BALANCING CHEMICAL EQUATIONS

Name _____

Rewrite and balance the equations below.

1. $N_2 + H_2 \rightarrow NH_3$ _____
2. $KClO_3 \rightarrow KCl + O_2$ _____
3. $NaCl + F_2 \rightarrow NaF + Cl_2$ _____
4. $H_2 + O_2 \rightarrow H_2O$ _____
5. $AgNO_3 + MgCl_2 \rightarrow AgCl + Mg(NO_3)_2$ _____
6. $AlBr_3 + K_2SO_4 \rightarrow KBr + Al_2(SO_4)_3$ _____
7. $CH_4 + O_2 \rightarrow CO_2 + H_2O$ _____
8. $C_3H_8 + O_2 \rightarrow CO_2 + H_2O$ _____
9. $C_8H_{18} + O_2 \rightarrow 1O_2 + H_2O$ _____
10. $FeCl_3 + NaOH \rightarrow Fe(OH)_3 + NaCl$ _____
11. $P + O_2 \rightarrow P_2O_5$ _____
12. $Na + H_2O \rightarrow NaOH + H_2$ _____
13. $Ag_2O \rightarrow Ag + O_2$ _____
14. $S_8 + O_2 \rightarrow SO_3$ _____
15. $CO_2 + H_20 \rightarrow C_6H_{12}O_6 + O_2$ _____
16. $K + MgBr_2 \rightarrow KBr + Mg$ _____
17. $HCl + CaCO_3 \rightarrow CaCl_2 + H_2O + CO_2$ _____

EXPLORE Exploration Activities

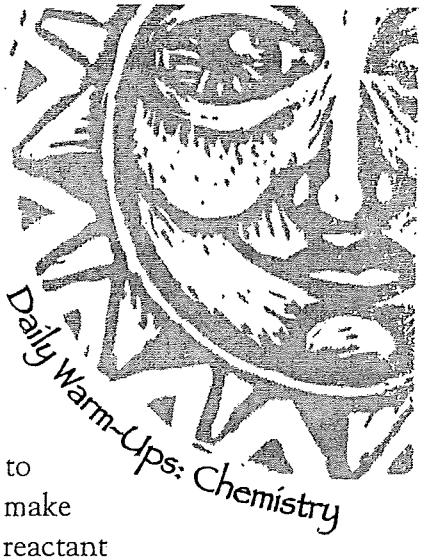
Identify each type of reaction.

1. $Pb(NO_3)_2 + KI \rightarrow PbI_2 + KNO_3$
2. $Al + Cl_2 \rightarrow Al_2Cl_3$
3. $C_2H_6 + O_2 \rightarrow CO_2 + H_2O$
4. $HCl + Sr(OH)_2 \rightarrow SrCl_2 + H_2O$
5. $Zn + HCl \rightarrow ZnCl_2 + H_2$
6. $K_2CO_3 \rightarrow K_2O + CO_2$
7. $SO_2 + O_2 \rightarrow SO_3$
8. $Fe_3O_4 + H_2 \rightarrow Fe + H_2O$
9. $AgNO_3 + MgCl_2 \rightarrow AgCl + Mg(NO_3)_2$
10. $KClO_3 \rightarrow KCl + O_2$
11. $CH_4 + Cl_2 \rightarrow CCl_4 + H_2$
12. $C_3H_8 + O_2 \rightarrow CO_2 + H_2O$
13. $O_2 + N_2 \rightarrow N_2O_4$
14. $NaF \rightarrow Na + F$
15. $NaI + Pb(NO_3)_2 \rightarrow NaNO_3 + PbI_2$
16. $Li_3PO_4 + Li \rightarrow P + O_2$
17. $CS_2 + F_2 \rightarrow CF_4 + S$

Identify the precipitate in each of the following reactions.

18. $Pb(NO_3)_2(aq) + K_2CrO_4(aq) \rightarrow PbCrO_4(s) + 2KNO_3(aq)$
19. $Ba(NO_3)_2(aq) + 2NH_4IO_3(aq) \rightarrow Ba(IO_3)_2(s) + 2NH_4NO_3(aq)$

Equation for Success



A chemical equation is a shorthand statement that uses chemical formulas to describe a chemical reaction. From the burning of gasoline in a car motor to the digestion of an apple, whenever a chemical reaction takes place, it must have certain qualities that make it work. There must be reactants, the chemicals that initially come into contact; and there must be products, the new substances that are formed when atoms combine chemically with other atoms.

