Chem 1515
During Class Invention
Spring 2008
Titration Between a Weak Acid and A Strong Base

Name____________________________
TA Name ________________________
Lab Section #______

1. Qualitatively, describe how the pH of a solution of a weak acid changes when a solution of strong base is added to it.

   The pH of a solution of a weak acid will increase when a solution containing a strong base is added to it.

   a. A titration is performed by adding 0.200 M NaOH to 24 mL of 0.350 M HOCl.

i)Calculate the pH before addition of any NaOH.

	$HOCl$	$\rightleftharpoons$	H^+	+	OCl^-	
I	**.350 M**		**~0**		**0**	
C	**-x**		**+x**		**+x**	**x = [HOCl]$_{diss}$**
E	**.350 - x**		**x**		**x**	

$$K_a = \frac{[H^+][OCl^-]}{[HOCl]}$$

$$3.0 \times 10^{-8} = \frac{(x)(x)}{.350 - x} \qquad \text{assume } x << 0.0350$$

$$3.0 \times 10^{-8} = \frac{x^2}{0.350}$$

$$1.05 \times 10^{-8} = x^2$$

$$1.02 \times 10^{-4}\ M = x = [H^+]$$

$$pH = 3.99$$

ii) Calculate the pH after the addition of 5.0 mL of the base.

Add 5.0 mL of NaOH

$$5.0\ mL \left(\frac{1\ L}{1000\ mL}\right)\left(\frac{0.200\ mol}{1\ L}\right) = 0.0010\ mol\ NaOH$$

$$24.0\ mL \left(\frac{1\ L}{1000\ mL}\right)\left(\frac{0.350\ mol}{1\ L}\right) = 0.0084\ mol\ HCl$$

	$HOCl(aq)$	+ $NaOH(aq)$	$\rightleftharpoons$	$OCl^-(aq)$ +	$H_2O(l)$
I	**0.0084**	**0.0010**		**0**	**-**
E	**0.0074**	**0**		**0.001**	**-**

$$[HOCl] = \frac{0.0074\ mol}{0.029\ L} = 0.255\ M \quad [OCl^-] = \frac{0.001\ mol}{0.029\ L} = 0.0345\ M$$

ii)Calculate the pH after the addition of 5.0 mL of the base. (Continued)

	HOCl	⇌	H^+	+	OCl^-	
I	.255		~0		0.0345	
C	-x		+x		+x	x = $[HOCl]_{diss}$
E	.255 - x		x		0.0345 + x	

$$K_a = \frac{[H^+][OCl^-]}{[HOCl]}$$

$$3.0 \times 10^{-8} = \frac{(x)(0.0345 + x)}{0.255\text{-}x} \qquad \text{assume } x << 0.0345$$

$$3.0 \times 10^{-8} = \frac{(x)(0.0345)}{0.255}$$

$$2.22 \times 10^{-7} = x = [H^+] \qquad pH = 6.65$$

Calculate the pH after the addition of 15.0 mL of the base.

Add 15.0 mL of NaOH

$$15.0 \text{ mL} \left(\frac{1 \text{ L}}{1000 \text{ mL}}\right)\left(\frac{0.200 \text{ mol}}{1 \text{ L}}\right) = 0.0030 \text{ mol NaOH}$$

	$HOCl_{(aq)}$ +	$NaOH_{(aq)}$	⇌	$OCl^-_{(aq)}$ +	$H_2O_{(l)}$
I	0.0084	0.0030		0	-
E	0.0054	0		0.0030	-

$$[HOCl] = \frac{.0054 \text{ mol}}{0.039 \text{ L}} = 0.138 \text{ M} \quad [OCl^-] = \frac{.003 \text{ mol}}{0.039 \text{ L}} = 0.0769 \text{ M}$$

	HOCl	⇌	H^+	+	OCl^-	
I	0.138		~0		0.0769	
C	-x		+x		+x	x = $[HOCl]_{diss}$
E	0.138-x		x		0.0769 + x	

$$K_a = \frac{[H^+][OCl^-]}{[HOCl]}$$

$$3.0 \times 10^{-8} = \frac{(x)(0.0769 + x)}{0.138\text{-}x} \qquad \text{assume } x << 0.0769$$

$$3.0 \times 10^{-8} = \frac{(x)(0.0769)}{0.138}$$

$$5.38 \times 10^{-8} = x = [H^+] \qquad pH = 7.27$$

Calculate the pH after the addition of 25.0 mL of the base.

