6.7 - Titration Curves

Titration curves are plotted to show the relationship between the pH of the original substance as the titrator is added. This titrating substance is called a **titrant**.

- A titration curve looks differently if you are titrating an acid vs a base. It will also look different if you are titrating a weak substance vs a strong substance.

In general the titrant will always be strong. That is, regardless of the strength of your original substance, the substance used to neutralize it will be strong.

Strong Acid/Base Titration

The simplest titration is when we have a strong acid and we are titrating with a strong base, or vice versa.

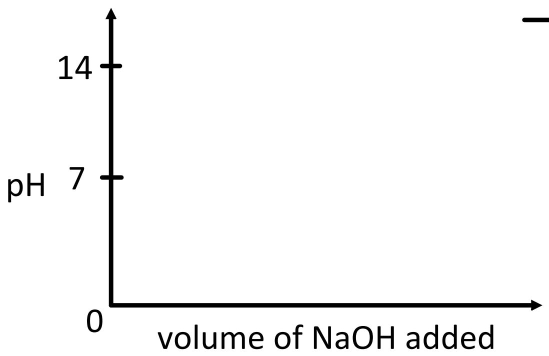
We will look at titrating 1.00 L of 1.00 M HCl with 1.00 M NaOH. Both strong substances. The 1.00 M HCl initially has a pH of 0. After the titration, the solution will have a pH closer to 14.

Initially, the HCl ionizes completely: $HCl_{(aq)} \rightarrow H^+_{(aq)} + Cl^-_{(aq)}$

We also know that we want to add some volume of NaOH in order to make the $[OH^-] = [H^+]$.

The NaOH is also completely dissociated: $NaOH_{(aq)} \rightarrow Na^+_{(aq)} + OH^-_{(aq)}$

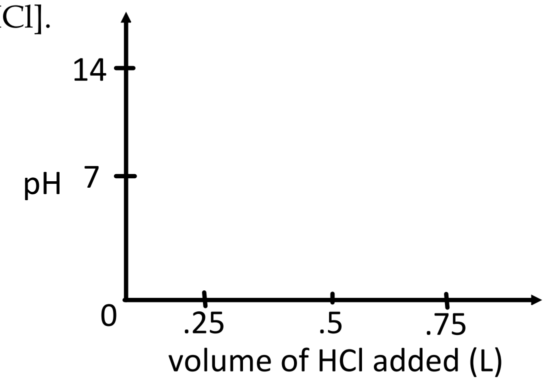
When this happens with strong and strong titrations the pH at the equivalency point will always equal 7.



Given the information above, what volume of NaOH is needed to reach the equivalency point?

The curve will look similar if we are titrating a strong base with a strong acid.

So, this time, let's imagine titrating 1.50 L of 1.00 M NaOH with an unknown concentration of HCl. Use the graph below to determine the [HCl].



Weak Acid/Base Titration

Remember, even if we start off with a weak acid we will titrate with a strong base.

The reason why this situation will look different on our graph is due to the properties of the ions initially in our solution.

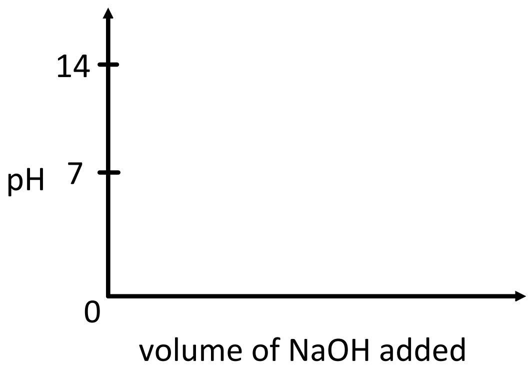
$HF_{(aq)} \rightleftharpoons H^+_{(aq)} + F^-_{(aq)}$

Because the F^- accepts the H^+ to form HF for the reverse reaction, it has basic properties.

As NaOH is added to the system, the OH^- ions will seek out the H^+ ions and neutralize them.

Le Chatelier's principle states that if H^+ is being removed, then HF will ionize more to replace the H^+. This also increases $[F^-]$, which will increase the pH (because this acts as a base).

Eventually, all the H^+ will be removed by the addition of OH^-. This only happens once all of the HF is ionized. The presence of the F^- at the equivalency point leaves the solution slightly basic.



6.7 - Titration Curves

If a weak base is titrated by a strong acid, we will get a similar curve.

- This time, the weak base will have an ion in the solution with acidic properties.