$2H_2 + O_2 \rightarrow 2H_2O$

This simple equation describes the combination of oxygen and hydrogen to form water. The coefficients in front of the hydrogen and water formulas make the equation balanced, and they are there to express the amount of each reactant and product needed to make the equation true.

Balance the following equations.

a. $C_2H_2 + O_2 \rightarrow CO_2 + H_2O$

b. $NaCl \rightarrow Cl_2 + Na$

c. $Ti + N_2 \rightarrow Ti_3N_4$

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WORD EQUATIONS

Name _____

Write the word equations below as chemical equations and balance.

1. zinc + lead (II) nitrate yield zinc nitrate + lead

2. aluminum bromide + chlorine yield aluminum chloride + bromine

3. sodium phosphate + calcium chloride yield calcium phosphate + sodium chloride

4. potassium chlorate when heated yields potassium chloride + oxygen gas

5. aluminum + hydrochloric acid yield aluminum chloride + hydrogen gas

6. calcium hydroxide + phosphoric acid yield calcium phosphate + water

7. copper + sulfuric acid yield copper (II) sulfate + water + sulfur dioxide

8. hydrogen + nitrogen monoxide yield water + nitrogen

Equations

Name _____

Date _____

Write a balanced chemical equation to represent each of the following chemical reactions.

1. iron + sulfur → iron(II) sulfide
2. zinc + copper(II) sulfate → zinc sulfate + copper
3. silver nitrate + sodium bromide → sodium nitrate + silver bromide
4. potassium chlorate (heated) → potassium chloride + oxygen
5. water (electricity) → hydrogen + oxygen
6. mercury(II) oxide (heated) → mercury + oxygen
7. potassium iodide + lead(II) nitrate → lead(II) iodide + potassium nitrate
8. aluminum + oxygen → aluminum oxide
9. magnesium chloride + ammonium nitrate → magnesium nitrate + ammonium chloride
10. iron(III) chloride + ammonium hydroxide → iron(III) hydroxide + ammonium chloride
11. sodium peroxide + water → sodium hydroxide + oxygen
12. iron(III) oxide + carbon → iron + carbon monoxide
13. iron + water → hydrogen + iron(III) oxide
14. iron(III) chloride + potassium hydroxide → potassium chloride + iron(III) hydroxide
15. aluminum + sulfuric acid → aluminum sulfate + hydrogen
16. sodium carbonate + calcium hydroxide → sodium hydroxide + calcium carbonate

(continued)

5

Equations *(continued)*

Name _____

Date _____

17. carbon dioxide + water → carbonic acid

18. phosphorus + oxygen → diphosphorus pentoxide

19. sodium + water → sodium hydroxide + hydrogen

20. zinc + sulfuric acid → zinc sulfate + hydrogen

21. aluminum sulfate + calcium hydroxide → aluminum hydroxide + calcium sulfate

22. calcium oxide + water → calcium hydroxide

23. iron + copper(I) nitrate → iron(II) nitrate + copper

24. iron(II) sulfide + hydrochloric acid → hydrogen sulfide + iron(II) chloride

25. potassium oxide + water → potassium hydroxide

26. ammonium sulfide + lead(II) nitrate → ammonium nitrate + lead(II) sulfide

27. mercury(II) hydroxide + phosphoric acid → mercury(II) phosphate + water

28. potassium hydroxide + phosphoric acid → potassium phosphate + water

29. calcium chloride + nitric acid → calcium nitrate + hydrochloric acid

30. potassium carbonate + barium chloride → potassium chloride + barium carbonate

31. magnesium hydroxide + sulfuric acid → magnesium sulfate + water

32. sulfur dioxide + water → sulfurous acid

33. sodium carbonate +hydrochloric acid → sodium chloride + water + carbon dioxide

34 magnesium + nitric acid → magnesium nitrate + hydrogen

(continued)

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35. aluminum + iron(III) oxide → aluminum oxide + iron

36. potassium phosphate + magnesium chloride → magnesium phosphate + potassium chloride

