IONIC REACTIONS IN WATER

Consider EXCHANGE REACTIONS

\[ AX + BY \rightarrow AY + BX \]

The anions exchange places with each other.

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Pb(NO\(_3\))\(_2\)(aq) + 2 KI(aq) \rightarrow PbI\(_2\)(s) + 2 KNO\(_3\) (aq)

Precipitation Reactions

The “driving force” is the formation of an insoluble compound — a precipitate.

\[ Pb(NO_3)_2(aq) + 2 KI(aq) \rightarrow 2 KNO_3(aq) + PbI_2(s) \]

Net ionic equation

\[ Pb^{2+}(aq) + 2 I^-(aq) \rightarrow PbI_2(s) \]

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Precipitation Reactions

To determine the NIE, first write all reactants in water. If they are soluble, show them ionized.

\[ \text{Pb}^{2+}(aq) + \text{NO}_3^-(aq) + 2 \text{K}^+(aq) + 2 \text{I}^-(aq) \]

Now look at all the combinations
- lead nitrate is soluble
- lead iodide is insoluble
- potassium iodide is soluble
- potassium nitrate is soluble

So the lead ion and iodide ion will react to make a precipitate, with \( \text{K}^+ \) and \( \text{NO}_3^- \) remaining in solution as spectators.

\[ \text{Pb}^{2+}(aq) + 2 \text{I}^-(aq) \rightarrow \text{PbI}_2(s) \]

Acid-Base Reactions

- The “driving force” in acid-base reactions is the formation of water.

\[ \text{NaOH}(aq) + \text{HCl}(aq) \rightarrow \text{NaCl}(aq) + \text{H}_2\text{O}(liq) \]

- Net ionic equation

\[ \text{OH}^-(aq) + \text{H}^+(aq) \rightarrow \text{H}_2\text{O}(liq) \]

- This applies to ALL reactions of STRONG acids and bases.

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Acid-Base Reactions

To determine the NIE, first write all reactants in water. These are strong electrolytes so show them ionized.

\[ \text{Na}^+(aq) + \text{OH}^-(aq) + H^+(aq) + \text{Cl}^+(aq) \]

Look at the ion combinations and remember that \( H^+ \) and \( \text{OH}^- \) react to form water.

\[ \text{OH}^-(aq) + H^+(aq) \rightarrow \text{H}_2\text{O(liq)} \]

Acid-Base Reactions

- Acid-base reactions are sometimes called NEUTRALIZATIONS because the solution is neither acidic nor basic at the end, it is neutral.
- The other product of the \( HX-MOH \) acid-base reaction is a SALT, \( MX \).

\[ \text{HCl} + \text{LiOH} \rightarrow \text{LiCl} + \text{H}_2\text{O} \]

\( \text{Li}^+ \) comes from base & \( \text{Cl}^- \) comes from acid

The final result is the same as dissolving \( \text{LiCl} \) in water.
Acid-Base Reactions

Not all acid-base reactions are for strong acids and/or bases. For example,

\[ \text{HX} + \text{MOH} \rightarrow \text{MX} + \text{H}_2\text{O} \]

could represent a reaction of a weak acid and an insoluble hydroxide.

In this case, start with the species as they would be found in water. Take acetic acid and insoluble calcium hydroxide as an example.

\[ \text{CH}_3\text{CO}_2\text{H}(\text{aq}) + \text{Ca(OH)}_2(\text{s}) \rightarrow ?? \]

Acid-Base Reactions

\[ \text{CH}_3\text{CO}_2\text{H}(\text{aq}) + \text{Ca(OH)}_2(\text{s}) \rightarrow ?? \]

The acetic acid will ionize slightly, producing a few \(\text{H}^+\) ions. These will react with the \(\text{OH}^-\) of the \(\text{Ca(OH)}_2\) to form water. This will continue until all the \(\text{OH}^-\) is removed from the \(\text{Ca(OH)}_2\), leaving acetate and \(\text{Ca}^{2+}\) ions:

\[ \text{CH}_3\text{CO}_2\text{H}(\text{aq}) + \text{Ca(OH)}_2(\text{s}) \rightarrow \text{H}_2\text{O}(\text{l}) + \text{Ca}^{2+}(\text{aq}) + \text{CH}_3\text{CO}_2^- (\text{aq}) \]

This is unbalanced! Must be fixed!
Acid-Base Reactions

\[ \text{CH}_3\text{CO}_2\text{H(aq)} + \text{Ca(OH)}_2(s) \rightarrow \text{H}_2\text{O(l)} + \text{Ca}^{2+}(aq) + \text{CH}_3\text{CO}_2^- (aq) \]

There are two hydroxide ions in each \text{Ca(OH)}_2 so we need two acetic acids to make two \text{H}^+ for each molecule of calcium hydroxide.

That would produce two water molecules,

or...

\[ 2 \text{CH}_3\text{CO}_2\text{H(aq)} + \text{Ca(OH)}_2(s) \rightarrow 2 \text{H}_2\text{O(l)} + \text{Ca}^{2+}(aq) + 2 \text{CH}_3\text{CO}_2^- (aq) \]

This is the net ionic equation.

Gas-Forming Reactions

• This is often the chemistry of metal carbonates.

\[ \text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3 \]

\[ \text{H}_2\text{CO}_3(aq) + \text{Ca}^{2+} \rightarrow 2 \text{H}^+(aq) + \text{CaCO}_3(s) \text{ (limestone)} \]

• Adding acid reverses this reaction:

\[ \text{CaCO}_3 + \text{acid} \rightarrow \text{CO}_2 + \text{calcium salt} \]
Gas-Forming Reactions

\[
\text{CaCO}_3(s) + \text{H}_2\text{SO}_4(aq) \rightarrow 2 \text{CaSO}_4(aq) + \text{H}_2\text{CO}_3(aq)
\]

Carbonic acid is unstable and forms CO₂ & H₂O:
\[
\text{H}_2\text{CO}_3(aq) \rightarrow \text{CO}_2(g) + \text{H}_2\text{O}(l)
\]

Antacid tablets use carbonate to make CO₂
(Note: the antacid tablet has citric acid + NaHCO₃)

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