Add 25.0 mL of NaOH

$$25.0 \text{ mL} \left(\frac{1 \text{ L}}{1000 \text{ mL}}\right)\left(\frac{0.200 \text{ mol}}{1 \text{ L}}\right) = 0.0050 \text{ mol NaOH}$$

	$HOCl_{(aq)}$ +	$NaOH_{(aq)}$	⇌	$OCl^-_{(aq)}$ +	$H_2O_{(l)}$
I	0.0084	0.0050		0	-
E	0.0034	0		0.005	-

$$[HOCl] = \frac{.0034 \text{ mol}}{0.049 \text{ L}} = 0.0694 \text{ M} \quad [OCl^-] = \frac{.005 \text{ mol}}{0.049 \text{ L}} = 0.102 \text{ M}$$

Calculate the pH after the addition of 25.0 mL of the base. (Continued)

	$HOCl$	$\rightleftharpoons$ H^+	+	OCl^-	
I	0.0694		~0	0.102	
C	-x		+x	+x	x = $[HOCl]_{diss}$
E	0.0694 -x		x	0.102 + x	

$$K_a = \frac{[H^+][OCl^-]}{[HOCl]}$$

$$3.0 \times 10^{-8} = \frac{(x)(0.102+x)}{0.0694 - x} \quad \text{assume } x << 0.0694$$

$$3.0 \times 10^{-8} = \frac{(x)(0.102)}{0.0694}$$

$$2.04 \times 10^{-8} = x = [H^+] \qquad pH = 7.69$$

Calculate the pH after the addition of 35.0 mL of the base.

Add 35.0 mL of NaOH

$$35.0 \text{ mL} \left(\frac{1 \text{ L}}{1000 \text{ mL}}\right)\left(\frac{0.200 \text{ mol}}{1 \text{ L}}\right) = 0.0070 \text{ mol NaOH}$$

	$HOCl_{(aq)}$ +	$NaOH_{(aq)}$	$\rightleftharpoons$ $OCl^-_{(aq)}$ +	$H_2O_{(l)}$
I	0.0084	0.0070	0	-
E	0.0014	0	0.007	-

$$[HOCl] = \frac{.0014 \text{ mol}}{0.059 \text{ L}} = 0.0237 \text{ M} \quad [OCl^-] = \frac{.007 \text{ mol}}{0.059 \text{ L}} = 0.119 \text{ M}$$

	$HOCl$	$\rightleftharpoons$ H^+	+	OCl^-	
I	0.0237		~0	0.119	
C	-x		+x	+x	x = $[HOCl]_{diss}$
E	0.0237 - x		x	0.119 + x	

$$K_a = \frac{[H^+][OCl^-]}{[HOCl]}$$

$$3.0 \times 10^{-8} = \frac{(x)(0.119+x)}{0.0237 - x} \quad \text{assume } x << 0.0237$$

$$3.0 \times 10^{-8} = \frac{(x)(0.119)}{0.0237}$$

$$5.97 \times 10^{-9} = x = [H^+] \qquad pH = 8.22$$

Calculate the pH after the addition of 40.0 mL of the base.

Add 40.0 mL of NaOH

$$40.0\text{ mL}\left(\frac{1\text{ L}}{1000\text{ mL}}\right)\left(\frac{0.200\text{ mol}}{1\text{ L}}\right) = 0.0080\text{ mol NaOH}$$

	$HOCl_{(aq)}$ +	$NaOH_{(aq)}$	⇌	$OCl^{-}_{(aq)}$ +	$H_2O_{(l)}$
I	0.0084	0.0080		0	-
E	0.0004	0		0.008	-

$$[HOCl] = \frac{.0004\text{ mol}}{0.064\text{ L}} = 0.00625\text{ M} \qquad [OCl^-] = \frac{.008\text{ mol}}{0.064\text{ L}} = 0.125\text{ M}$$

Calculate the pH after the addition of 40.0 mL of the base. (Continued)