37. ammonia + oxygen → nitrogen + water

38. calcium carbonate (heated) → calcium oxide + carbon dioxide

39. sodium chloride + sulfuric acid → sodium sulfate + hydrochloric acid

40. fluorine + sodium hydroxide → sodium fluoride + oxygen + water

41. magnesium nitrate + calcium iodide → calcium nitrate + magnesium iodide

42. aluminum sulfate + ammonium bromide → aluminum bromide + ammonium sulfate

43. potassium fluoride + barium bromide → barium fluoride + potassium bromide

44. copper(II) nitrate + ammonium hydroxide → copper(II) hydroxide + ammonium nitrate

45. sodium nitrate (heated) → sodium nitrite + oxygen

46. lead(II) hydroxide (heated) → lead(II) monoxide + water

47. ammonia + sulfuric acid → ammonium sulfate

48. hydrochloric acid + ammonia → ammonium chloride

49. copper(II) sulfate + iron → iron(II) sulfate + copper

50. aluminum + hydrochloric acid → aluminum chloride + hydrogen

51. carbon + oxygen → carbon dioxide

52. calcium bicarbonate + calcium hydroxide → calcium carbonate + water

(continued)

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Equations *(continued)*

Name _____

Date _____

53. hydrogen sulfide + oxygen → water + sulfur

54. sodium hydroxide + calcium nitrate → sodium nitrate + calcium hydroxide

55. potassium iodide + chlorine → potassium chloride + iodine

56. sulfuric acid + potassium hydroxide → potassium sulfate + water

57. carbon dioxide + carbon → carbon monoxide

58. calcium sulfate + sodium carbonate → calcium carbonate + sodium sulfate

59. water + diphosphorous pentoxide → phosphorus acid

60. aluminum + phosphoric acid → hydrogen + aluminum phosphate

61. ammonium chloride + sodium nitrite → sodium chloride + nitrogen + water

62. chlorine + sodium hydroxide → sodium chloride + sodium hypochlorite + water

63. lead(II) nitrate (heated) → lead monoxide + nitrogen dioxide + oxygen

64. mercury(I) oxide + oxygen → mercury(II) oxide

65. calcium oxide + magnesium chloride → magnesium oxide + calcium chloride

66. calcium + water → calcium hydroxide + hydrogen

67. chromium(III) chloride + sulfuric acid → chromium(III) sulfate + hydrochloric acid

68. iron(III) nitrate + ammonium hydroxide → iron(III) hydroxide + ammonium nitrate

69. aluminum chloride + potassium phosphate → aluminum phosphate + potassium chloride

(continued)

8

Name _____

Date _____

70. aluminum oxide + carbon + chlorine → carbon monoxide + aluminum chloride

71. copper(I) oxide + hydrochloric acid → copper(I) chloride + water

72. magnesium bicarbonate + hydrochloric acid → magnesium chloride + water + carbon dioxide

73. iron + oxygen → iron(III) oxide

74. silicon + water (heated) → silicon dioxide + hydrogen

75. iron(III) oxide + carbon monoxide → iron + carbon dioxide

76. calcium chloride + chromium(III) nitrate → calcium nitrate + chromium(III) chloride

77. zinc sulfide + oxygen → zinc oxide + sulfur dioxide

78. calcium phosphate + sulfuric acid → calcium sulfate + phosphoric acid

79. iron(III) hydroxide (heated) → iron(III) oxide + water

80. aluminum sulfate + sodium bicarbonate → aluminum hydroxide + sodium sulfate + carbon dioxide

81. calcium phosphate + silicon dioxide + carbon → phosphorus + calcium silicate + carbon monoxide

82. calcium oxide + sulfur dioxide → calcium sulfite

83. carbon dioxide + magnesium hydroxide → magnesium carbonate + water

84. calcium oxide + hydrochloric acid → calcium chloride + water

85. calcium carbonate + silicon dioxide → calcium silicate + carbon dioxide

86. antimony + chlorine → antimony trichloride

(continued)

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87. magnesium nitride + water → magnesium hydroxide + ammonia

88. arsenic + oxygen → arsenic(III) oxide

89. ammonium bicarbonate (heated) → ammonia + water + carbon dioxide

90. copper(II) oxide + ammonia → copper + water + nitrogen

91. ammonium dichromate (heated) → chromium trioxide + nitrogen + water

92. hydrogen sulfide + cadmium nitrate → nitric acid + cadmium sulfide

93. barium bromide + sodium phosphate → barium phosphate + sodium bromide

94. aluminum chloride + ammonium fluoride → aluminum fluoride + ammonium chloride

