Titration Curves (IV. 18)

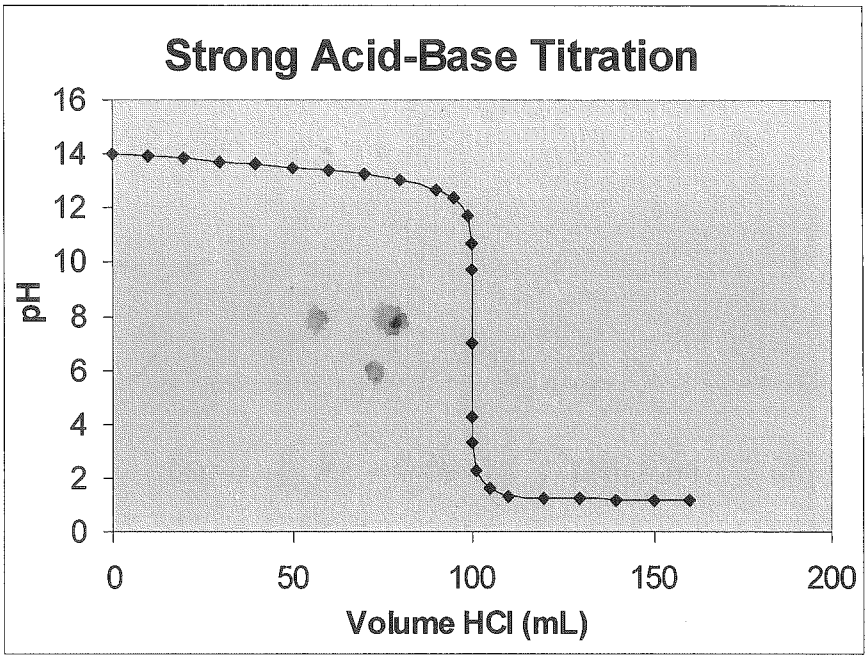
iv) Titration Curve

The above story can be summarized:

1. From 0 mL to ~99 mL, all the H_3O^+ gets soaked up
2. Then, over a very small range in volume (from ~99 mL to ~101 mL) the $[H_3O^+]$ spikes.
3. After ~101 mL, the $[H_3O^+]$ is very high.

The above story can be graphed:

Volume HCl (mL)	$[H_3O^+]$	pH
0	1.00E-14	14
10	1.20E-14	13.92
20	1.40E-14	13.85
30	1.80E-14	13.74
40	2.30E-14	13.64
50	3.00E-14	13.52
60	4.00E-14	13.40
70	5.60E-14	13.25
80	9.10E-14	13.04
90	2.00E-13	12.70
95	3.80E-13	12.42
99	2.00E-12	11.70
99.9	2.00E-11	10.70
99.99	2.00E-10	9.70
100	1.00E-07	7.00
100.01	5.00E-05	4.30
100.1	5.00E-04	3.30
101	5.00E-03	2.30
105	2.40E-02	1.62
110	4.80E-02	1.32
120	5.50E-02	1.26
130	6.00E-02	1.22
140	6.20E-02	1.21
150	6.40E-02	1.19
160	6.60E-02	1.18



(see top of page 168 for a titration curve for a strong base titrating a strong acid)

v) Indicators

- At equivalence point, only a salt and H_2O is present
- the salt of a strong acid and strong base will dissociate into **two** spectator ions
- thus, the solution at the equivalence point is **neutral**. pH = 7
- thus, choose an indicator that will change colour at pH = 7. Has a pKa = 7

Example: $HCl + NaOH \rightarrow NaCl + H_2O$ $Na^+_{(aq)}$ and $Cl^-_{(aq)}$ are neutral. No hydrolysis!

b) Strong Base with Weak Acid

i) Example: 150 mL of unknown [CH_3COOH] is titrated with 220 mL of 0.250 M NaOH to reach the equivalence point. What is the [CH_3COOH]?

Calculation is the same as strong base with strong acid!

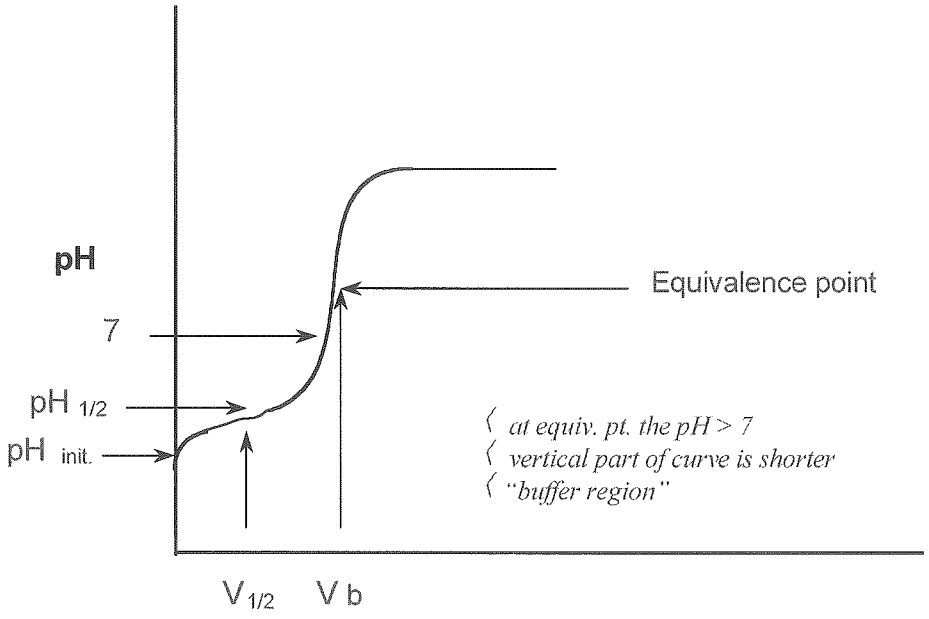
$CH_3COOH + NaOH \rightarrow H_2O + NaCH_3COO$

