2{}^{-}_{(aq)} + Ag^{+}_{(aq)} + \cancel{NO^{-}_{3(aq)}} \rightarrow AgC_2H_3O_{2(s)} + \cancel{Na^{+}_{(aq)}} + \cancel{NO^{-}_{3(aq)}}$
$Ag^{+}_{(aq)} + C_2H_3O_2{}^{-}_{(aq)} \rightarrow AgC_2H_3O_{2(s)}$ (net ionic equation)

(c) $3\ Ba(NO_3)_{2(aq)} + 2\ (NH_4)_3PO_{4(aq)} \rightarrow Ba_3(PO_4)_{2(s)} + 6\ NH_4NO_{3(aq)}$
$3\ Ba^{2+}_{(aq)} + 6\ NO^{-}_{3(aq)} + 6\ NH^{+}_{4(aq)} + 2\ PO^{3-}_{4(aq)} \rightarrow Ba_3(PO_4)_{2(s)} + 6\ NH^{+}_{4(aq)} + 6\ NO^{-}_{3(aq)}$ (total ionic equation)
$3\ Ba^{2+}_{(aq)} + \cancel{6\ NO^{-}_{3(aq)}} + \cancel{6\ NH^{+}_{4(aq)}} + 2\ PO^{3-}_{4(aq)} \rightarrow Ba_3(PO_4)_{2(s)} + \cancel{6\ NH^{+}_{4(aq)}} + \cancel{6\ NO^{-}_{3(aq)}}$
$3\ Ba^{2+}_{(aq)} + 2\ PO^{3-}_{4(aq)} \rightarrow Ba_3(PO_4)_{2(s)}$ (net ionic equation)

(d) $2\ NaOH_{(aq)} + Ca(NO_3)_{2(aq)} \rightarrow Ca(OH)_{2(s)} + 2\ NaNO_{3(aq)}$
$2\ Na^{+}_{(aq)} + 2\ OH^{-}_{(aq)} + Ca^{2+}_{(aq)} + 2\ NO^{-}_{3(aq)} \rightarrow Ca(OH)_{2(s)} + 2\ Na^{+}_{(aq)} + 2\ NO^{-}_{3(aq)}$ (total ionic equation)
$\cancel{2\ Na^{+}_{(aq)}} + 2\ OH^{-}_{(aq)} + Ca^{2+}_{(aq)} + \cancel{2\ NO^{-}_{3(aq)}} \rightarrow Ca(OH)_{2(s)} + \cancel{2\ Na^{+}_{(aq)}} + \cancel{2\ NO^{-}_{3(aq)}}$
$Ca^{2+}_{(aq)} + 2\ OH^{-}_{(aq)} \rightarrow Ca(OH)_{2(s)}$ (net ionic equation)

Making Connections

4. Pollutants in natural water can enter the water cycle through runoff from agricultural areas or landfills, or industrial tailings ponds. Some pollutants are toxic and/or noxious at extremely low concentrations, so they may be dangerous even if they have very low solubility.

1.16 ACTIVITY: ANALYZING A HOUSEHOLD CLEANING PRODUCT

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Materials

(a) Student answers will vary depending on the cleaning product chosen. Possible ions are ammonium ions and/or hydroxide ions. We will need a solution containing calcium ions.

Observations

Table 1 Precipitation Reactions

Ionic solution	Reacting ions	Formation of precipitate? (P or NP)	Precipitate formed	Ion present
OH^-	Ca^{2+}	P	calcium hydroxide, $Ca(OH)_2$	OH^-

Student answers will vary depending on which cleaning product they are using.