Strong Acids – Strong Bases Titrations

0.100M NaOH is added to 50.0mL of 0.100M HCl

First find the equivalence point for the titration. Use \( M_A V_A = M_B V_B \). This will let you know where you are in the graph so that you know how to find pH.

1. Initial pH: For a strong acid, the concentration of the acid is equal to the concentration of the hydrogen ion \([H^+]\).
   Just use that to find the pH. \((pH = -\log[H^+])\)
   \[
   \text{ex. } -\log(0.100M) = pH = 1
   \]

2. Between initial pH and equivalence point: First you need to write the neutralization reaction. Find the number of moles of the acid. From the amount of base added and the concentration of the base find the number of moles of the base that you have added. Determine how many moles of the acid after left after the neutralization. Calculate the new volume of the solution (mL of acid + mL of base added). Use these two numbers to find the concentration of the unneutralized acid. Calculate the pH. \((pH = -\log[H^+])\)
   
   ex. 49.0mL of 0.100M NaOH are added to 50.0mL of 0.100M HCl
   \[
   \text{NaOH + HCl } \rightarrow \text{NaCl + H}_2\text{O}
   \]
<table>
<thead>
<tr>
<th>moles</th>
<th>0.049</th>
<th>0.0050</th>
<th>total volume = 99.0mL = 0.099L</th>
</tr>
</thead>
<tbody>
<tr>
<td>-.049</td>
<td>-0.0049</td>
<td>new concen. = .0001mol/.099L = .001M</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0.0001</td>
<td>pH = -log(.001) = 3.00</td>
<td></td>
</tr>
</tbody>
</table>

3. Equivalence point: The pH at the equivalence point for a strong acid-base titration is always 7.

4. After the equivalence point: After the equivalence point, the acid has been completely neutralized. The pH is determined solely by the amount of excess base present. Using the number moles of acid and the moles of base added you can find out the excess moles of base. Calculate the new volume of the solution (mL of acid + mL of base added). Use these two numbers to find the concentration of the excess base. Calculate the pOH. Use this to find the pH.
   
   ex. 51.0mL of 0.100M NaOH are added to 50.0mL of 0.100M HCl
   \[
   \text{NaOH + HCl } \rightarrow \text{NaCl + H}_2\text{O}
   \]
<table>
<thead>
<tr>
<th>moles</th>
<th>0.051</th>
<th>0.0050</th>
<th>total volume = 99.0mL = 0.099L</th>
</tr>
</thead>
<tbody>
<tr>
<td>-.050</td>
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<td>new concen. = .0001mol/.099L = .001M</td>
<td></td>
</tr>
<tr>
<td>.0001</td>
<td>0</td>
<td>pOH = -log(.001) = 3.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>pH = 14 – pOH = 14 – 3 = 11</td>
<td></td>
</tr>
</tbody>
</table>

Weak Acid – Strong Base Titrations

0.100M NaOH is added to 50.0mL of 0.100M HC\(_2\)H\(_3\)O\(_2\)

First find the equivalence point for the titration. Use \( M_A V_A = M_B V_B \). This will let you know where you are in the graph so that you know how to find pH.

1. Initial pH: Initially the only compound present in the solution is the weak acid. It will react with the water. Using the \( K_a \) of the weak acid and the initial concentration of the weak acid, you can find the hydrogen concentration \([H^+]\) present in the water. Setup an ICE chart and solve for the \([H^+]\). Find the pH using \(-\log[H^+]\).
   
   ex. \( K_a = 1.8\times10^{-5} \)
   \[
   \text{HC}_2\text{H}_3\text{O}_2 \leftrightarrow [H^+] + \text{C}_2\text{H}_3\text{O}_2^-
   \]
   I \[
   \begin{array}{ccc}
   \text{0.100} & 0 & 0 \\
   \end{array}
   \]
   C \[
   \begin{array}{ccc}
   \pm x & \pm x & \pm x \\
   \end{array}
   \]
   E \[
   \begin{array}{ccc}
   \text{0.100-x} & x & x \\
   \end{array}
   \]
   \[
   K_a = \frac{x^2}{0.100-x}
   \]
   \[
   x = 0.0013
   \]
   \[
   \text{pH} = -\log(0.0013) = 2.87
   \]

