4. [redacted] (rule 5)
[redacted]ble (rule 1)
[redacted] (rule 6)
[redacted]ble (rule 3)

5. a. $Na_2SO_4(aq) + Pb(NO_3)_2(aq) \rightarrow PbSO_4(s) + 2\ NaNO_3(aq)$
The product is lead(II) sulfate.

b. $NiCl_2(aq) + 2\ KOH(aq) \rightarrow Ni(OH)_2(s) + 2\ KCl(aq)$
The product is nickel(II) hydroxide.

c. $K_2S(aq) + Zn(NO_3)_2(aq) \rightarrow ZnS(s) + 2\ KNO_3(aq)$
The product is zinc sulfide.

d. $3\ AgNO_3(aq) + (NH_4)_3PO_4(aq) \rightarrow Ag_3PO_4(s) + 3\ NH_4NO_3(aq)$
The product is silver phosphate.

6. a. $3\ Ca^{2+} + 6Cl^- + 6\ Na^+ + 2\ PO_4^{3-} \rightarrow Ca_3(PO_4)_2(s) + 6\ Na^+ + 6\ Cl^-$
b. $Cu^{2+} + 2\ NO_3^- + 2\ K^+ + S^{2-} \rightarrow CuS(s) + 2\ K^+ + 2\ NO_3^-$
c. $2\ Ag^+ + 2\ NO_3^- + 2\ K^+ + SO_4^{2-} \rightarrow Ag_2SO_4(s) + 2\ K^+ + 2\ NO_3^-$

7. a. $Ca(NO_3)_2(aq) + K_2SO_4(aq) \rightarrow CaSO_4(s) + 2\ KNO_3(aq)$
K^+ and NO_3^- are the spectator ions.

b. $(NH_4)_2CO_3(aq) + CuCl_2(aq) \rightarrow CuCO_3(s) + 2\ NH_4Cl(aq)$
NH_4^+ and Cl^- are the spectator ions.

c. $2\ NaOH(aq) + Pb(NO_3)_2(aq) \rightarrow Pb(OH)_2(s) + 2\ NaNO_3(aq)$
Na^- and NO_3^- are the spectator ions.

d. $Na_2S(aq) + Zn(NO_3)_2(aq) \rightarrow ZnS(s) + 2\ NaNO_3(aq)$
Na^+ and NO_3^- are the spectator ions.

e. $CoCl_2(aq) + Ca(OH)_2(aq) \rightarrow Co(OH)_2(s) + CaCl_2(aq)$
Ca^{2+} and Cl^- are the spectator ions.

8. a. $Ca^{2+} + CO_3^{2-} \rightarrow CaCO_3(s)$
b. $Pb^{2+} + S^{2-} \rightarrow PbS(s)$
c. $Hg_2^{2+} + 2\ Cl^- \rightarrow Hg_2Cl_2(s)$
d. $Mg^{2+} + 2\ OH^- \rightarrow Mg(OH)_2(s)$

9. It is possible to produce the solids below from several different soluble salts, so your answer could be correct and not the same as the answer below. If your answer does not match the one below, use the solubility rules to help you determine whether the aqueous salt solutions you chose would be soluble in water, and whether an exchange of anions would produce the desired insoluble salt.

a. $Zn(NO_3)_2$ and NaOH
b. $Ba(NO_3)_2$ and K_3PO_4
c. $Pb(NO_3)_2$ and NaCl
d. $CaCl_2$ and $(NH_4)_2SO_4$
e. $Co(NO_3)_2$ and Na_2CO_3
f. $AgNO_3$ and K_2SO_4

4. [redacted] (rule 5)
[redacted]ble (rule 1)
[redacted] (rule 6)
[redacted]ble (rule 3)

5. a. $Na_2SO_4(aq) + Pb(NO_3)_2(aq) \rightarrow PbSO_4(s) + 2\ NaNO_3(aq)$
The product is lead(II) sulfate.

b. $NiCl_2(aq) + 2\ KOH(aq) \rightarrow Ni(OH)_2(s) + 2\ KCl(aq)$
The product is nickel(II) hydroxide.

c. $K_2S(aq) + Zn(NO_3)_2(aq) \rightarrow ZnS(s) + 2\ KNO_3(aq)$
The product is zinc sulfide.

d. $3\ AgNO_3(aq) + (NH_4)_3PO_4(aq) \rightarrow Ag_3PO_4(s) + 3\ NH_4NO_3(aq)$
The product is silver phosphate.

