The following titration curve is for the titration of 20 mL of 0.1000 M H₃A with 0.1000 M NaOH. The acid dissociation constants for H₃A are: $K_{a1} = 3 \times 10^{-5}$, $K_{a2} = 5 \times 10^{-7}$, and $K_{a3} = 2 \times 10^{-11}$.

1. Write the equilibrium reactions that correspond to the 3 acid dissociation constants.

   \[
   \begin{align*}
   H_3A + H_2O & \rightleftharpoons H_2A^- + H_3O^+ \\
   H_2A^- + H_2O & \rightleftharpoons HA^{2-} + H_3O^+ \\
   HA^{2-} + H_2O & \rightleftharpoons A^{3-} + H_3O^+
   \end{align*}
   \]

2. Write the neutralization reaction for a titration to point (a).

   \[
   H_3A + NaOH \rightarrow NaH_2A + H_2O \\
   or \\
   H_3A + OH^- \rightarrow H_2A^- + H_2O
   \]
3. Write the neutralization reaction for a titration to point (d).

\[ \text{H}_3\text{A} + 3\text{NaOH} \rightarrow \text{Na}_3\text{A} + 3\text{H}_2\text{O} \]

or

\[ \text{H}_3\text{A} + 3\text{OH}^- \rightarrow \text{A}^{3-} + 3\text{H}_2\text{O} \]

4. Identify the predominant form(s) of H\(_3\)A at each of the indicated points on the titration curve. Give only species expected to have \(\alpha\)-values greater than 0.4.

At point (c):

\(\text{A}^{3-}\) and \(\text{HA}^{2-}\)

At point (b):

\(\text{HA}^{2-}\)

5. What is the pH at the indicated points?

At point (c):

Half-equivalence point, so:

\[ \text{pH} = pK_{a3} = -\log\left(2 \times 10^{-11}\right) = 10.7 \]

At point (b):

We have a beaker of almost all \(\text{HA}^{2-}\), so we use \(K_{a3}\) and \(K_{a2}\) in the amphiprotic salt equation:

\[
c_{\text{HA}^{2-}} = \frac{n_{\text{HA}^{2-}}}{V_{\text{soln}}} = (20 \, \text{mL H}_3\text{A soln}) \left( \frac{0.1000 \, \text{mol H}_3\text{A}}{1000 \, \text{mL soln}} \right) \left( \frac{1 \, \text{mol HA}^{2-}}{1 \, \text{mol H}_3\text{A}} \right) \left( \frac{1}{0.060 \, \text{L soln}} \right) = 0.033 \, \text{M} 
\]
\[
[H_3O^+] = \sqrt{\frac{K_a c_{HA^2-} + K_w}{1 + \left( \frac{c_{HA^2-}}{K_a} \right)}} \\
= \sqrt{\frac{(2 \times 10^{-11})(0.033) + 1.00 \times 10^{-14}}{1 + \left( \frac{0.033}{5 \times 10^{-7}} \right)}} \\
= 3.2 \times 10^{-9}
\]

\[pH = -\log(3.2 \times 10^{-9}) = 8.5\]

What would the curve look like for the titration of the weak base \(\text{Na}_3\text{A}\) with HCl? Could you answer similar questions for that titration curve?