Reaction Types for Chemistry 1A

To become proficient at recognizing and predicting the products of a chemical reaction you must know your acids, bases and salts! Since in most every reaction, ions are the reacting or formed species you must also be able to write these as net-ionic equations

1. Precipitation or Double Displacement Reactions
In these reactions two strong electrolytes (SE) react to form one soluble and one insoluble salt.

\[ \text{SE(aq)} + \text{SE(aq)} \rightarrow \text{Salt(aq)} + \text{Salt(s)} \]

Examples:

\[ \text{Pb(NO}_3\text{)}_2(\text{aq}) + 2\text{KI(aq)} \rightarrow 2\text{KNO}_3(\text{aq}) + \text{PbI}_2(\text{s}) \]
\[ \text{Pb(NO}_3\text{)}_2(\text{aq}) + 2\text{HI(aq)} \rightarrow 2\text{HNO}_3(\text{aq}) + \text{PbI}_2(\text{s}) \]

Note that the net-ionic equation is the same for the above two reactions.

1.1. Insoluble Hydroxide Formation from Ammonia and a Soluble Salt
Here an insoluble hydroxide will form if the cation of the reacting salt is not \( \text{Na}^+, \text{K}^+, \text{Li}^+, \text{Cs}^+, \text{or Ba}^{2+}, \text{Sr}^{2+}, \text{Ca}^{2+} \). These seven cations form soluble hydroxides (the strong bases). The products are an insoluble hydroxide and a soluble ammonium salt.

\[ \text{H}_2\text{O(l)} + \text{NH}_3(\text{aq}) + \text{Salt(aq)} \rightarrow \text{Hydroxide Salt(s)} + \text{Ammonium Salt(aq)} \]

Example:

\[ 2\text{H}_2\text{O(l)} + 2\text{NH}_3(\text{aq}) + \text{Pb(NO}_3\text{)}_2(\text{aq}) \rightarrow \text{Pb(OH)}_2(\text{s}) + 2\text{NH}_4\text{NO}_3(\text{aq}) \]

2. Acid and base ionization/dissociation reactions
These are the behaviors of acids and bases in water. They show the physical form of the acids and bases in water before reaction. Strong acids IONIZE 100%, weak acids IONIZE <5%, strong bases DISSOCIATE 100%, and weak bases HYDROLYZE <5%.

- **Strong Acids (100% ionization):** \( \text{HX(aq)} \rightarrow \text{H}^+(\text{aq}) + \text{X}^-(\text{aq}) \)
- **Weak Acids (<5% ionization):** \( \text{HX(aq)} <\rightarrow \text{H}^+(\text{aq}) + \text{X}^-(\text{aq}) \)
- **Strong bases (100% dissociation):** \( \text{MOH(aq)} \rightarrow \text{M}^+(\text{aq}) + \text{OH}^-(\text{aq}) \) or \( \text{M(OH)}_2(\text{aq}) \rightarrow \text{M}^{2+}(\text{aq}) + 2 \text{OH}^-(\text{aq}) \)
- **Weak bases (<5% hydrolyzed):** \( \text{NH}_3(\text{aq}) + \text{H}_2\text{O(l)} <\rightarrow \text{NH}_4^+(\text{aq}) + \text{OH}^-(\text{aq}) \)

3. Acid-base chemical reactions

3.1. Acid/base with a Hydroxide Base
In these reactions a hydroxide base (salt) reacts with an acid to form water and another salt. The base may be soluble (strong base) or not.

\[ \text{Hydroxide base(aq or s)} + \text{Acid(aq)} \rightarrow \text{H}_2\text{O(l)} + \text{Salt(aq or s)} \]

Examples:

\[ \text{KOH(aq)} + \text{HCl(aq)} \rightarrow \text{H}_2\text{O(l)} + \text{KCl(aq)} \]
\[ \text{Pb(OH)}_2(\text{s}) + 2\text{CH}_3\text{COOH(aq)} \rightarrow 2\text{H}_2\text{O(l)} + \text{Pb(CH}_3\text{COO)}_2(\text{aq)} \]
\[ \text{Ba(OH)}_2(\text{aq}) + \text{H}_2\text{SO}_4(\text{aq}) \rightarrow 2\text{H}_2\text{O(l)} + \text{BaSO}_4(\text{s}) \]

3.2. Acid/base with Ammonia
Here ammonia is the base and a soluble ammonium salt is produced, no water is formed.

\[ \text{NH}_3(\text{aq}) + \text{Acid(aq)} \rightarrow \text{Ammonium Salt(aq)} \]

Examples:

\[ \text{NH}_3(\text{aq}) + \text{HNO}_3(\text{aq}) \rightarrow \text{NH}_4\text{NO}_3(\text{aq}) \]
\[ 2\text{NH}_3(\text{aq}) + \text{H}_2\text{SO}_4(\text{aq}) \rightarrow (\text{NH}_4)_2\text{SO}_4(\text{aq}) \]
4. **Acid/base with Gas Formation**

Here an acid reacts with a carbonate, bicarbonate or sulfite salt to produce a salt, water and a gas.

\[
\text{Acid(aq) + Carbonate (or bicarbonate) Salt(aq or s)} \rightarrow \text{Salt(aq) + H}_2\text{O(l) + CO}_2(g)
\]

\[
\text{Acid(aq) + Sulfide Salt(aq or s)} \rightarrow \text{Salt(aq) + H}_2\text{S(g)}
\]

Examples:

\[
2\text{HNO}_3(aq) + \text{PbCO}_3(s) \rightarrow \text{Pb(NO}_3)_2(aq) + \text{H}_2\text{O(l) + CO}_2(g)
\]

\[
2\text{HNO}_3(aq) + \text{Na}_2\text{S(aq)} \rightarrow 2\text{NaNO}_3(aq) + \text{H}_2\text{S(g)}
\]

5. **Redox Reactions of a Metal and an Acid or Salt. Single Replacement Reactions.**

Here a metal or \([\text{H}_2(g)]\) is oxidized in the presence of an acid, \(\text{HX}\), or a salt \(\text{AX}\), where \(\text{A}\) is a metal cation. A salt of the metal, \(\text{MX}\), and the element, \(\text{A}\), are formed as products. Use the activity series to predict if the reaction will take place.

\[
\text{M(s) + [HX(aq) or AX(aq)]} \rightarrow \text{MX(aq) + [H}_2\text{(g) or A(s)]}
\]

Examples:

\[
\text{Zn(s) + CuSO}_4(aq) \rightarrow \text{ZnSO}_4(aq) + \text{Cu(s)}
\]

\[
\text{Zn(s) + 2HCl(aq)} \rightarrow \text{ZnCl}_2(aq) + \text{H}_2(g)
\]

**Reminders**

**Strong Electrolytes**: the soluble salts (includes strong bases) and the strong acids.

**Strong Acids (7)**: \(\text{HCl(aq)}, \text{HI(aq)}, \text{HBr(aq)}, \text{HNO}_3(aq), \text{HClO}_4(aq), \text{H}_2\text{SO}_4(aq), \text{HClO}_3(aq)\)

**Strong Bases (7)**: \(\text{LiOH(aq)}, \text{NaOH(aq)}, \text{KOH(aq)}, \text{CsOH(aq)}, \text{Ba(OH)}_2(aq), \text{Sr(OH)}_2(aq), \text{Ca(OH)}_2(aq)\)