6. a. $3\ Ca^{2+} + 6Cl^- + 6\ Na^+ + 2\ PO_4^{3-} \rightarrow Ca_3(PO_4)_2(s) + 6\ Na^+ + 6\ Cl^-$
b. $Cu^{2+} + 2\ NO_3^- + 2\ K^+ + S^{2-} \rightarrow CuS(s) + 2\ K^+ + 2\ NO_3^-$
c. $2\ Ag^+ + 2\ NO_3^- + 2\ K^+ + SO_4^{2-} \rightarrow Ag_2SO_4(s) + 2\ K^+ + 2\ NO_3^-$

7. a. $Ca(NO_3)_2(aq) + K_2SO_4(aq) \rightarrow CaSO_4(s) + 2\ KNO_3(aq)$
K^+ and NO_3^- are the spectator ions.

b. $(NH_4)_2CO_3(aq) + CuCl_2(aq) \rightarrow CuCO_3(s) + 2\ NH_4Cl(aq)$
NH_4^+ and Cl^- are the spectator ions.

c. $2\ NaOH(aq) + Pb(NO_3)_2(aq) \rightarrow Pb(OH)_2(s) + 2\ NaNO_3(aq)$
Na^+ and NO_3^- are the spectator ions.

d. $Na_2S(aq) + Zn(NO_3)_2(aq) \rightarrow ZnS(s) + 2\ NaNO_3(aq)$
Na^+ and NO_3^- are the spectator ions.

e. $CoCl_2(aq) + Ca(OH)_2(aq) \rightarrow Co(OH)_2(s) + CaCl_2(aq)$
Ca^{2+} and Cl^- are the spectator ions.

8. a. $Ca^{2+} + CO_3^{2-} \rightarrow CaCO_3(s)$
b. $Pb^{2+} + S^{2-} \rightarrow PbS(s)$
c. $Hg_2^{2+} + 2\ Cl^- \rightarrow Hg_2Cl_2(s)$
d. $Mg^{2+} + 2\ OH^- \rightarrow Mg(OH)_2(s)$

9. It is possible to produce the solids below from several different soluble salts, so your answer could be correct and not the same as the answer below. If your answer does not match the one below, use the solubility rules to help you determine whether the aqueous salt solutions you chose would be soluble in water, and whether an exchange of anions would produce the desired insoluble salt.

a. $Zn(NO_3)_2$ and NaOH
b. $Ba(NO_3)_2$ and K_3PO_4
c. $Pb(NO_3)_2$ and NaCl
d. $CaCl_2$ and $(NH_4)_2SO_4$
e. $Co(NO_3)_2$ and Na_2CO_3
f. $AgNO_3$ and K_2SO_4

10. a. HNO_3 is a strong acid.
b. $C_2H_4O_2$ is a weak acid, so the correct answer is neither of these.
c. H_2SO_4 is a strong acid.
d. HCl is a strong acid.
e. NaCl is a salt produced when HCl and NaOH react, so it is neither a strong acid nor a strong base.
f. K_2SO_4 is a salt produced when H_2SO_4 and KOH react.

11. a. $2\ Na^+ + 2\ OH^- + 2\ H^+ + SO_4^{2-} \rightarrow 2\ Na^+ + SO_4^{2-} + 2\ H_2O(l)$
b. $K^+ + OH^- + H^+ + Cl^- \rightarrow K^+ + Cl^- + H_2O(l)$
c. $Na^+ + OH^- + H^+ + NO_3^- \rightarrow Na^+ + NO_3^- + H_2O(l)$

12. a. $H^+ + OH^- \rightarrow H_2O(l)$
b. $H^+ + OH^- \rightarrow H_2O(l)$
c. $H^+ + OH^- \rightarrow H_2O(l)$

13. a. This is a precipitation reaction.
b. This is an acid-base reaction. The products are water and the salt KNO_3.
c. This is an acid-base reaction. The products are water and the salt Na_2SO_4.
d. This is a precipitation reaction.

14. When atoms or molecules lose electrons, a positively charged cation is produced. When electrons are gained, then a negatively charged anion is produced. You can show how electrons are gained or lost by adding electrons to either the right side or the left side of an equation.

a. $Br_2 + 2e^- \rightarrow 2Br^-$
b. $Mg \rightarrow Mg^{2+} + 2e^-$
c. $H_2 \rightarrow 2H^+ + 2e^-$
d. $Al \rightarrow Al^{3+} + 3e^-$
e. $O_2 + 4e^- \rightarrow 2O^{2-}$
f. $S + 2e^- \rightarrow S^{2-}$

15. Ions can either gain or lose electrons to become neutral atoms or molecules. You can show whether the ions must lose or gain electrons by adding electrons to either the right side or the left side of an equation.

a. $2Cl^- \rightarrow Cl_2 + 2e^-$
b. $K^+ + e^- \rightarrow K$
c. $4P^{3-} \rightarrow P_4 + 12e^-$
d. $Ca^{2+} + 2e^- \rightarrow Ca$
e. $2I^- \rightarrow I_2 + 2e^-$
f. $Al^{3+} + 3e^- \rightarrow Al$

