Lecture 18 – Chapter 17, Sections 5-7
More weak acids and bases

- Salts of weak acids and bases
- Chemistry of weak vs. strong acids
- Multiple equilibria – polyprotic acids
Acids and Bases

- Strong vs. Weak
- $K_a$ vs. $K_b$
- pH = -log([H])
- pH + pOH = 14
- Conjugate acids and bases

- Should be able to calculate pH (or pOH) of some solution given that you have some concentration of some weak acid.
HF is a weak acid. What is its conjugate base?

<table>
<thead>
<tr>
<th></th>
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<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>20%</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
Is NaF an acid or a base?

• Neither at first glance
• But notice that in aqueous solution two ions are formed
  \( \text{Na}^+ \) and \( \text{F}^- \)

• Since \( \text{F}^- \) is a base (the conjugate base of HF) NaF must act
  as a base.

\[
\begin{align*}
\text{NaF}_\text{(s)} & \rightarrow \text{Na}^+_{\text{(aq)}} + \text{F}^-_{\text{(aq)}} \\
\text{F}^-_{\text{(aq)}} & + \text{H}_2\text{O} \rightarrow \text{HF}_{\text{(aq)}} + \text{OH}^-_{\text{(aq)}}
\end{align*}
\]
What about Na$^+$

- NaOH is a base, so Na$^+$ must be a conjugate acid
  \[ \text{Na}^+_{(aq)} + 2\text{H}_2\text{O} \rightarrow \text{NaOH}_{(aq)} + \text{H}_3\text{O}^+_{(aq)} \]

- Why doesn’t this matter?

- Because NaOH is a strong base, Na$^+$ is essentially not acidic at all

- F$^-$ acts as a base because HF is a weak acid
$K_a$ and $K_b$ are related

- Note the two equilibria related to hydrofluoric acid

$$HF_{(aq)} + H_2O \rightarrow F^{-}_{(aq)} + H_3O^+_{(aq)}$$

$$K_a = \frac{[F^-][H_3O^+]}{[HF]}$$

$$F^-_{(aq)} + H_2O \rightarrow HF_{(aq)} + OH^-_{(aq)}$$

$$K_b = \frac{[HF][OH^-]}{[F^-]}$$
$K_a$ and $K_b$ are related (ii)

• If we add these two equations...

\[
\begin{align*}
HF_{(aq)} &+ H_2O \rightarrow F^{-}_{(aq)} + H_3O^+_{(aq)} \\
F^{-}_{(aq)} &+ H_2O \rightarrow HF_{(aq)} + OH^-_{(aq)}
\end{align*}
\]

\[
2H_2O \rightarrow OH^-_{(aq)} + H_3O^+_{(aq)}
\]

• If we add equations, we multiply equilibrium constants

\[
K_aK_b = \frac{[F^-][H_3O^+]}{[HF]} \cdot \frac{[HF][OH^-]}{[F^-]} = [H_3O^+][OH^-] = K_w
\]
$K_a$ and $K_b$ are related \ (iii) \\

If \[ K_a K_b = K_w \]

then \[ \text{p}K_a + \text{p}K_b = \text{p}K_w = 14 \]

(for a conjugate acid-base pair)
Important points about $K_a$ and $K_b$

<table>
<thead>
<tr>
<th>Acid Strength</th>
<th>$K_a$</th>
<th>Conjugate Base Strength</th>
<th>$K_b$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strong</td>
<td>$&gt;1$</td>
<td>Very Weak</td>
<td>$&lt;10^{-16}$</td>
</tr>
<tr>
<td>Weak</td>
<td>$10^{-16}$ to $1$</td>
<td>Weak</td>
<td>$10^{-16}$ to $1$</td>
</tr>
<tr>
<td>Very Weak</td>
<td>$&lt;10^{-16}$</td>
<td>Strong</td>
<td>$&gt;1$</td>
</tr>
</tbody>
</table>

Of course, we could also have a similar table with Base Strength and Conjugate Acid Strength.
Example: Bleach

- The bleach we used for the kinetics demos was standard 5% NaOCl solution (aqueous) approx. 0.67 M

- What are the concentrations of ALL species in this solution?
  - Identify all species
  - Recognize conjugate base and find $K_b$
  - Set up equilibrium table
  - Solve for species concentrations
### Recognizing Acids

