pH Titrations

- Next week we will repeat our titrations with the pH meter.
- pH curve is different for different types of acid/base.

**Strong Acid / Weak Base**

\[ \text{Titrant: 0.1 M NaOH} \]
\[ \text{Titrant: 0.1 M HCl} \]

1. **Start:** \[ [H^+] = [HCl] = 0.1 \]
   \[ \text{pH} = -\log (0.1) = 2 \]

2. Add 0.05 M NaOH
   \[ H^+ + OH^- \rightarrow H_2O, \text{ consume} \]
   \[ 0.05 \text{M H}^+ \rightarrow 0.05 \text{M left over} \]
   \[ \text{pH} = -\log (0.05) = 1.3 \]

3. At 0.1 M NaOH (equal molar amounts H\(^+\), OH\(^-\))
   \[ \text{pH} = 7 \]

4. At 50% excess NaOH, 0.05 M NaOH
   \[ \text{pH} = 13.3, \text{ pH} = 13.7 \]


**Weak acid / Strong Base**

\[ \text{use H-H agm.} \]

- Consider 2 solutions:

  **Soln 1**
  - 0.05 M NaAc
  - 0.05 M HAC
  \[ \text{pH} = \text{pK}_a + \log \left( \frac{\text{Ac}^-}{\text{HAC}} \right) \]
  \[ \text{pH} = \text{pK}_a = 4.74 \]

  **Soln 2**
  - 0.1 M HAC
  - 0.05 M NaOH
  \[ \text{HAC + NaOH} \rightarrow \text{H}_2O + \text{NaAc} \]
  \[ 0.05 \text{M NaOH consumes} \]
  \[ 0.05 \text{M HAC making 0.05M} \]
  \[ \text{HAC} \rightarrow \text{NaAc} \]
  \[ 0.05 \text{M} \]
Solution 1 & 2 are the same

How to mix Soln 2?

\[ \text{H}_2 \xrightarrow{\text{+NaOH}} \text{Na}_2\text{CO}_3 \]

or

\[ \text{HA} \xrightarrow{\text{+NaOH}} \text{NaAc} \]

\[ \text{pH Titratin Curve:} \]

1. Start: What's in the beaker?

HA only: ICE Calculation

\[ \text{HA} \rightleftharpoons \text{H}^+ + \text{Ac}^- \quad K_a = 1.8 \times 10^{-5} \]

\[ \begin{array}{c|ccc}
\text{I} & 0.10M & 0 & 0 \\
\text{C} & x & +x & +x \\
\text{E} & 0.10M-x & +x & +x \\
\end{array} \]

\[ K_a = \frac{[\text{H}^+][\text{Ac}^-]}{[\text{HA}]} \]

\[ 1.8 \times 10^{-5} = \frac{x^2}{0.10-x} \]

\[ x = 1.8 \times 10^{-3} \approx 0.018 \]

\[ \text{pH} = \text{pH}[\text{H}^+] = -\log(x) = 2.87 \]

2. Added 0.05 M NaOH

\[ \text{ICE Initial:} \quad [\text{HA}] = 0.05, \quad [\text{NaAc}] = 0.05 \]

\[ \text{H}^+ + \text{H}^+ + \text{Ac}^- \quad \text{pH} = pK_a + \log \left( \frac{[\text{Ac}^-]}{[\text{HA}]} \right) \]

\[ = 4.74 + \log(1) \]

\[ = 4.74 \]

\[ \text{pH} = 4.74 + \log \left( \frac{0.005}{0.05} \right) = 4.65 \]

\[ \text{Added 0.045 M NaOH} \]

\[ \text{pH} = 4.74 + \log \left( \frac{0.005}{0.05} \right) = 4.65 \]

\[ \text{Added 0.045 M NaOH} \]

\[ \text{pH} = 4.56 \]

\[ 0.035 \Rightarrow 4.47 \]

3. Added 0.10 M NaOH

\[ \text{All HA} \rightarrow \text{NaAc} \]

\[ \text{Use ICE for NaAc:} \quad K_a = 1.8 \times 10^{-5} \]

\[ \begin{array}{c|ccc}
\text{I} & 0.05 & 0 & 0 \\
\text{C} & -x & +x & +x \\
\text{E} & 0.10-x & +x & +x \\
\end{array} \]

\[ K_b = \frac{[\text{HAc}][\text{OH}^-]}{[\text{Ac}^-]} \quad (x)(x) \Rightarrow \frac{x^2}{0.10} \]

\[ x = \sqrt{K_b \cdot 0.1} \approx 7.45 \times 10^{-6} \]

\[ \text{pOH} = -\log(x) = 5.13 \]

\[ \text{pH} = 14 - \text{pOH} = 8.87 \]
After adding lotsa NaOH, \( \Rightarrow 0.1 \text{ M NaOH} \)

\[ \text{pH} = 13 \]

Wow! That’s a lot of calculating!

Notes/Summary:

- Use ICE for start
- Use H-H for half way point
- Use \( K_b \) conversion & ICE for end point
- Wave hands (or do ICE) for way past point

(except) Ignore dilution

Examine the Graph:

\[
\begin{align*}
\text{pH} & \quad \text{Added base} \\
\uparrow & \quad \uparrow \quad \quad \text{added base}
\end{align*}
\]

- Here the pH doesn’t change much w/ added base

- This area is a stable \( \text{pH} \) = “buffer”
  - Useful for many things (food, life)

- Buffers feel confusing but are really quite “fun” (no ICE)