95. silver nitrate + potassium sulfate → silver sulfate + potassium nitrate

96. bismuth nitrate + calcium iodide → bismuth iodide + calcium nitrate

97. aluminum chromate + ammonium sulfate → ammonium chromate + aluminum sulfate

98. zinc nitrate + ammonium bromide → zinc bromide + ammonium nitrate

99. bismuth nitrate + ammonium hydroxide → bismuth hydroxide + ammonium nitrate

100. cadmium nitrate + sulfuric acid → cadmium sulfate + nitric acid

101. zinc + silver iodide → zinc iodide + silver

102. iron(III) chloride + sulfuric acid → iron(III) sulfate + hydrochloric acid

103. bismuth sulfate + ammonium hydroxide → bismuth hydroxide + ammonium sulfate

104. hydrogen iodide + oxygen → iodine + water

(continued)

Name _____

Date _____

105. potassium sulfate + barium chloride → barium sulfate + potassium chloride

106. barium sulfate + carbon → barium sulfide + carbon monoxide

107. aluminum oxide + hydrofluoric acid → aluminum fluoride + water

108. aluminum fluoride + sulfuric acid → aluminum sulfate + hydrogen fluoride

109. potassium iodide + hydrogen peroxide → potassium hydroxide + iodine

110. zinc + iron(III) sulfate → zinc sulfate + iron(II) sulfate

111. lead(II) sulfide + lead monoxide → lead + sulfur dioxide

112. copper + sulfuric acid → copper(II) sulfate + water + sulfur dioxide

113. aluminum hydroxide (heated) → aluminum oxide + water

114. nitrogen + hydrogen → ammonia

115. sodium carbonate + carbonic acid → sodium bicarbonate

116. silicon dioxide + hydrofluoric acid → water + silicon tetrafluoride

117. sodium hypochlorite → sodium chloride + sodium chlorate

118. sodium chlorite + chlorine → sodium chloride + chlorine dioxide

119. methane + sulfur dioxide (heated) → hydrogen sulfide + carbon dioxide + hydrogen

120. tellurous acid → tellurium dioxide + water

121. iron(II) selenide + hydrochloric acid → iron(II) chloride + hydrogen selenide

122. magnesium + nitrogen → magnesium nitride

(continued)

Equations *(continued)*

123. silver cyanide + potassium → potassium cyanide + silver

124. copper(II) sulfate + ammonia → cupriammonia sulfate

125. calcium carbide + nitrogen → calcium cyanamide + carbon

126. calcium cyanamide + water → calcium carbonate + ammonia

127. zinc arsenide + hydrochloric acid → arsine + zinc chloride

128. lead(II) hydroxide + sodium stannite → lead + sodium stannate + water

129. sodium silicate + hydrochloric acid → sodium chloride + silicic acid

130. boron trioxide + magnesium → magnesium oxide + boron

131. iron(II) cyanide + potassium cyanide → potassium ferrocyanide

132. sodium aluminate + ammonium chloride → ammonium aluminum oxide + sodium chloride

133. aluminum hydroxide + sodium hydroxide → sodium aluminate + water

134. tungsten + chlorine (heated) → tungsten hexachloride

135. calcium + ammonia → calcium hydride + nitrogen

136. sodium wolframate + sulfuric acid → sodium sulfate + tungstic acid

137. lithium hydride + water → lithium hydroxide + hydrogen

138. boric acid → tetraboric acid + water

139. zinc hydroxide + potassium hydroxide → potassium zincate + water

140. nickel + carbon monoxide → nickel carbonyl

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CLASSIFICATION OF CHEMICAL REACTIONS

Name _____

Classify the reactions below as synthesis, decomposition, single replacement (cationic or anionic) or double replacement.