Moles NaOH = M x L = (0.250 M)(0.220 L) = 0.055 moles

At equiv. point: moles NaOH = moles CH_3COOH = 0.055 moles

[CH_3COOH] = 0.055 mol / 0.150 L = **0.37 M**

ii) Titration Curve



iii) Indicators

- At equivalence point, only a salt and H_2O is present
- the salt of a strong base and weak acid will produce **one** spectator ion and **one** weak base
- thus the solution at the equivalence point will be **basic**. pH > 7
- thus, choose an indicator that will change colour around pH 8-10

Example: $CH_3COOH + NaOH \rightarrow H_2O + NaCH_3COO$

Na^+ is a spectator, but CH_3COO^- is a weak base in H_2O.
(although the equivalence point has been reached, the resulting solution is not neutral!)

c) Strong Acid with Weak Base

i) Example: 240 mL of NH_3 of unknown concentration is titrated to the equivalence point with 180 mL of 0.500 M HCl. What is $[NH_3]$?

Calculation is the same as strong base with strong acid!

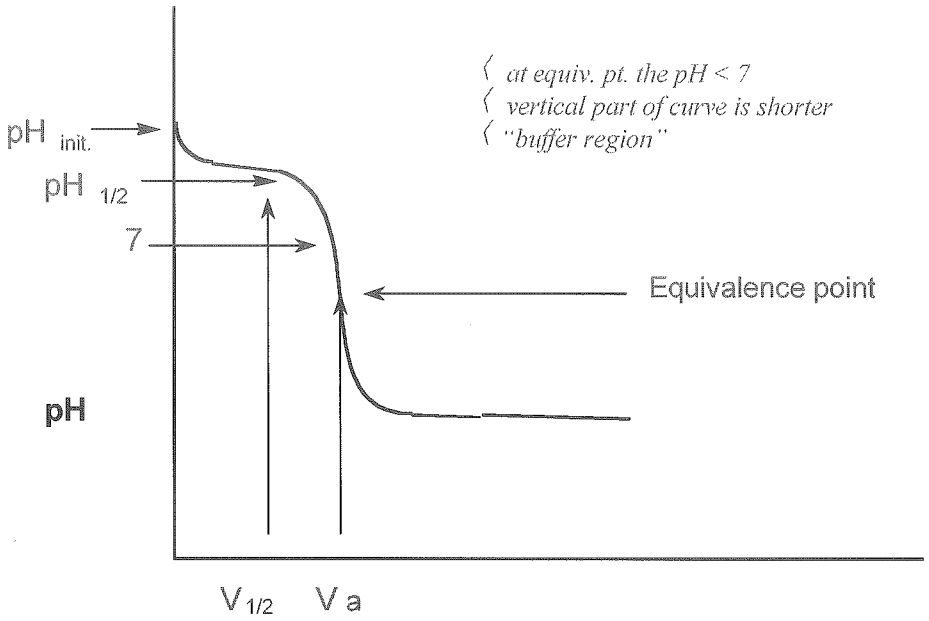
$HCl + NH_3 \rightarrow NH_4Cl \quad (NH_3 + H_3O^+ \rightleftharpoons NH_4^+ + H_2O)$

Moles HCl = M x L = (0.500 M)(0.180 L) = 0.090 moles

At equiv. point: moles HCl = moles NH_3 = 0.090 moles

$[NH_3]$ = 0.090 mol / 0.240 L = 0.375 M ~ **0.38 M**

ii) Titration Curve



iii) Indicators

- At equivalence point, only a salt and H_2O is present
- the salt of a strong acid and weak base will produce **one** spectator ion and **one** weak acid
- thus the solution at the equivalence point will be **acidic.** pH < 7
- thus, choose an indicator that will change colour around pH 4-6

Example: $HCl + NH_3 \rightarrow NH_4Cl$

Cl^- is a spectator, but NH_4^+ is a weak acid in H_2O.
(although the equivalence point has been reached, the resulting solution is not neutral!)