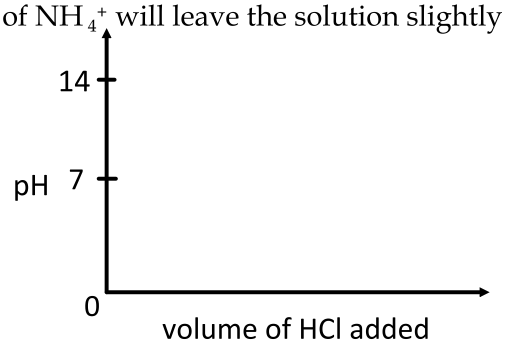
For example, we will titrate NH_3 with HCl.

$$NH_{3(aq)} + H_2O_{(l)} \rightleftharpoons NH_4^+{}_{(aq)} + OH^-{}_{(aq)}$$

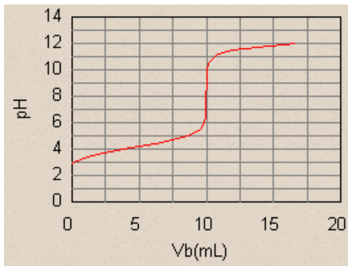
When the HCl is introduced, the H^+ ions will seek out the OH^- ions and get rid of them. This will cause more NH_3 to dissolve and create more NH_4^+.

This ammonium ion acts as an acid because the reverse reaction shows NH_4^+ donating a proton to OH^-.

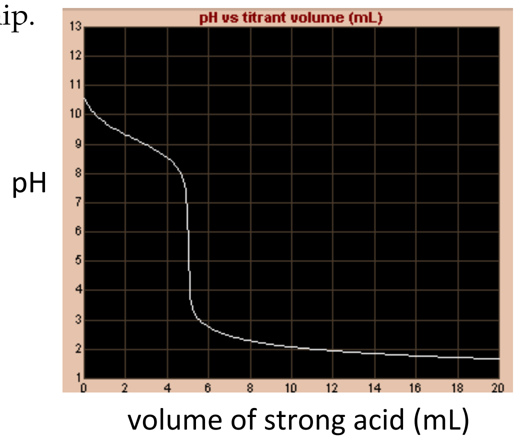
This excess of NH_4^+ will leave the solution slightly acidic.



Ex) Use the following graph to determine the concentration of $Ca(OH)_2$ used to titrate a 0.250 L solution of 0.00196 M HNO_2.



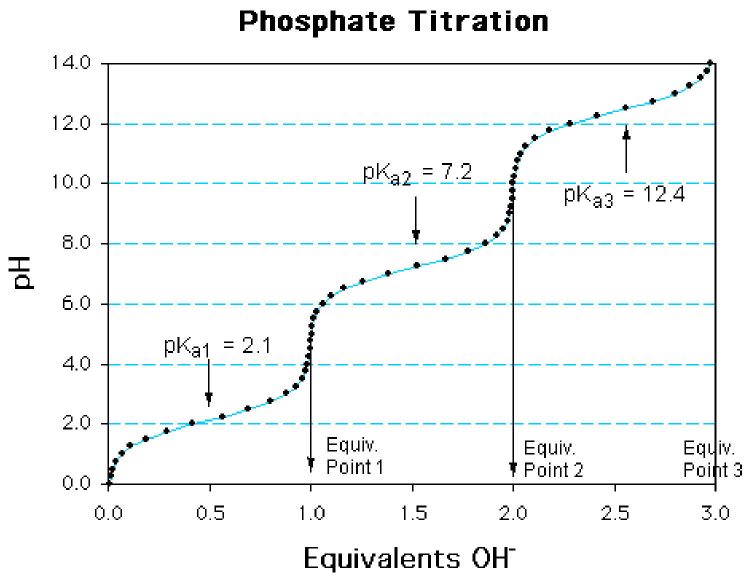
Ex) The curve below shows the titration of a weak base and a strong acid. What is the concentration of the strong acid if the initial solution contained 50.0 mL of the weak base with a concentration of 0.0100 M. Assume a 1:1 relationship.