16. When presented with a reaction where electrons are transferred, it is possible to extract the parts of the reaction where electrons are lost and where electrons are gained and to write each part separately. Notice that the number of electrons lost is equal to the number gained.

a. $Cu \rightarrow Cu^{2+} + 2e^-$ — 2 electrons are lost
$2Ag^+ + 2e^- \rightarrow 2Ag$ — 2 electrons are gained

b. $Zn \rightarrow Zn^{2+} + 2e^-$ — 2 electrons are lost
$2H^+ + 2e^- \rightarrow H_2$ — 2 electrons are gained

c. $2Br^- \rightarrow Br_2 + 2e^-$ 2 electrons are lost
$Cl_2 + 2e^- \rightarrow 2Cl^-$ 2 electrons are gained

d. $2Hg \rightarrow 2Hg^{2+} + 4e^-$ 4 electrons are lost
$O_2 + 4e^- \rightarrow 2O^{2-}$ 4 electrons are gained

17. a. In this reaction, two chloride ions lose electrons to become a chlorine molecule, and a bromine molecule gains two electrons to become two bromide ions. This is an oxidation-reduction reaction. Because the chloride ion paired with sodium is exchanged for a bromide ion, this kind of reaction is often called a replacement reaction.

b. Two aqueous solutions containing ionic compounds react and one of the products is the ionic solid $PbSO_4$. This is a precipitation reaction.

c. The base NaOH reacts with the acid H_2SO_4 to produce water. This is an acid-base reaction.

d. In this reaction, two Ag^+ ions gain two electrons to become two atoms of silver, and an atom of iron loses two electrons to become an Fe^{2+} ion. This is an oxidation-reduction reaction. Because the silver ion paired with the nitrate ion is exchanged for an iron ion, this kind of reaction is called a replacement reaction.

e. Two aqueous solutions containing ionic compounds react and one of the products is the ionic solid $Zn(OH)_2$. This is an example of a precipitation reaction.

18. a. Molecular nitrogen and molecular hydrogen react to produce a larger molecule, ammonia. This is a synthesis reaction.

b. A molecule which is composed of carbon and hydrogen reacts with oxygen gas. The products are carbon dioxide and water. Reactions which have oxygen as a reactant are members of a sub-class of oxidation-reduction reactions called combustion reactions.

c. Elemental copper reacts with elemental sulfur. A compound containing both elements is the product. This is a synthesis reaction.

d. Solid sodium nitrate is converted to two simpler molecules, sodium nitrite and molecular oxygen. This is an example of a decomposition reaction.

e. In this reaction, two small molecules combine to produce one larger molecule. This is an example of a synthesis reaction.

19. a. $C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(g)$
A molecule reacts with oxygen gas. Because this reaction has oxygen as a reactant, it is an oxidation-reduction reaction.

b. $(NH_4)_2S(aq) + Pb(NO_3)_2(aq) \rightarrow PbS(s) + 2NH_4NO_3(aq)$
Two aqueous solutions are mixed to produce a solid product. This is a precipitation reaction.

c. $4Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(s)$
Elemental aluminum loses 3 electrons to become Al^{3+} and molecular oxygen gains 2 electrons to become O^{2-}. This is an oxidation-reduction reaction.

d. $2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$
Sodium metal loses an electron to become Na^+ and two hydrogen ions gain an electron to become hydrogen gas. This is an oxidation-reduction reaction.

e. $KOH(aq) + HNO_3(aq) \rightarrow KNO_3(aq) + H_2O(l)$
Aqueous solutions of the base KOH and the acid HNO_3 are mixed to produce liquid water. So this is an acid-base reaction.

f. $Na_3PO_4(aq) + 3AgNO_3(aq) \rightarrow Ag_3PO_4(s) + 3NaNO_3(aq)$
Two aqueous solutions are mixed. The product is a solid, Ag_3PO_4. So this is a precipitation reaction.

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    c. H_2SO_4 is a strong acid.
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    c. $Na^+ + OH^- + H^+ + NO_3^- \rightarrow Na^+ + NO_3^- + H_2O(l)$

12. a. $H^+ + OH^- \rightarrow H_2O(l)$
    b. $H^+ + OH^- \rightarrow H_2O(l)$
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13. a. This is a precipitation reaction.
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       $2Ag^+ + 2e^- \rightarrow 2Ag$ — 2 electrons are gained

    b. $Zn \rightarrow Zn^{2+} + 2e^-$ — 2 electrons are lost
       $2H^+ + 2e^- \rightarrow H_2$ — 2 electrons are gained