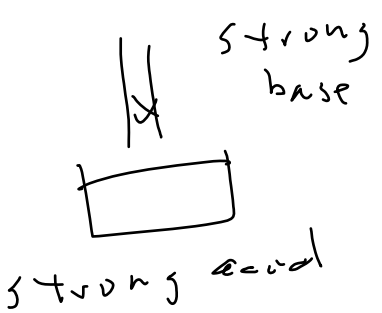
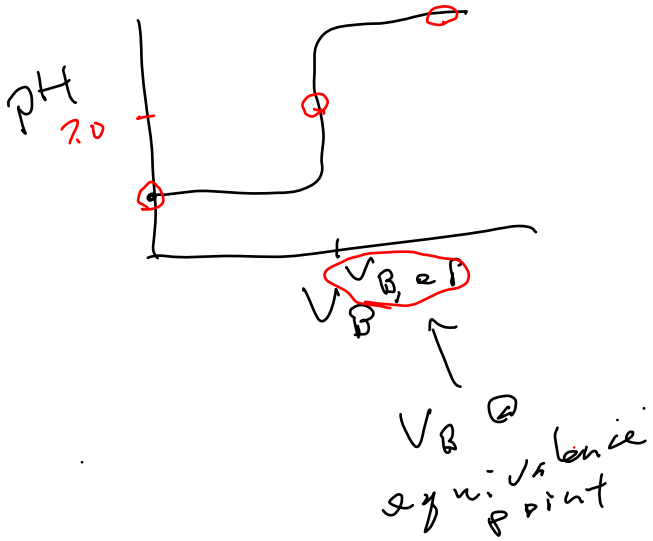
ch. 17.3 acid-base titration curves

strong acid + strong base

Case 1:





titration curve described by a piecewise function with 3 domains

$V_B = V_{B,eq}$

$V_B > V_{B,eq}$

$V_B < V_{B,eq}$

domain 1: @ $V_B = V_{B,eq}$

$[A]V_A = [B]V_B$

ex: HCl (strong acid) + $NaOH$ (strong base) $\rightarrow H_2O$ + $NaCl$ (neutral salt) $\Rightarrow pH = 7.0$ @ $V_B = V_{B,eq}$

domain 2: @ $V_B < V_{B,eq}$

$\Rightarrow$ excess acid

i.e. $n_{acid} > n_{base}$

ii) $[H^+] = \frac{n_{H^+}}{V_{total}} = \frac{n_{H^+ \text{ from acid}} - n_{OH^- \text{ from}}}{V_{total}}$

$$\approx \frac{[A]V_A - [B]V_B}{V_A + V_B}$$

iii) $pH = -\log[H^+]$

domain 3: @ $V_B > V_{B,ep}$

$\exists$ excess base

ii) $[OH^-] = \frac{n_{OH^-}}{V_{total}} = \frac{n_{OH^- \text{ from base}} - n_{H^+ \text{ from acid}}}{V_{total}}$

$$\approx \frac{[B]V_B - [A]V_A}{V_A + V_B}$$

iii) use $[OH^-][H^+] = K_w$ to find $[H^+]$, then use $pH = -\log[H^+]$

or use $pOH = -\log[OH^-]$, then use $pH + pOH = 14$ to find pH

note: @ $V_B \approx \infty$; i.e., @ "large" V_B

$$\lim_{V_B \to \infty} [OH^-] = \frac{[B]V_B - [A]V_A}{V_A + V_B}$$

$$= \lim_{V_B \to \infty} \frac{[B] - [A]\frac{V_A}{V_B}}{1 + \frac{V_A}{V_B}} = \frac{[B] + 0}{1 + 0} = [B]$$

so pH @ $V_B \approx \infty$ is the pH of the base

plan: to sketch the titration curve

i) find $V_{B,ep}$

ii) compare V_B to $V_{B,ep}$ to identify which domain/eqn to use

alternative: use "mice" table

modified ICE table

"stoichiometry" calculation

basis:

