Lecture 18 – Chapter 16, Sections 5-6
Equilibrium

- Nifty $K_{eq}$ math
- $K_{eq}$ pseudonyms
Aqueous solutions

- Because aqueous solutions are so common, they have some specific nomenclature
  - Acids and bases
  - Soluble salts
  - Complexes
Acids and Bases

\[ \text{HA}_{(aq)} + \text{H}_2\text{O}_{(l)} \rightarrow \text{A}^-_{(aq)} + \text{H}_3\text{O}^+_{(aq)} \]

\( K_{eq} \) is called \( K_a \) (acid ionization constant)

\[
K_a = \frac{[\text{A}^-]_{eq}[\text{H}_3\text{O}^+]_{eq}}{[\text{HA}]_{eq}}
\]

\[ \text{B}_{(aq)} + \text{H}_2\text{O}_{(l)} \rightarrow \text{BH}^+_{(aq)} + \text{OH}^-_{(aq)} \]

\( K_{eq} \) is called \( K_b \) (base ionization constant)

\[
K_b = \frac{[\text{BH}^+]_{eq}[\text{OH}^-]_{eq}}{[\text{B}]_{eq}}
\]
Soluble Salts

\[
\text{NaCl} \,(s) \, + \, \text{H}_2\text{O} \,(l) \, \rightarrow \, \text{Na}^+(\text{aq}) \, + \, \text{Cl}^-\,(\text{aq}) \\
K_{eq} \text{ is called } K_{sp} \text{ (solubility product)}
\]

\[
K_{sp} = \left[ \text{Na}^+ \right]_{eq} \left[ \text{Cl}^- \right]_{eq}
\]

\[
\text{CuCl}_2 \,(s) \, + \, \text{H}_2\text{O} \,(l) \, \rightarrow \, \text{Cu}^{2+} \,(\text{aq}) \, + \, 2 \, \text{Cl}^-\,(\text{aq}) \\
K_{eq} \text{ is called } K_{sp} \text{ (solubility product)}
\]

\[
K_{sp} = \left[ \text{Cu}^{2+} \right]_{eq} \left[ \text{Cl}^- \right]_{eq}^2
\]
Complexes

\[
\text{Ag}^+_{(aq)} + 2 \text{NH}_3_{(aq)} \rightarrow [\text{Ag(NH}_3)_2]^+_{(aq)}
\]

\( K_{eq} \) is called \( K_f \) (formation constant)

\[
K_f = \frac{\left[ \text{Ag(NH}_3)_2 \right]^{+}_{eq}}{\left[ \text{Ag}^+ \right]_{eq} \left[ \text{NH}_3 \right]^{2}_{eq}}
\]
Review – LeChatelier’s

\[
\text{Co(H}_2\text{O)}_6^{2+}_{\text{(aq)}} + 4\text{Cl}^-_{\text{(aq)}} \rightarrow \text{CoCl}_4^-_{\text{(aq)}} + 6\text{H}_2\text{O}_{\text{(l)}}
\]

\[\Delta H > 0\]
What will we see in the demo?

**25%**
1. Hot = blue   cold = blue

**25%**
2. Hot = pink   cold = pink

**25%**
3. Hot = blue   cold = pink

**25%**
4. Hot = pink   cold = blue
Example

- How do we work with these things when the algebra isn’t simple?
- Let’s work through one of the worksheet examples (part C)

<table>
<thead>
<tr>
<th></th>
<th>$N_2$</th>
<th>$H_2$</th>
<th>$NH_3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial</td>
<td>0.15</td>
<td>0.25</td>
<td>0</td>
</tr>
<tr>
<td>Change</td>
<td>$-x$</td>
<td>$-3x$</td>
<td>$+2x$</td>
</tr>
<tr>
<td>Equilibrium</td>
<td>$0.15-x$</td>
<td>$0.25-3x$</td>
<td>$2x$</td>
</tr>
</tbody>
</table>

\[ K_{eq} = 0.040 = \frac{(2x)^2}{(0.15-x)(0.25-3x)^3} \]
Example

\[ K_{eq} = 0.040 = \frac{(2x)^2}{(0.15 - x)(0.25 - 3x)^3} \]

- If \( x \) is small?
- Then ignore compared to 0.15 and 0.25
- Solve for \( x \)
- Is \( x \) small? Is 3\( x \) small?

\[ 0.040 = \frac{(2x)^2}{(0.15)(0.25)^3} \]
\[ 4x^2 = (0.040)(0.15)(0.25)^3 \]
\[ x = 0.004841 \]

\[ 4x_1^2 = (0.040)(0.15 - x_0)(0.25 - 3x_0)^3 \]
\[ x_1 = \sqrt{\frac{1}{4}(0.040)(0.15 - x_0)(0.25 - 3x_0)^3} \]

- Treat \( x \) alone differently than those added to or subtracted from big numbers.
Example

\[ x_1 = \sqrt{\left(\frac{1}{4}\right)(0.040)(0.15 - x_0)(0.25 - 3x_0)^3} \]

- Now, start with \( x_0 = 0 \) then solve for \( x_1 \).
- Plug this in as a new \( x_0 \) and solve for a new \( x_1 \).
- Repeat until \( x_0 \) and \( x_1 \) are the same.

<table>
<thead>
<tr>
<th>Iteration</th>
<th>( x_0 )</th>
<th>( x_1 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>0.004841</td>
</tr>
<tr>
<td>2</td>
<td>0.004841</td>
<td>0.004354</td>
</tr>
<tr>
<td>3</td>
<td>0.004354</td>
<td>0.004402</td>
</tr>
<tr>
<td>4</td>
<td>0.004402</td>
<td>0.004397</td>
</tr>
<tr>
<td>5</td>
<td>0.004397</td>
<td>0.004397</td>
</tr>
</tbody>
</table>

- Don’t forget to plug this back into equilibrium expressions to get final concentrations.
Today

• Go to seminar
• Review this week’s CAPA
• Do extra problems from book (end-of-chapt 16)

Monday

• Finish CAPA #11 (and #10)
• Start reading Chapt 17