**1. Strong Acids.** Memorize the formulas and names of the six common strong acids.

<table>
<thead>
<tr>
<th>Acid Name</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCl (hydrochloric acid)</td>
<td>HCl</td>
</tr>
<tr>
<td>HBr (hydrobromic acid)</td>
<td>HBr</td>
</tr>
<tr>
<td>HI (hydroiodic acid)</td>
<td>HI</td>
</tr>
<tr>
<td>HNO(_3) (nitric acid)</td>
<td>HNO(_3)</td>
</tr>
<tr>
<td>HClO(_4) (perchloric acid)</td>
<td>HClO(_4)</td>
</tr>
<tr>
<td>H(_2)SO(_4) (sulfuric acid)</td>
<td>H(_2)SO(_4)</td>
</tr>
</tbody>
</table>

**2. Weak Acids.** Recognize these from general formulas.

- **A. Oxoacids:** \(H_xE\_O_y\), where \(x = 1 \sim 3\), \(y = 1 \sim 4\), \(E = B, C, N, P, S, Cl, Br, I, others\)
  - HClO (hypochlorous acid)
  - HBrO (hydrobromous acid)
  - HI (hydroiodic acid)
  - HNO\(_2\) (nitrous acid)
  - H\(_2\)CO\(_3\) (carbonic acid)
  - H\(_2\)SO\(_3\) (sulfurous acid)
- **B. Carboxylic acids:** \(RCO\_2\_H\), where \(R = H\) or any organic group
  - HCO\(_2\_H\) (formic acid)
  - CH\(_3\)CO\(_2\_H\) (acetic acid)
  - C\(_6\)H\(_5\)CO\(_2\_H\) (benzoic acid)
  - (CO\(_2\_H\))\(_2\) (oxalic acid)
  - HOCH\(_2\)CO\(_2\_H\) (glycolic acid)
  - HO\(_2\)CCH\(_2\)CH\(_2\)CO\(_2\_H\) (adipic acid)
- **C. Conjugate acid of a weak base**
  - NH\(_3\)\(^+\) (ammonium ion)
  - C\(_5\)H\(_5\)NH\(_3\)\(^+\) (pyridinium ion)
  - C\(_6\)H\(_5\)NH\(_3\)\(^+\) (anilinium ion)
- **D. Miscellaneous examples**
  - HF (hydrofluoric acid)
  - HCN (hydrocyanic acid)
  - H\(_2\)S (hydrogen sulfide)
  - H\(_2\)O\(_2\) (hydrogen peroxide)

### Recognizing Bases

**1. Strong Bases.** Memorize the Group 1 hydroxides (MOH) and the soluble Group 2 hydroxides (MOH\(_2\)).

<table>
<thead>
<tr>
<th>Base Name</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>LiOH</td>
<td>NaOH</td>
</tr>
<tr>
<td>Ca(OH)(_2)</td>
<td>Sr(OH)(_2)</td>
</tr>
<tr>
<td>KOH</td>
<td></td>
</tr>
</tbody>
</table>

**2. Weak Bases.** Recognize these from general formulas.

- **A. Ammonia (NH\(_3\)) and amines** \(RNH\(_2\), R\(_2\)NH, RN\)
  - CH\(_3\)NH\(_2\) (methylamine)
  - (CH\(_3\))\(_2\)NH (diethylaniline)
  - (C\(_6\)H\(_5\))\(_2\)NH (diphenylamine)
  - C\(_6\)H\(_5\)NH\(_2\) (aniline)
- **B. Conjugate base of a weak acid**
  - F\(^-\) (fluoride)
  - CN\(^-\) (cyanide)
  - CH\(_3\)CO\(_2\)\(^-\) (acetate)
  - OCl\(^-\) (hypochlorite)
  - SO\(_4\)\(^2\-) (sulfate)
  - PO\(_4\)\(^3\-) (phosphate)
  - HCO\(_3\)\(^-\) (hydrogen carbonate)
  - NO\(_2\)\(^-\) (nitrite)
  - C\(_6\)H\(_5\)CO\(_2\)\(^-\) (benzoate)
What makes an acid stronger or weaker?

- Charge
- Strength of X-H bond

- Charge is pretty simple
  - Something positive is a good acid, lousy base
  - Something negative is a lousy acid, good base
  - Something neutral is somewhere between
Acid strength?

- More polar bond $\rightarrow$ stronger acid
  - HF stronger acid than CH$_4$
- Weaker X-H bond $\rightarrow$ stronger acid
  - HCl stronger acid than HF
  - HClO$_4$ stronger acid than HOCl
Today
• Finish CAPA #10

Wednesday
• Start on CAPA #11
• Start reading Chapt 18
• It’s not too early to start thinking about Exam 2…