Worksheet 22 – Salts

Shown below is a chart of acid, their conjugate bases and their respective $K_a$ and $K_b$ values. Fill in the missing information. ($K_a \times K_b = K_w = 1 \times 10^{-14}$)

<table>
<thead>
<tr>
<th>$K_a$</th>
<th>Acid</th>
<th>$K_b$</th>
<th>Base</th>
<th>$K_b$</th>
</tr>
</thead>
<tbody>
<tr>
<td>strong acid</td>
<td>HNO$_3$, HI, HCl, etc</td>
<td>NO$_3^-$, I$^-$, Cl$^-$, etc</td>
<td>negligible basicity</td>
<td></td>
</tr>
<tr>
<td>______</td>
<td>HSO$_4^-$</td>
<td>7.7 x $10^{-13}$</td>
<td>SO$_4^{2-}$</td>
<td></td>
</tr>
<tr>
<td>7.1 x $10^{-4}$</td>
<td>HNO$_2$</td>
<td>1.4 x $10^{-11}$</td>
<td>______</td>
<td></td>
</tr>
<tr>
<td>6.8 x $10^{-4}$</td>
<td>HF</td>
<td>1.5 x $10^{-11}$</td>
<td>F$^-$</td>
<td></td>
</tr>
<tr>
<td>______</td>
<td>CH$_3$COOH</td>
<td>5.6 x $10^{-10}$</td>
<td>CH$_3$COO$^-$</td>
<td></td>
</tr>
<tr>
<td>4.5 x $10^{-7}$</td>
<td>______</td>
<td>2.3 x $10^{-8}$</td>
<td>HCO$_3^-$</td>
<td></td>
</tr>
<tr>
<td>9 x $10^{-8}$</td>
<td>H$_2$S</td>
<td>______</td>
<td>HS$^-$</td>
<td></td>
</tr>
<tr>
<td>5.6 x $10^{-10}$</td>
<td>NH$_4^+$</td>
<td>1.8 x $10^{-5}$</td>
<td>______</td>
<td></td>
</tr>
<tr>
<td>6.2 x $10^{-10}$</td>
<td>______</td>
<td>1.6 x $10^{-5}$</td>
<td>CN$^-$</td>
<td></td>
</tr>
<tr>
<td>4.7 x $10^{-11}$</td>
<td>HCO$_3^-$</td>
<td>______</td>
<td>CO$_3^{2-}$</td>
<td></td>
</tr>
<tr>
<td>1 x $10^{-17}$</td>
<td>______</td>
<td>1 x $10^{-13}$</td>
<td>S$^{2-}$</td>
<td></td>
</tr>
<tr>
<td>negligible acidity</td>
<td>Li$^+$, Na$^+$, Ca$^{2+}$, etc.</td>
<td>O$^{2-}$, OH$^-$</td>
<td>strong base</td>
<td></td>
</tr>
</tbody>
</table>

**Salts** are ionic compounds, which dissociate in water to produce ions. They are formed in the neutralization reaction between acids and bases. Depending on the nature of the acids and bases (strong or weak), the solutions of the salts will be acidic, basic or neutral.

1. Decide which of the following salts will form **acidic**, **basic** or **neutral** solutions when dissolved in water. (Hint: look at the acids and bases that formed them)

   For example: KCH$_3$COO was formed in the reaction between KOH and CH$_3$COOH

   **KOH** is a **strong base**. Its conjugate acid, K$^+$, has negligible acidity and will leave the pH at 7.00, a **neutral** solution.

   **CH$_3$COOH** is a **weak acid**, making its conjugate base, CH$_3$COO$^-$ a relatively strong base. It will produce a **basic solution**.
Analyze the following salts in the same way.

a) KF          d) KCN
b) NaNO₃       e) Rbl
c) NH₄NO₃      f) Na₂CO₃

2. Rank the following salts in order of increasing pH of 0.1 M aqueous solutions. (Hint: write out the reactions of the salts + water)

a) KNO₃      K₂SO₄      K₂S

b) NH₄NO₃     NaHSO₄     NaHCO₃     Na₂CO₃

3. In an experiment, it is found that the pHs of three salts, KX, KY and KZ are 7.0, 9.0 and 11.0. Arrange the acids, HX, HY and HZ in order of increasing acid strength.
4. Calculate the pH of a 0.1 M NaCN solution.

5. Suppose that 50.00 mL of 0.10 M CH₃COOH is neutralized by 50.00 mL of 0.10 M NaOH. What is the pH of the resulting system?

   a) Write the neutralization reaction.

   b) How many moles of CH₃COO⁻ are formed?

   c) What is the final volume of the solution?

   d) What is the concentration of CH₃COO⁻?

   e) Characterize CH₃COO⁻ (i.e. weak/strong acid/base).

   f) Write the reaction of the product and water.

   g) Set up an ICE table for the reaction and calculate the pH of the solution.
6. A 0.10 M solution of KOC₆H₅ has a pH of 11.40. Calculate the \( K_a \) value for HOC₆H₅.

7. What is the pH at the end of the following neutralization reactions?

a) 50.00 mL of 0.10 M CH₃COOH titrated with 0.10 M NaOH

b) 50.00 mL of 0.10 M NaOH titrated with 0.10 M HCl

c) 50.00 mL of 0.10 M HCl titrated with 0.10 M NaOH

d) 50.0 mL of 0.10 M NH₃ titrated with 0.10 M HCl
8. Four different bases, all at 0.10 M concentrations and 1.0 L volumes, are reacted with 100 mL of 1.00 M HNO₃. What are the pH values of the solutions after the reaction?

a) \( \text{CH}_3\text{NH}_2 \ (K_b = 4.4 \times 10^{-4}) \)

b) \( \text{NH}_3 \ (K_b = 1.8 \times 10^{-5}) \)

c) \( \text{C}_5\text{H}_5\text{N} \ (K_b = 1.7 \times 10^{-9}) \)

d) \( \text{NaOH} \)