2. Buffer Region: The buffer region exists in between the initial point and the equivalence point. To find the pH in this region you first need to write the neutralization reaction (the net ionic equation for this is more helpful). Next determine the initial number of moles of the acid and the base. Subtract the limiting reagent from both the acid and the base. Add that same amount to the moles of the conjugate base. Calculate the new total volume of the solution. Use the new total volume and the moles of the compounds (acid and conjugate base) to find the new
concentrations. Plug these two values, along with pKa into the Henderson-Hasselbach equation to get the pH.

ex. 49mL of 0.100M NaOH are added to 50.0mL 0.100M

HC₂H₅O₂⁻ + NaOH → H₂O + NaC₂H₅O₂⁻

HC₂H₅O₂⁻ + OH⁻ → H₂O + C₂H₅O₂⁻

Acid 0.0001mole/.099L = 0.001M

0.0050 0.0049 0  Conj. Base 0.0049mole/.099L = 0.049M

-0.0049 -0.0049 +0.0049 pH = pKa + log (Base)/(Acid)

0.0001 0 0.0049 pH = -log(1.8x10⁻⁵) + log (0.049/.001) = 6.4

3. **Equivalence Point:** At the equivalence point all the acid has been converted into the conjugate base. So the initial number of moles of the acid is equal to number of moles as the conjugate base at the equivalence point. Calculate the total volume at the equivalence point. Use these two values to determine the initial concentration of the base. Write the reaction that occurs between the conjugate base and water. Use the Kₐ of the weak acid to find the Kₐ of the conjugate base. Now that you have the initial concentration of the base and its Kₐ, set up an ICE chart and find the concentration of OH⁻ produced. Use that value to find pH.

ex. 50.0mL of 0.100M NaOH is added to 50.0mL of 0.100M C₃H₄O₂⁻

0.005moles of HCl₃H₄O₂⁻ initially = 0.005moles of C₃H₄O₂⁻ at the equivalence point

total volume at the equivalence point is 100.0mL 0.005moles/.1L = .05M C₃H₄O₂⁻

Kₐ of HC₃H₄O₂⁻ = 1.8x10⁻⁵ Kₑₐ = KₐKₐ Kₐ = 5.6x10⁻¹⁰

C₃H₄O₂⁻ + H₂O ↔ HC₃H₄O₂⁻ + OH⁻

Kₐ = x² / 0.05M⁻x pOH = -log(5.27x10⁻⁶) = 5.28

-x +x +x

0.05M-x x x

pH = 14 - pOH = 14 - 5.28 = 8.72

4. **After the Equivalence Point:** After the equivalence point, the acid has been completely neutralized. The pH is determined solely by the amount of excess base present. Using the number moles of acid and the moles of base added you can find out the excess moles of base. Calculate the new volume of the solution (mL of acid + mL of base added). Use these two numbers to find the concentration of the excess base. Calculate the pOH. Use this to find the pH.

ex. 51.0mL of 0.100M NaOH is added to 50.0mL of 0.100M HC₃H₄O₂⁻

HC₃H₄O₂⁻ + NaOH → H₂O + NaC₃H₄O₂⁻

HC₃H₄O₂⁻ + OH⁻ → H₂O + C₃H₄O₂⁻

0.0050 0.0051 0.0001mole OH⁻/.101L = 9.9x10⁻⁴M OH⁻

-0.0050 -0.0050 pOH = -log(9.9x10⁻⁴) = 3

0 0.0001 pH = 14 - pOH = 14 - 3 = 11