1. $2H_2 + O_2 \rightarrow 2H_2O$ _____

2. $2H_2O \rightarrow 2H_2 + O_2$ _____

3. $Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$ _____

4. $2CO + O_2 \rightarrow 2CO_2$ _____

5. $2HgO \rightarrow 2Hg + O_2$ _____

6. $2KBr + Cl_2 \rightarrow 2KCl + Br_2$ _____

7. $CaO + H_2O \rightarrow Ca(OH)_2$ _____

8. $AgNO_3 + NaCl \rightarrow AgCl + NaNO_3$ _____

9. $2H_2O_2 \rightarrow 2H_2O + O_2$ _____

10. $Ca(OH)_2 + H_2SO_4 \rightarrow CaSO_4 + 2H_2O$ _____

ROUND 2

Synthesis Reactions occur when two or more reactants combine to form a single product. There are several common types of synthesis reactions.

A metal combines with a nonmetal to form a binary salt.

example A piece of lithium metal is dropped into a container of nitrogen gas.

$6Li + N_2 \longrightarrow 2Li_3N$

Metallic oxides and water form bases (metallic hydroxides).

example Solid sodium oxide is added to water.

$Na_2O + HOH \longrightarrow 2NaOH$

Solid magnesium oxide is added to water.

$MgO + 2HOH \longrightarrow Mg(OH)_2$

Nonmetallic oxides and water form acids. The nonmetal retains its oxidation number.

example Carbon dioxide is bubbled into water.

$CO_2 + H_2O \longrightarrow H_2CO_3$ (Oxidation number of C is +4)

Dinitrogen pentoxide is bubbled into water.

$N_2O_5 + H_2O \longrightarrow 2HNO_3$ (Oxidation number of N is +5)

Metallic oxides and nonmetallic oxides form salts.

example Solid sodium oxide is added to carbon dioxide.

$Na_2O + CO_2 \longrightarrow Na_2CO_3$

Solid calcium oxide is added to sulfur trioxide.

$CaO + SO_3 \longrightarrow CaSO_4$

Decomposition Reactions occur when a single reactant is broken down into two or more products.

Metallic carbonates decompose into metallic oxides and carbon dioxide.

example A sample of magnesium carbonate is heated.

$MgCO_3 \longrightarrow MgO + CO_2$

Metallic chlorates decompose into metallic chlorides and oxygen.

example A sample of magnesium chlorate is heated.

$Mg(ClO_3)_2 \longrightarrow MgCl_2 + 3O_2$

Ammonium carbonate decomposes into ammonia, water and carbon dioxide.

example A sample of ammonium carbonate is heated.

$(NH_4)_2CO_3 \longrightarrow 2NH_3 + H_2O + CO_2$

Sulfurous acid decomposes into sulfur dioxide and water.

example A sample of sulfurous acid is heated.

$H_2SO_3 \longrightarrow H_2O + SO_2$

Carbonic acid decomposes into carbon dioxide and water.

example A sample of carbonic acid is heated.

$H_2CO_3 \longrightarrow H_2O + CO_2$

A binary compound may break down to produce two elements.

example Molten sodium chloride is electrolyzed.

$2NaCl \longrightarrow 2Na + Cl_2$

Hydrogen peroxide decomposes into water and oxygen.

example $2H_2O_2 \longrightarrow 2H_2O + O_2$

Ammonium hydroxide decomposes into ammonia and water.

example $NH_4OH \longrightarrow NH_3 + HOH$

Exercise 7–2: Predict and balance the following synthesis and decomposition reactions. Use abbreviations to indicate the phase of reactants and products where possible [i.e., (aq) (s) (l) (g)].

1. A sample of calcium carbonate is heated.

2. Sulfur dioxide gas is bubbled through water.

3. Solid potassium oxide is added to a container of carbon dioxide gas.

4. Liquid hydrogen peroxide is warmed.

5. Solid lithium oxide is added to water.

6. Molten aluminum chloride is electrolyzed.

7. A pea-sized piece of sodium is added to a container of iodine vapor.

8. A sample of carbonic acid is heated.

9. A sample of potassium chlorate is heated.

10. Solid magnesium oxide is added to sulfur trioxide gas.

Chapter 8

Single Replacement Reactions

Single replacement reactions are reactions that involve an element replacing one part of a compound. The products include the displaced element and a new compound. An element can only replace another element that is less active than itself.

General activity series for metals

(most active) Li Ca Na Mg Al Zn Fe Pb [H_2] Cu Ag Pt *(least active)*

General activity series for nonmetals

(most active) F_2 Cl_2 Br_2 I_2 *(least active)*

Here are some common types of single replacement reactions.

