Table 1. Dissociation Constants for some Acids.

<table>
<thead>
<tr>
<th>Acid</th>
<th>pK_a Value</th>
<th>Acid</th>
<th>pK_a Value</th>
<th>Acid</th>
<th>pK_a Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>NH_4^+</td>
<td>10</td>
<td>HBF_4</td>
<td>-9</td>
<td>formic</td>
<td>4</td>
</tr>
<tr>
<td>HClO</td>
<td>8</td>
<td>H_2CO_3</td>
<td>7</td>
<td>benzoic</td>
<td>5</td>
</tr>
</tbody>
</table>

1. (5 pts) Which of the acids listed in Table 1, given a 0.01 M solution in water, will have a pH closest to 2?

   a) NH_4^+    b) benzoic    c) H_2CO_3    d) formic    e) HBF_4

2. (5 pts) Which of the acids listed in Table 1, when reacted with an equivalent amount of NaOH, will form a solution with the highest pH?

   a) NH_4^+    b) benzoic    c) H_2CO_3    d) formic    e) HBF_4

3. (5 pts) Order the acids in Table 1 from strongest to weakest. Circle the correct choice.

   a) benzoic > formic > H_2CO_3 > HBF_4 > NH_4^+ > HClO
   b) HBF_4 > formic > benzoic > H_2CO_3 > HClO > NH_4^+
   c) NH_4^+ > benzoic > HBF_4 > formic > H_2CO_3 > HClO
   d) benzoic > HBF_4 > NH_4^+ > formic > H_2CO_3 > HClO
   e) NH_4^+ > HClO > H_2CO_3 > benzoic > formic > HBF_4

4. (5 pts) What is the pH of a 0.01 M solution of the weak base benzylamine (C_6H_5CH_2NH_2)? pK_a = 8. Circle the answer below and clearly show all your work.

   Initial: 0.01M pure liq 0M 0M
   Base(aq) + H_2O(l) BaseH^+(aq) + OH^−(aq)
   @ Equib: 0.01 − x pure liq x x

   You first need to convert the pK_a into a K_a, then into a K_b for this basic equilibrium:

   \[ K_b = \frac{K_w}{K_a} = \frac{1 \times 10^{-14}}{1 \times 10^{-8}} = 1 \times 10^{-6} \]

   now you can setup your equilib: K_b = \frac{(x)(x)}{(0.01 − x)} = 1 \times 10^{-6}

   assume that x << 0.01, \( \frac{(x)(x)}{(0.01)} = 1 \times 10^{-6} \) or \( x^2 = 1 \times 10^{-8} \), or \( x = [OH^−] = 1 \times 10^{-4} \) pOH = 4.

   BUT THIS IS NOT YOUR ANSWER, since I asked for the pH!! \( pH = 14 − 4 = 10 \)

   a) 4    b) 5    c) 9    d) 10    e) 13

5. (10 pts) Will FeCl_3 generate an acidic, neutral, or basic solution when dissolved in water. Clearly discuss your reasoning.

   FeCl_3 is composed of a Fe^{3+} cation and three Cl^− anions. The Cl^− anions are “do nothing” or “neutral” (acid-base property, extremely poor conjugate base) so will not make a basic solution. The Fe^{3+} cation, on the other hand, is a Lewis acid and will react with water to release H^+: Fe^{3+}(aq) + H_2O \rightarrow [Fe(OH)]^{2+} + H^+(aq).

   This is called hydrolysis and most +2 or higher cations can interact with water in a similar fashion to release H^+ and make an acidic solution. Note that the [Fe(OH)]^{2+} is not a typical hydroxide base as the Fe-OH bond is reasonably strong and will not dissociate OH^−.
6. (5 pts) What is the pH of a 1 M solution of KClO? See Table 1 for pK\textsubscript{a} values. Clearly show all your work. The first thing to realize is that this is a basic salt that will generate a basic solution! K\textsuperscript{+} is a do-nothing cation, while ClO\textsuperscript{−} is an active anion that acts as a weak base in solution.

\begin{align*}
\text{Initial:} & \quad 1\text{M pure liq} \quad 0\text{M} \quad 0\text{M} \\
\text{Base}^{-}(aq) + \text{H}_{2}\text{O}(l) & \rightleftharpoons \text{BaseH}^{+}(aq) + \text{OH}^{-}(aq) \\
\text{@ Equib:} & \quad 1 - x \quad \text{pure liq} \quad x \quad x
\end{align*}

