Which of the following is true about a weak base?

1. $K_b \ll 1$
2. $K_b \approx 1$
3. $K_b \gg 1$
4. $K_b \gg K_w$
5. $K_b \ll K_w$
6. 1 and 4
7. 1 and 5
8. 1, 4, and 5

Step 2: $[H_3O^+]$ when “too little” base added

$K_w = 100$ mL of $c_b = 0.20$ M of OH$^-$ is combined with $V_a = 100$ mL of $c_a = 0.40$ M of HA. $K_a = 1.0 \times 10^{-5}$. Step 1 results:

$[HA] = c'_a = (c_a V_a - c_b V_b) / (V_a + V_b) = 0.020 \text{ mol} / (0.200 \text{ L}) = 0.10 \text{ M}$

$[A^-] = c'_b = (c_b V_b) / (V_a + V_b) = (0.020) \text{ mol} / (0.200 \text{ L}) = 0.10 \text{ M}$

$[OH^-] = 0$

$K_b = K_w / K_a = 10^{-14} / (1.0 \times 10^{-5}) = 1.0 \times 10^{-9} \ll K_a$, so in this case ...

when “too little” base has been added, we find $[H_3O^+]$ using the ICE table for

$HA(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + A^-(aq)$
Step 2: [H$_3$O$^+$] when “too little” base added

\[ K_a = 100. \text{ mL of } c_a = 0.20 \text{ M of OH}^- \text{ is combined with } V_a = 100. \text{ mL of } c_a = 0.40 \text{ M of HA, } K_a = 1.0 \times 10^{-5} \]

\[
\begin{array}{|c|c|c|c|}
\hline
& HA(aq) & H_3O^+(aq) & A^-(aq) & Q \\
\hline
\text{Initial} & 0.10 & 10^{-7} & 0.10 & 10^{-7} < K_a \\
\text{Change} & -x & +x & +x & \\
\text{Equilibrium} & 0.10 - x & 10^{-7} + x & 0.10 + x & 1.0 \times 10^{-5} \\
\text{Approximate} & \approx 0.10 & \approx x & \approx 0.10 & 1.0 \times 10^{-5} \\
\hline
\end{array}
\]

\[ [H_3O^+] = \frac{K_a \times [HA]}{[A^-]} = \frac{(1.0 \times 10^{-5} \times 0.10)}{0.10} = 1.0 \times 10^{-5} \]

Step 2: [H$_3$O$^+$] when “just enough” base added

\[ K_a = 100. \text{ mL of } c_a = 0.20 \text{ M of OH}^- \text{ is combined with } V_a = 100. \text{ mL of } c_a = 0.40 \text{ M of HA, } K_a = 1.0 \times 10^{-5} \]

\[ [H_3O^+] = \frac{K_a \times [HA]}{[A^-]} = \frac{(1.0 \times 10^{-5} \times 0.40)}{0.40} = 1.0 \times 10^{-5} \]

Step 2: [H$_3$O$^+$] when “too little” base added

\[ K_a = 100. \text{ mL of } c_a = 0.20 \text{ M of OH}^- \text{ is combined with } V_a = 100. \text{ mL of } c_a = 0.40 \text{ M of HA, } K_a = 1.0 \times 10^{-5} \]

\[ [H_3O^+] = \frac{K_a \times [HA]}{[A^-]} = \frac{(1.0 \times 10^{-5} \times 0.10)}{0.10} = 1.0 \times 10^{-5} \]

Step 2: [H$_3$O$^+$] when “just enough” base added

\[ K_a = 100. \text{ mL of } c_a = 0.40 \text{ M of OH}^- \text{ is combined with } V_a = 100. \text{ mL of } c_a = 0.40 \text{ M of HA, } K_a = 1.0 \times 10^{-5} \]
Step 2: $[\text{H}_3\text{O}^+]$ when “just enough” base added

We can get $[\text{H}_3\text{O}^+]$ by equilibrating the limiting reagent reaction outcome. When “just enough” base is added, only the conjugate base will be present after the limiting reagent reaction.

But what equilibrium do we work with?

If only conjugate base is present, then work with

$$\text{H}_2\text{O}(l) + A^- (aq) \rightleftharpoons \text{HA}(aq) + \text{OH}^- (aq), \ K_b = K_w / K_a$$
[Quiz] Which of the following is true about the conjugate base $A^-$ of the weak acid $HA$?

- 25% 1. $A^-$ is a strong base
- 25% 2. $A^-$ is a weak base
- 25% 3. Not a base, since $K_b \ll K_w$
- 25% 4. Further information needed

Step 2: $[H_3O^+]$ when “just enough” base added

$K_a = \frac{K_w}{K_b} = 1.0 \times 10^{-8}$

<table>
<thead>
<tr>
<th>$A^-(aq)$</th>
<th>HA(aq)</th>
<th>OH-(aq)</th>
<th>Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial</td>
<td>0.20</td>
<td>0</td>
<td>$10^{-7}$</td>
</tr>
<tr>
<td>Change</td>
<td>$-x$</td>
<td>$+x$</td>
<td>$+x$</td>
</tr>
<tr>
<td>Equilibrium</td>
<td>$0.20 - x$</td>
<td>$x$</td>
<td>$10^{-7} + x$</td>
</tr>
<tr>
<td>Approximate</td>
<td>$0.20$</td>
<td>$x$</td>
<td>$\approx x$</td>
</tr>
</tbody>
</table>

$[OH^-] = x = (K_b \times [A^-])^{1/2} = (1.0 \times 10^{-8} \times 0.20)^{1/2} = 4.5 \times 10^{-5}$

$[H_3O^+] = K_a / [OH^-] = (1.0 \times 10^{-14}) / (4.5 \times 10^{-5}) = 2.2 \times 10^{-10}$