Active metals replace less active metals from their compounds in aqueous solution.

example Magnesium turnings are added to a solution of iron(III) chloride.

$3Mg + 2FeCl_3 \longrightarrow 2Fe + 3MgCl_2$

Active metals replace hydrogen in water.

example Sodium is added to water.

$2Na + 2HOH \longrightarrow H_2 + 2NaOH$

Active metals replace hydrogen in acids.

example Lithium is added to hydrochloric acid.

$2Li + 2HCl \longrightarrow H_2 + 2LiCl$

Active nonmetals replace less active nonmetals from their compounds in aqueous solution.

example Chlorine gas is bubbled into a solution of potassium iodide.

$Cl_2 + 2KI \longrightarrow I_2 + 2KCl$

If a less reactive element is combined with a more reactive element in compound form, there will be no resulting reaction.

example Chlorine gas is bubbled into a solution of potassium fluoride.

$Cl_2 + KF \longrightarrow$ no reaction

example Zinc is added to a solution of sodium chloride.

$Zn + NaCl \longrightarrow$ no reaction

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ROUND 3

Exercise 8–1: Using the activity series, predict and balance the following single replacement reactions. Use abbreviations to indicate the appropriate phase of reactants and products where possible. *Note: Not all of the reactions will occur. For those that do not, write no reaction.*

1. A piece of copper is dropped into a container of water.

2. Liquid bromine is added to a container of sodium iodide crystals.

3. An aluminum strip is immersed in a solution of silver nitrate.

4. Zinc pellets are added to a sulfuric acid solution.

5. Fluorine gas is bubbled into a solution of aluminum chloride.

6. Magnesium turnings are added to a solution of lead(II) acetate.

7. Iodine crystals are added to a solution of sodium chloride.

8. Calcium metal is added to a solution of nitrous acid.

9. A pea-sized piece of lithium is added to water.

10. A solution of iron(III) chloride is poured over a piece of platinum wire.

Note: On the AP reaction prediction section, all reactions "work"; in other words there will be no "No reactions" on the AP Exam.

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Chapter 9

Double Replacement (Metathesis) Reactions

In many reactions between two compounds in aqueous solution, the cations and anions appear to switch partners according to the following equation:

$$AX + BY \longrightarrow AY + BX$$

The two compounds react to form two new compounds. No changes in oxidation numbers occur. Reactions of this type are known as *double replacement* or *metathesis reactions*. An example of such a reaction would be the mixing of aqueous solutions of potassium bromide and silver nitrate forming insoluble silver bromide (precipitate) and aqueous potassium nitrate:

$$KBr(aq) + AgNO_3(aq) \longrightarrow AgBr(s) + KNO_3(aq)$$

Note that each cation pairs up with the anion in the other compound, thus switching partners. Anions do not pair up with anions and cations do not pair up with cations. Likes repel; opposites attract!

All double replacement reactions must have a "driving force" or a reason why the reaction will occur or "go to completion." The "driving force" in metathesis reactions is the removal of at least one pair of ions from solution.

This removal of ions can occur in one of three ways:

1. **Formation of a precipitate:** A precipitate is an insoluble substance (solid) formed by the reaction of two aqueous substances. It is the result of ions bonding together so strongly that the solvent (water) cannot pull them apart. The insoluble solid (or solids if a double precipitate occurs) will settle out (precipitate) from the solution and this results in the removal of ions from the solution.
2. **Formation of a gas:** Gases may form directly in a double replacement reaction or from the decomposition of one of the products. The gases will bubble off or evolve from the solution.
3. **Formation of primarily molecular species:** The formation of primarily unionized molecules in solution removes ions from the solution and the reaction "works" or is said to go to completion. Unionized or partially ionized molecules give solutions that are known as *nonelectrolytes* or *weak electrolytes*. The best known nonelectrolyte is water formed in acid–base neutralization reactions. Acetic acid is an example of an acid that is primarily molecular (weak electrolyte) when placed in water.