	HOCl	⇌	H^+	+	OCl^-	
I	0.00625		~0		0.125	
C	-x		+x		+x	x = $[HOCl]_{diss}$
E	0.00625 - x		x		0.125 + x	

$$K_a = \frac{[H^+][OCl^-]}{[HOCl]}$$

$$3.0 \times 10^{-8} = \frac{(x)(0.125 + x)}{0.00625 - x} \quad \text{assume } x << 0.00625$$

$$3.0 \times 10^{-8} = \frac{(x)(0.125)}{0.00625}$$

$$1.5 \times 10^{-9} = x = [H^+] \qquad pH = 8.82$$

iii) Calculate the volume of base needed to reach the equivalence point.

$$M_{acid}V_{acid} = M_{base}V_{base}$$

$$0.350\text{ M} \cdot 24.0\text{ mL} = 0.200\text{ M} \cdot V_{base}$$

$$\frac{0.350\text{ M} \cdot 24.0\text{ mL}}{0.200\text{ M}} = V_{base} = 42.0\text{ mL}$$

iv) What is the pH at the equivalence point?

Add 42.0 mL of NaOH

$$42.0\text{ mL}\left(\frac{1\text{ L}}{1000\text{ mL}}\right)\left(\frac{0.200\text{ mol}}{1\text{ L}}\right) = 0.0084\text{ mol NaOH}$$

	$HOCl(aq)$ +	$NaOH(aq)$	⇌	$OCl^-(aq)$ +	$H_2O(l)$
I	0.0084	0.0084		0	-
E	0	0		0.0084	-

$$[OCl^-] = \frac{0.0084\text{ mol}}{0.066\text{ L}} = 0.127\text{ M}$$

	$OCl^-(aq)$	+ $H_2O(l)$	⇌	$HOCl(aq)$ +	$OH^-(aq)$	
I	0.127	–		0	0	-
C	–x	–		+x	+x	
E	0.127-x	–		+x	+x	-

$$K_b = \frac{K_w}{K_a} = \frac{1 \times 10^{-14}}{3.0 \times 10^{-8}} = \frac{[OH^-][HOCl]}{[OCl^-]}$$

$$3.33 \times 10^{-7} = \frac{(x)(x)}{0.127-x} \qquad \text{assume } x \ll 0.127$$

$$3.33 \times 10^{-7} = \frac{(x^2)}{0.127}$$

$$2.06 \times 10^{-4} = x = [OH^-]$$

$$pOH = 3.69 \qquad pH = 10.31$$

v) Calculate the pH after adding 5.00 mL of NaOH past the equivalence point.

Add 47.0 mL of NaOH

$$47.0\text{ mL}\left(\frac{1\text{ L}}{1000\text{ mL}}\right)\left(\frac{0.200\text{ mol}}{1\text{ L}}\right) = 0.0094\text{ mol NaOH}$$

	$HOCl(aq)$	+ $NaOH(aq)$	ä	$OCl^-(aq)$ +	$H_2O(l)$
I	0.0084	0.0094		0	-
E	0	0.0010		0.0084	-

$$[OCl^-] = \frac{0.0084\text{ mol}}{0.071\text{ L}} = 0.118\text{ M} \qquad [OH^-] = \frac{0.0010\text{ mol}}{0.071\text{ L}} = 0.0141\text{ M}$$

	$OCl^-(aq)$	+ $H_2O(aq)$	⇌	$HOCl(aq)$ +	$OH^-(l)$	
I	0.118	–		0	.0141	-
C	–x	–		+x	+x	
E	0.118-x	–		+x	.0141+x	-

$$K_b = \frac{K_w}{K_a} = \frac{1 \times 10^{-14}}{3.0 \times 10^{-8}} = \frac{[OH^-][HOCl]}{[OCl^-]}$$

$$3.33 \times 10^{-7} = \frac{(.0141 + x)(x)}{.118-x} \quad \text{assume } x << 0.0141$$

$$3.33 \times 10^{-7} = \frac{(.0141)(x)}{.118}$$

$$2.79 \times 10^{-6} = x$$

$[OH^-]$= 0.0141 + x = 0.0141 M

pOH = 1.85 pH = 12.15

6. Using the designated space below, draw the titration curve for each of the following cases. **See Appendix III for recommended demonstration, video, or computer resources.**

a) 50.0 mL of 1.00 M $HC_2H_3O_2$ and 1.00 M NaOH

b) 50.0 mL of 0.0100 M $HC_2H_3O_2$ and 0.0100 M NaOH