$$\text{WIE: } H^+ + OH^- \rightleftharpoons H_2O$$

$$K_c = \frac{1}{K_w} = 10^{14} \gg 0$$

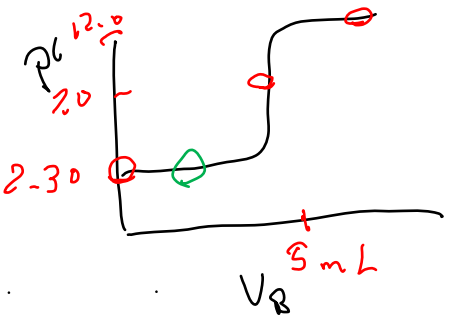
problem: ① sketch titration curve

$[NaOH] = 10\ mM$

V_{NaOH}

10 mL

$[HCl] = 5\ mM$



plan

find $V_{B,ep}$

find pH of acid; i.e. pH @ $V_B = 0$

find pH of base; i.e. pH @ $V_B \to \infty$

i) @ $V_{B,ep}$

$$[A]V_A = [B]V_B$$

$$[HCl]V_{HCl} = [NaOH]V_{NaOH}$$

$5\ mM\ (10\ mL) = 10\ mM\ V_{NaOH}$

$$V_{NaOH} = \frac{5\ mM\ (10\ mL)}{10\ mM} = 5\ mL$$

ii) $[H^+] = [HCl] = 5 \times 10^{-3}$ M

$pH = -\log [H^+] = -\log (5 \cdot 10^{-3})$

$= 2.30$

iii) $[OH^-] = [NaOH] = 10^{-2}$ M

$pOH = -\log [OH^-] = -\log (10^{-2}) = 2$

$pH + pOH = 14$

$pH + 2 = 14$

$pH = 12$

(2) At pt ② $V_B = 3$ mL

i) $n_{OH^-} = [B] V_B = [NaOH] V_{NaOH}$

$= 10 \frac{\text{mmol}}{\text{L}} \cdot 3 \text{ mL} \cdot \frac{\text{L}}{10^3 \text{ mL}}$

$= 0.03$ mmol

$n_{H^+} = [A] V_A = [HCl] V_{HCl}$

$= 5 \frac{\text{mmol}}{\text{L}} \cdot 10 \text{ mL} \cdot \frac{\text{L}}{10^3 \text{ mL}}$

$= 0.05$ mmol

ii) use "mice" table to do stochiometry calculation

$HCl + NaOH \longrightarrow H_2O + NaCl$

	HCl	$NaOH$		
I	0.05 mmol	0.03 mmol		
C	−0.03 mmol	−0.03 mmol		
E	0.02 mmol	0		

iii) $[H^+] = \frac{n_{H^+}}{V_{total}} = \frac{0.02 \text{ mmol}}{13 \text{ mL}} \cdot \frac{10^3 \text{ mL}}{1 \text{ L}} \cdot \frac{1 \text{ mol}}{10^3 \text{ mmol}}$

$= 0.00154$ M

iv) $pH = -\log[H^+] = -\log[0.00154]$

$= 2.81$

(3) for pH @ $V_B = 7\,mL$

i) $n_B = [NaH]\,V_B = 10\,\frac{mmol}{L} \cdot 7\,mL \cdot \frac{L}{10^3\,mL}$

$= 0.007\,mmol$

ii) $NaOH + HCl \longrightarrow H_2O + NaCl$

I	0.07 mmol	0.05 mmol
C	−0.05 mmol	−0.05 mmol
E	0.02 mmol	0

iii) $[OH^-] = \frac{n_{OH^-}}{V_{total}} = \frac{0.02\,mmol}{17\,mL} \cdot \frac{10^3\,mL}{L} \cdot \frac{mol}{10^3\,mmol}$

$= 0.00118\,M$

iv) $pOH = -\log[OH^-] = -\log(0.00118) = 2.93$

v) $pH + pOH = 14$

$pH + 2.93 = 14$

$pH = 11$

pH = 11.1