Reversible Reactions

If a double replacement reaction does not go to completion (no precipitate, gas or molecular species is formed), then the reaction is reversible (no ions have been removed). Reversible reactions are at equilibrium and have both forward and reverse reactions taking place. In a reversible reaction, evaporation of the water solvent will result in solid residues of both reactants and products. The reaction is not driven to completion (products) because no ions have been removed. A double arrow is used to designate a reversible reaction at equilibrium.

$$BaCl_2(aq) + 2NaNO_3(aq) \rightleftharpoons Ba(NO_3)_2(aq) + 2NaCl(aq)$$

Solubility Rules Table

The solubility classification of ionic substances according to their solubility in water is difficult. Nothing is completely "insoluble" in water. The degree of solubility varies from one "soluble" substance to another. Nevertheless, a solubility classification scheme is useful even though it must be regarded as an approximate guideline.

MAINLY WATER SOLUBLE	
NO_3^-	All nitrates are soluble.
CH_3COO^- or $C_2H_3O_2^-$	All acetates are soluble except $AgCH_3COO$*.
ClO_3^-	All chlorates are soluble.
Cl^-	All chlorides are soluble except AgCl, Hg_2Cl_2 $PbCl_2$*.
Br^-	All bromides are soluble except AgBr, $PbBr_2$*, Hg_2Br_2 and $HgBr_2$*.
I^-	All iodides are soluble except AgI, Hg_2I_2, HgI_2 and PbI_2.
SO_4^{2-}	All sulfates are soluble except $BaSO_4$, $PbSO_4$, Hg_2SO_4, $CaSO_4$, Ag_2SO_4* and $SrSO_4$*.
Alkali metal cations (Group IA) and NH_4^+	All are soluble.
H^+	All common inorganic acids and low molecular mass organic acids are soluble.

MAINLY WATER INSOLUBLE	
CO_3^{2-}	All carbonates are insoluble except those of the IA elements and NH_4^+.
CrO_4^{2-}	All chromates are insoluble except those of of the IA elements, NH_4^+, $CaCrO_4$* and $SrCrO_4$*.
OH^-	All hydroxides are insoluble except those of the IA elements, NH_4^+, $Ba(OH)_2$, $Sr(OH)_2$*, and $Ca(OH)_2$*.
PO_4^{3-}	All phosphates are insoluble except those of the IA elements and NH_4^+.
SO_3^{2-}	All sulfites are insoluble except those of the IA elements and NH_4^+.
S^{2-}	All sulfides are insoluble except those of the IA and IIA elements and NH_4^+.

*Soluble compounds dissolve to the extent of at least 10 g/L at 25 °C. *Slightly soluble* compounds (marked with an *) dissolve in the range of from 1 g/L to 10 g/L at 25 °C. Those compounds that have a solubility of less than 1 g/L are considered to be *insoluble*. These standards are common but arbitrary.

ROUND 4

Formation of a Precipitate

In order to predict double replacement reactions yielding precipitates, one **must memorize** the solubility rules listed on page 48.

Exercise 9–1: Predict and balance the following metathesis reactions based on the solubility of the products. Use the abbreviations (aq) and (s) for the reactants and products. All reactants are aqueous. *Note:* Some of these reactions do not go to completion.

1. silver nitrate + potassium chromate

2. ammonium chloride + cobalt(II) sulfate

3. lithium hydroxide + sodium chromate

4. zinc acetate + cesium hydroxide

5. ammonium sulfide + lead(II) nitrate

6. iron(III) sulfate + barium iodide

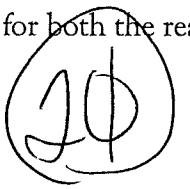
7. chromium(III) bromide + sodium nitrate

8. rubidium phosphate + titanium(IV) nitrate

9. ammonium carbonate + nickel(II) chloride

10. tin(IV) nitrate + potassium sulfite

Note: Correct molecular formulas must be written for both the reactants and products before an equation may be balanced.



Combustion reactions involve the oxidation of an organic compound. Incomplete combustion products are carbon/carbon monoxide and water. The more commonly seen, complete combustion products include carbon dioxide and water.

Ethane burns in oxygen.

$$2C_2H_6 + 7O_2 \longrightarrow 4CO_2 + 6H_2O$$

Ethanol is burned in oxygen gas.

$$C_2H_5OH + 3O_2 \longrightarrow 2CO_2 + 3H_2O$$

6. Octane is burned in oxygen.

Reaction Prediction

Name _____

Date _____

In each of the following examples:

(a) State what type of reaction is expected.