Next you need to convert the pK\textsubscript{a} value I've given you into a K\textsubscript{a}, then K\textsubscript{b} for the conjugate base in this basic equilibrium:

\[
\frac{(x)(x)}{(1-x)} = 1 \times 10^{-6} \quad \text{or} \quad x^2 = 1 \times 10^{-6}, \quad \text{or} \quad x = [\text{OH}^{-}] = 1 \times 10^{-3} \quad \text{pOH} = 3. \quad \text{pH} = 14 - \text{pOH} = 11 \quad \text{so the } \text{pH} = 11
\]

7. (10 pts) Consider the following list of salts:

A) NH\textsubscript{4}Cl  B) KI  C) CsF  D) potassium benzoate  
E) MoCl\textsubscript{4}  F) BaI\textsubscript{2}  G) AlBr\textsubscript{3}  H) LiNO\textsubscript{3}  
I) KClO\textsubscript{4}  J) NaClO

Which salts will generate an acidic solution? A, E, G  
Which salts will generate a basic solution? C, D, J  
Which salts will generate a neutral solution? B, F, H, I

8. (5 pts) Calculate the pK\textsubscript{b} of the weak base phenylamine if a 1 M solution has a pH = 10.

\begin{align*}
\text{Initial:} & \quad 1\text{M pure liq} \quad 0\text{M} \quad 0\text{M} \\
\text{Base}^{-}(aq) + \text{H}_{2}\text{O}(l) & \rightleftharpoons \text{BaseH}^{+}(aq) + \text{OH}^{-}(aq) \\
\text{@ Equib:} & \quad 0.1 - x \quad \text{pure liq} \quad x \quad x
\end{align*}

But I have given you the pH, so you know the OH\textsuperscript{−} concentration (and [BaseH\textsuperscript{+}]) at equilibrium. If pH = 10, pOH = 4 and the [OH\textsuperscript{−}] = 1 \times 10^{-4} M. This is also small enough relative to 1 – x, that we can drop the x here and really make a very simple expression to solve for K\textsubscript{b}:

\[
\frac{[\text{BaseH}^{+}][\text{OH}^{-}]}{[\text{base}]} = 1 \times 10^{-4}(1 \times 10^{-4}) = 1 \times 10^{-8} \quad \text{so} \quad \text{pK}_{b} = 8
\]

9. (10 pts) What is the pH if 800 mL of 0.125 M KOH is added to 200 mL of 0.5 M sucoloic acid (a monoprotic acid)? pK\textsubscript{a} = 11 (clearly show all your work)

The first thing to realize is that sucoloic acid is a weak acid and that we are titrating it with a strong base. If there are equal amounts of each, we will be making the salt of a weak acid, which is a weak base! So we may be generating a basic solution depending on the amount of acid and base reacting. Convert the # of mL and molarity of each into moles:

- # moles base = (800 mL OH\textsuperscript{−})(0.125 M OH\textsuperscript{−}) = 100 mmoles OH\textsuperscript{−}
- # moles weak acid = (200 mL weak acid)(0.5 M weak acid) = 100 mmoles weak acid

So we have an equal amount of each. Don’t forget that we are adding 800 mL to 200 mL to make 1000 mL total solution volume. This will generate a 100 mmoles/1000 mL = 0.1 M solution that will act as a weak base:

\begin{align*}
\text{Initial:} & \quad 0.1\text{M pure liq} \quad 0\text{M} \quad 0\text{M} \\
\text{Base}^{-}(aq) + \text{H}_{2}\text{O}(l) & \rightleftharpoons \text{BaseH}^{+}(aq) + \text{OH}^{-}(aq) \\
\text{@ Equib:} & \quad 0.1 - x \quad \text{pure liq} \quad x \quad x
\end{align*}

Next you need to convert the pK\textsubscript{a} value I’ve given you into a K\textsubscript{a}, then K\textsubscript{b} for the conjugate base in this basic equilibrium:

\[
K_b = \frac{[\text{baseH}^{+}][\text{OH}^{-}]}{[\text{base}]} = \frac{(1 \times 10^{-4})(1 \times 10^{-4})}{1} = 1 \times 10^{-8} \quad \text{so} \quad \text{pK}_{b} = 8
\]

\[
K_b = \frac{[\text{baseH}^{+}][\text{OH}^{-}]}{[\text{base}]} = \frac{(1 \times 10^{-4})(1 \times 10^{-4})}{1} = 1 \times 10^{-8} \quad \text{so} \quad \text{pK}_{b} = 8
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