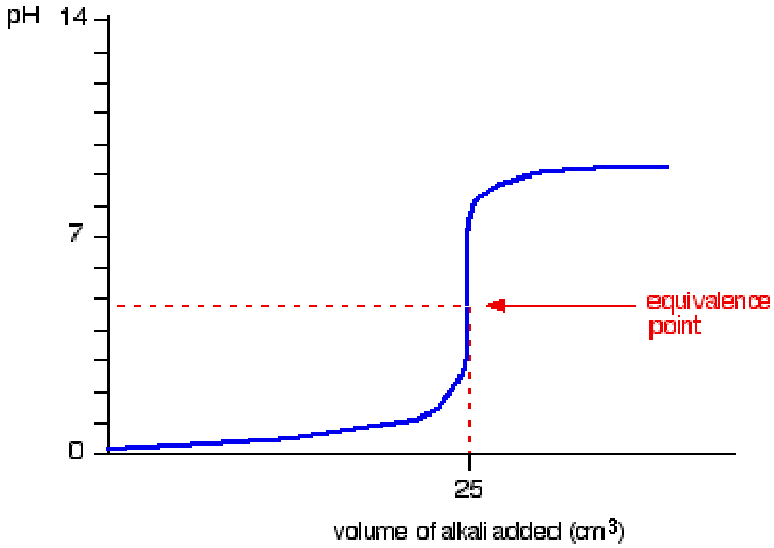
CHM152 Name:
16280 SU08

Weak Acid – Strong Base & Strong Acid – Weak Base Titrations

1. A Student plotted a titration curve using formic acid (HCOOH) with NaOH. The student started by placing 15.00 mL of 0.150 M HCOOH in a beaker and titrated the acid with 0.100 M NaOH in the buret.

a. Draw a rough sketch of what the titration curve might look like:



b. What is the pH of the solution after the addition of 10.00 mL of NaOH?

HCOOH (aq) +	OH^- (aq) →	$HCOO^-$ (aq) + H_2O (l) $K_a = 1.8 \times 10^{-4}$
2.25 mmol	1.00 mmol	
-1.00 mmol	-1.00 mmol	+ 1.00 mmol
1.25 mmol	0	1.00 mmol

Total volume is 25.00 mL so [HCOOH] = 0.0500 M [HCOO-] = 0.0400 M
Since the concentrations of the weak acid and its conj base are different, we can apply the H-H equation!
$pH = pK_a + \log([base]/[acid]) = -\log(1.8 \times 10^{-4}) + \log(0.0400/0.0500) =$ **pH = 3.64**

c. What is the pH after 30.00 mL of NaOH?

HCOOH (aq) +	OH^- (aq) →	$HCOO^-$ (aq) + H_2O (l) $K_a = 1.8 \times 10^{-4}$
2.25 mmol	3.00 mmol	
-2.25 mmol	-2.25 mmol	+ 2.25 mmol
0	0.75 mmol	2.25 mmol

At this point all the acid has reacted with base and there is some base remaining. the pH is determined from the concentration of the remaining base: pOH = - log(0.75 mmol/45.0 mL) = 1.78 **So pH = 12.22**

d. When does the equivalence point occur? What is the pH at the equivalence point?

The equivalence point occurs when equal moles of acid react with equal moles of base.
Use stoichiometry to determine the moles of base and then use the molarity of the base to determine the volume.
From the original problem: 15.00 mL HCOOH (0.150 mmol/mL)(1mmol NaOH/1 mmol acid) = 2.25 mmol OH^-
2.25 mmol NaOH (1 mL/0.100 mmol) = **22.4 mL NaOH**. So after 22.5 mL of 0.100 M NaOH is added, the eq. pt. is reached. Th pH is determined from the reaction of the $HCOO^-$ reacting with water: (next page)

$HCOO^-$ (aq) + H_2O (l) → HCOOH (aq) + OH^- $K_b = K_w/K_a = K_b = 5.6 \times 10^{-11}$
2.25 mmol
-x +x +x
(2.25mmol/37.5 mL) – x x x

$5.6 \times 10^{-11} = x^2 / (0.0600-x)$ Assume x is small and solve. $x = 1.8 \times 10^{-6}$ M OH^- pOH = 5.74, **pH = 8.26**