(b) Tell whether the reaction will occur or not, and why.

(c) Write the balanced equation for those reactions that do take place; write the symbols and formulas of the reactants for those reactions that do occur.

(d) Indicate whether double replacement reactions are reversible or irreversible.

1. aluminum plus hydrochloric acid SR
2. calcium hydroxide plus nitric acid DR
3. aluminum plus magnesium S
4. magnesium plus zinc nitrate SR
5. mercury plus oxygen S
6. zinc chloride plus hydrogen sulfide DR
7. dinitrogen pentoxide plus water S
8. silver chloride plus sodium nitrate DR
9. sodium chlorate (heated) D
10. barium nitrate plus sodium chromate DR
11. sodium bromide plus silver nitrate DR
12. calcium phosphate plus aluminum sulfate DR
13. zinc carbonate (heated) D
14. mercury(I) sulfate plus ammonium nitrate DR

(continued)

 S

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Reaction Prediction *(continued)*

Name _____

Date _____

33. mercury(I) sulfate plus hydrochloric acid DR
34. potassium nitrate (heated) D
35. chlorine plus bromine S
36. mercury(I) nitrate plus sodium carbonate DR
37. magnesium plus hydrochloric acid S R
38. water (electrolyzed) D
39. ammonium nitrite plus barium hydroxide DR
40. ammonium sulfate plus calcium hydroxide DR
41. mercury(II) oxide (heated) D
42. ammonium phosphate plus aluminum chloride DR
43. barium oxide plus water S
44. iron(III) hydroxide plus nitric acid
45. calcium plus oxygen
46. calcium plus phosphoric acid
47. calcium chloride plus ammonium hydroxide
48. aluminum sulfide plus hydrochloric acid
49. magnesium plus sulfur
50. calcium plus aluminum chloride

(continued)

Reaction Prediction *(continued)*

Name _____

Date _____

15. potassium plus fluorine S
16. potassium nitrate plus zinc phosphate DR
17. lithium oxide plus water S
18. sodium chloride (electrolyzed) D
19. silver plus barium D
20. iron(III) hydroxide plus phosphoric acid S
21. sodium plus nitric acid SR
22. iron(III) iodide plus cupric nitrate DR
23. copper plus sulfuric acid SR
24. lead plus potassium chlorate SR
25. sulfur dioxide plus water S
26. oxygen plus sulfur S
27. sodium sulfate plus barium chloride DR
28. ammonium phosphate plus lithium hydroxide DR
29. hydrogen plus oxygen S
30. mercury plus nitric acid SR
31. sodium oxide plus water S
32. calcium carbonate plus lithium chloride DR

(continued)

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Reaction Prediction *(continued)*

Name _____

Date _____

51. potassium hydroxide plus hydrosulfuric acid

52. sodium carbonate plus sulfuric acid

53. barium sulfate plus calcium chloride

54. silver plus mercury(I) nitrate

55. barium carbonate (heated)

56. lithium plus bromine

57. sodium chloride plus potassium chromate

58. potassium sulfide plus iron(II) nitrate

59. iodine plus ammonium fluoride

60. sodium plus calcium

61. aluminum chloride (electrolyzed)

62. lead(II) chlorate plus sodium sulfide

63. sulfur trioxide plus water

64. calcium carbonate plus hydrochloric acid

65. iron plus sodium bromide

66. ammonium acetate plus iron(II) chloride

67. silver bromide plus ammonium sulfate

68. zinc plus sulfuric acid

(continued)

25

Reaction Prediction *(continued)*

Name _____

Date _____

69. neon plus potassium

70. iron plus potassium iodide

71. lead(II) hydroxide plus hydrochloric acid

72. iron plus sulfur

73. potassium chlorate (heated)

74. oxygen plus chlorine

75. silver iodide plus iron(III) sulfide

76. iron(II) carbonate plus phosphoric acid

77. potassium iodide plus ammonium nitrate

78. potassium plus sodium nitrate (heated)

79. bromine plus sodium chloride

80. silver sulfide plus hydrochloric acid

81. magnesium nitrate plus hydrochloric acid

82. ammonia plus hydrogen chloride

83. zinc hydroxide plus sulfuric acid

84. calcium oxide plus water

85. sodium plus chlorine

86. calcium hydroxide (heated)

(continued)