During Class Invention
Titration Between a Strong Acid and A Strong Base

Name_____

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

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

a. A titration is performed by adding 0.600 M KOH to 40.0 mL of 0.800 M HCl.

   i) Calculate the pH before addition of any KOH.

	HCl	→	H^+	+	Cl^-
I	.800 M		~0		0
F	0		.800 M		.800 M

HCl is a strong acid and completely dissociates in water. Therefore, $[H^+] = 0.800$ M and pH = 0.097

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

Add 5.0 mL of 0.600 M KOH.

$$\textbf{5.0 mL}\left(\frac{\textbf{1 L}}{\textbf{1000 mL}}\right)\left(\frac{\textbf{0.600 mol}}{\textbf{1 L}}\right) = \textbf{0.0030 mol KOH}$$

$$\textbf{40.0 mL}\left(\frac{\textbf{1 L}}{\textbf{1000 mL}}\right)\left(\frac{\textbf{0.800 mol}}{\textbf{1 L}}\right) = \textbf{0.032 mol HCl}$$

	HCl	+	KOH	→	H_2O	+	KCl
initial	0.032 mol		0.003 mol		–		0
final	0.029 mol		0		–		0.003 mol

$$\textbf{[HCl]} = \frac{\textbf{0.029 mol}}{\textbf{0.045 L}} = \textbf{0.644 M}$$

$$\textbf{pH} = \textbf{0.191}$$

ii) (Continued)

Calculate the pH after the addition of 20.0 mL of the base.

Add 20.0 mL of 0.600 M KOH

$$\mathbf{20.0\ mL}\left(\frac{\mathbf{1\ L}}{\mathbf{1000\ mL}}\right)\left(\frac{\mathbf{0.600\ mol}}{\mathbf{1\ L}}\right) = \mathbf{0.0120\ mol\ KOH}$$

$$\mathbf{40.0\ mL}\left(\frac{\mathbf{1\ L}}{\mathbf{1000\ mL}}\right)\left(\frac{\mathbf{0.800\ mol}}{\mathbf{1\ L}}\right) = \mathbf{0.0320\ mol\ HCl}$$

	HCl	**+ KOH**	**→**	**H_2O**	**+ KCl**
initial	**0.032 mol**	**0.012 mol**		**–**	**0**
final	**0.020 mol**	**0**		**–**	**0.012 mol**

$$\mathbf{[HCl]} = \frac{\mathbf{0.020\ mol}}{\mathbf{0.060\ L}} = \mathbf{0.333\ M}$$

$$\mathbf{pH} = \mathbf{0.478}$$

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

Add 40.0 mL of 0.600 M KOH

$$\mathbf{40.0\ mL}\left(\frac{\mathbf{1\ L}}{\mathbf{1000\ mL}}\right)\left(\frac{\mathbf{0.600\ mol}}{\mathbf{1\ L}}\right) = \mathbf{0.0240\ mol\ KOH}$$

	HCl	**+ KOH**	**→**	**H_2O**	**+ KCl**
initial	**0.032 mol**	**0.024 mol**		**–**	**0**
final	**0.008 mol**	**0**		**–**	**0.024 mol**

$$\mathbf{[HCl]} = \frac{\mathbf{0.008\ mol}}{\mathbf{0.080\ L}} = \mathbf{0.100\ M}$$

$$\mathbf{pH} = \mathbf{1.00}$$

Calculate the pH after the addition of 52.0 mL of the base.

Add 52.0 mL of 0.600 M KOH

$$\mathbf{52.0\ mL}\left(\frac{\mathbf{1\ L}}{\mathbf{1000\ mL}}\right)\left(\frac{\mathbf{0.600\ mol}}{\mathbf{1\ L}}\right) = \mathbf{0.0312\ mol\ KOH}$$

	HCl	**+ KOH**	**→**	**H_2O**	**+ KCl**
initial	**0.0320 mol**	**0.0312 mol**		**–**	**0**
final	**0.0008 mol**	**0**		**–**	**0.0312 mol**

$$\mathbf{[HCl]} = \frac{\mathbf{0.0008\ mol}}{\mathbf{0.092\ L}} = \mathbf{8.7 \times 10^{-3}\ M}$$

$$\mathbf{pH} = \mathbf{2.06}$$

Calculate the pH after the addition of 53.0 mL of the base.

Add 53.0 mL of 0.600 M KOH

$$\mathbf{53.0\ mL}\left(\frac{\mathbf{1\ L}}{\mathbf{1000\ mL}}\right)\left(\frac{\mathbf{0.600\ mol}}{\mathbf{1\ L}}\right) = \mathbf{0.0318\ mol\ KOH}$$

	HCl	**+ KOH**	**→**	**H_2O**	**+ KCl**
initial	**0.0320 mol**	**0.0318 mol**		**–**	**0**
final	**0.0002 mol**	**0**		**–**	**0.0318 mol**

[HCl] = $\frac{0.0002\ \text{mol}}{0.093\ \text{L}}$ = 2.2×10^{-3} M

pH = 2.67

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

40.0 mL $\left(\frac{1\ \text{L}}{1000\ \text{mL}}\right)\left(\frac{0.800\ \text{mol}}{1\ \text{L}}\right)$ = 0.032 mol HCl

	HCl	+ KOH	→ H_2O	+ KCl
initial	0.0320		–	0
final				

At the equivalence point the moles of the acid reacted equals the moles of base reacted.

	HCl	+ KOH	→ H_2O	+ KCl
initial	0.0320		–	0
final	-0.0320	-0.0320	–	+0.0320

0.032 mol HCl $\left(\frac{1\ \text{mol KOH}}{1\ \text{mol HCl}}\right)$ = 0.032 mol KOH

0.032 mol KOH $\left(\frac{1\ \text{L}}{0.600\ \text{mol}}\right)$ = 0.0533 L (53.3 mL)

iv) What is the pH at the equivalence point?

Add 53.3 mL of 0.600 M KOH

	HCl	+ KOH	→ H_2O	+ KCl
initial	0.0320	0.0320	–	0
final	0	0	–	0.0320

KCl is the salt of a strong acid and strong base, so the pH = 7.00 at the equivalence point.

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

Add 58.3 mL of 0.600 M KOH

58.3 mL $\left(\frac{1\ \text{L}}{1000\ \text{mL}}\right)\left(\frac{0.600\ \text{mol}}{1\ \text{L}}\right)$ = 0.0350 mol KOH

	HCl	+ KOH	→ H_2O	+ KCl
Initial	0.0320	0.0350	–	0
Final	0	0.0030	–	0.0320

[KOH] = $\frac{0.0030\ \text{mol}}{0.0983\ \text{L}}$ = 3.05×10^{-2} M

pOH = 1.52 pH = 12.48

2. Using the designated space below sketch the titration curve for each of the following cases.

a) 50.0 mL of 0.100 M HCl and 0.100 M NaOH

b) 50.0 mL of 0.00100 M HCl and 0.00100 M NaOH