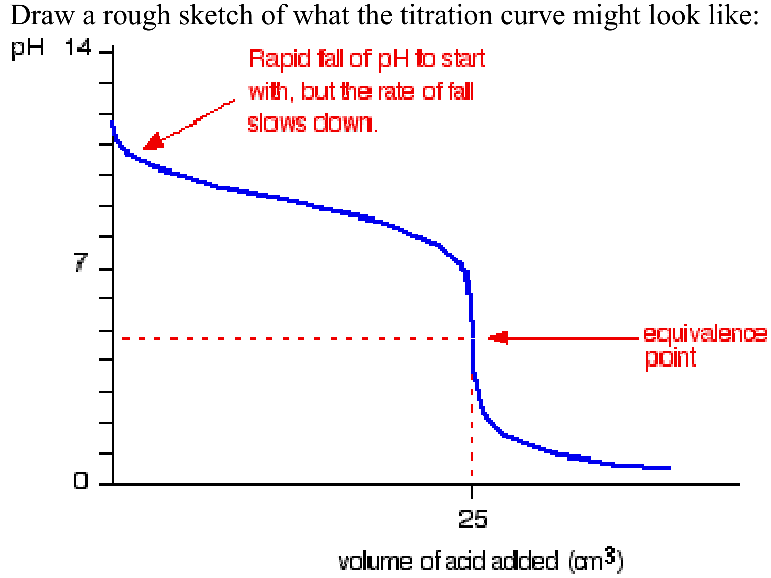
e. How much NaOH needs to be added to reach the point where pH equals pK_a? What is the pH at this point?

pH = pK_a at the ½ equivalence point. So that is when you have ½ the moles of acid available reacted with base. The total moles of acid available is 2.25 mmol so ½ that is 1.125 mmol (round later). That is how much base is added to react with ½ the available acid. So 1.125 mmol (1mL/0.100 mmol NaOH) = **11.25 mL NaOH**. It so happens that this is also ½ the volume of base required to reach the equivalence point. So why does pH = pKa? If we reacted 1.125 mmol of acid with 1.125 mmol of NaOH then 1.125 mmol of $HCOO^-$ also forms. Using the H-H equation:

pH = pKa + log ((1.125 mmol base/37.5 mL)/(1.125 mmol base/37.5 mL)) and **pH = pKa = 3.74**

2. A student plotted a titration curve using ammonia with nitric acid. The student started by placing 25.0 mL of 0.150 M NH_3 in a beaker and titrated the base with 0.200 HNO_3 in the buret.

a. Draw a rough sketch of what the titration curve might look like:



b. What is the pH of the solution after the addition of 10.00 mL of HNO_3?

NH_3 (aq) +	H_3O^+ (aq) →	NH_4^+ (aq) + H_2O (l)	K_b for $NH_3 = 1.8 \times 10^{-5}$
3.75 mmol	2.00 mmol		
-2.00 mmol	-2.00 mmol	+ 2.00 mmol	
1.75 mmol	0	2.00 mmol	

Using the H-H equation: pH = - log (K_w/K_b) + log $[NH_3]/[NH_4^+]$ = **9.19**

c. What is the pH after 20.00 mL of HNO_3?

NH_3 (aq) +	H_3O^+ (aq) →	NH_4^+ (aq) + H_2O (l)	K_b for $NH_3 = 1.8 \times 10^{-5}$
3.75 mmol	4.00 mmol		
-3.75 mmol	-3.75 mmol	+ 3.75 mmol	
0	0.25 mmol	3.75 mmol	

pH = - log $[H_3O^+]$ = - log (0.25 mmol/45.0 mL) = **pH = 2.25**

d. When does the equivalence point occur? What is the pH at the equivalence point?

The equivalence point occurs after 18.75 mL of HCl is added.

NH_4^+ (aq)	+ H_2O (l)	→	NH_3 (aq)	+	H_3O^+ (aq)	$K_a = K_w/K_b = K_a = 5.6 \times 10^{-10}$
3.75 mmol						
-x			+x		+x	
(3.75 mmol/43.75 mL) – x			x		x	

$5.6 \times 10^{-10} = x^2 / (0.0857\text{-}x)$ Assume x is small and solve. $x = 6.9 \times 10^{-6}$ M H_3O^+ **pH = 5.16**

e. How much HNO_3 needs to be added to reach the point where pH equals pK_a? What is the pH at this point?

(18.75 mL HCl / 2) = **9.38 mL of HCl** is required to reach the point where **pH = pKa = 9.25**