and camphor, have low melting points, are softer than ionic compounds, and their solutions do not conduct electricity.

(f) Student answers will vary depending on whether their unidentified sample is ionic or molecular. Students should compare the properties of the unidentified solid with those of the category to which the solid belongs.

Evaluation

(g) The physical properties studied in this investigation are sufficient for classifying the solids into two categories. Other properties that may be investigated to further distinguish between molecular and ionic compounds include boiling point, solubility in solvents other than water, and volatility (odour).

(h) A possible source of error in this Procedure is the ranking of the hardness of samples. It may be difficult to tell how hard the samples are relative to each other using this test. Another possible source of error in this Procedure is the amount of solid placed in solution for dissolving and testing for conductivity. If not enough solid is placed in solution, the solution may not register a current even though the compound is an electrolyte. Stirring is important when testing for solubility. A substance may be soluble, but if it is not stirred to help it dissolve, it may appear insoluble. The Procedure could be improved by measuring identical masses of each solid and stirring each sample the same number of times and with the same vigour.

(i) The Prediction is correct, based on the Analysis.

1.14 CHEMICAL REACTIONS

SECTION 1.14 QUESTIONS

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Understanding Concepts

1. (a) decomposition reaction—a compound is broken down into two elements
   (b) synthesis reaction—two elements combine to form a compound
   (c) decomposition reaction—a complex compound is broken down into two simpler compounds
2. $2\ H_2O_{(l)} \rightarrow 2\ H_{2(g)} + O_{2(g)}$
3. A synthesis reaction is the combination of two or more simple substances to form a more complex substance. A combustion reaction is the rapid combination of oxygen and another element or compound to form new substances. Thus, a combustion reaction is a type of synthesis reaction where one of the reactants is oxygen. For example, $4\ Na_{(s)} + O_{2(g)} \rightarrow 2\ Na_2O_{(s)}$ is a combustion reaction as well as a synthesis reaction.
4. (a) $Zn_{(s)} + CuCl_{2(aq)} \rightarrow ZnCl_{2(aq)} + Cu_{(s)}$
   (b) $Ca_{(s)} + 2\ HCl_{(aq)} \rightarrow CaCl_{2(s)} + H_{2(g)}$
   (c) $2\ Na_{(s)} + 2\ H_2O_{(l)} \rightarrow 2\ NaOH_{(aq)} + H_{2(g)}$
5. In general, a synthesis reaction involves the reaction of two elements to form a new compound. A decomposition reaction involves the breaking down of a compound into elements or simpler compounds. A single displacement reaction is a reaction between an element and a compound. A double displacement reaction occurs between two compounds.
6. The general equation for a synthesis reaction is $A + B \rightarrow AB$, whereas the general equation for a decomposition reaction is $AB \rightarrow A + B$. The decomposition reaction is the reverse of the synthesis reaction and vice versa. They are therefore opposite reactions.
7. (a) $Al_{(s)} + 3\ AgNO_{3(aq)} \rightarrow Al(NO_3)_{3(aq)} + 3\ Ag_{(s)}$ single displacement reaction
   (b) zinc + sulfuric acid $\rightarrow$ zinc sulfate + hydrogen gas
   $Zn_{(s)} + H_2SO_{4(aq)} \rightarrow ZnSO_{4(aq)} + H_{2(g)}$ single displacement reaction
   (c) aqueous magnesium chloride + aqueous silver nitrate $\rightarrow$ solid silver chloride + aqueous magnesium nitrate
   $MgCl_{2(aq)} + 2\ AgNO_{3(aq)} \rightarrow 2\ AgCl_{(s)} + Mg(NO_3)_{2(aq)}$ double displacement reaction
   (d) sodium + water $\rightarrow$ sodium hydroxide + hydrogen gas
   $2\ Na_{(s)} + 2\ H_2O_{(l)} \rightarrow 2\ NaOH_{(aq)} + H_{2(g)}$ single displacement reaction
   (e) $3\ KOH_{(aq)} + FeCl_{3(aq)} \rightarrow Fe(OH)_{3(s)} + 3\ KCl_{(aq)}$ double displacement reaction

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