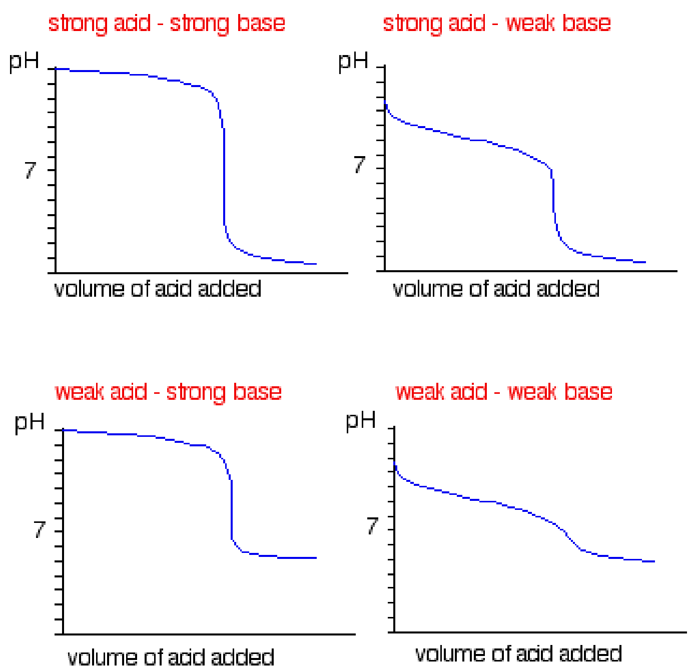
Polyprotic Acids

When titrating a polyprotic acid, you are essentially titrating two acids at once.

The curve shows the same trend as a weak acid titration where the pH does not change for a while, spikes up and levels off again. The difference occurs when the second acid reaction is taking place. The same curve happens again where a slow change in pH is followed by a spike and leveling off.



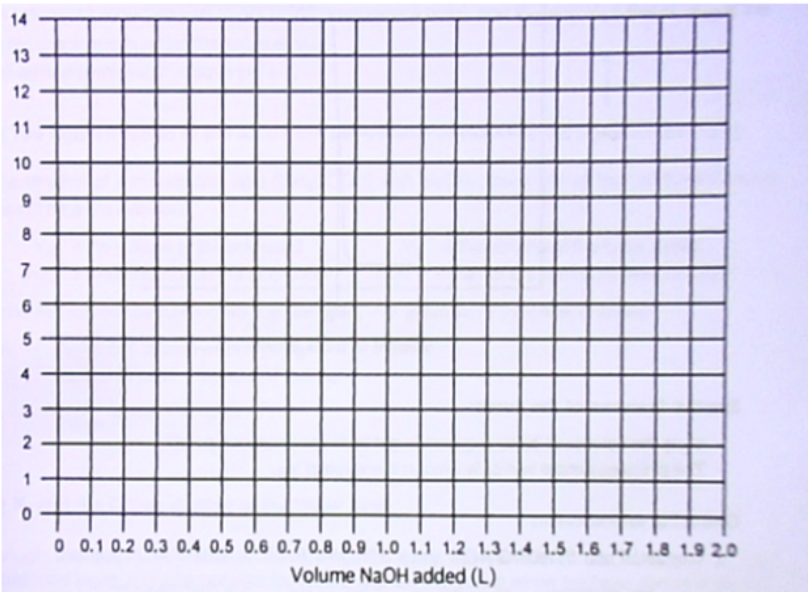
-a titration curve allows for proper indicator to be selected as the pH range of the indicator should be found in the steep portion of the curve



6.7 – Titration Curves Assignment

1. a) The following table gives the result of slowly adding 1.000 M NaOH to 1.000 L of 1.000 M HCl. Plot this data on the given graph. Label the equivalence point.

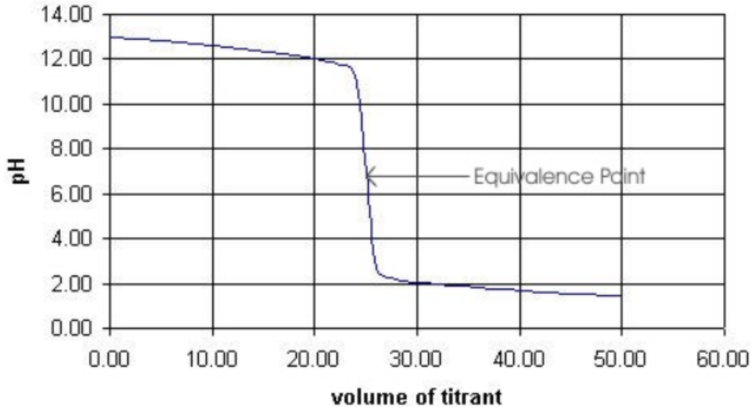
Volume of NaOH added (L)	pH
0.0000	0.00
0.2500	0.22
0.5000	0.48
0.7500	0.85
0.9000	1.28
0.9900	2.30
0.9990	3.30
0.9999	4.30
1.000	7.00
1.0001	9.70
1.0010	10.70
1.0100	11.70
1.1000	12.68
1.2500	13.05
1.5000	13.30
1.7500	13.44
2.0000	13.52



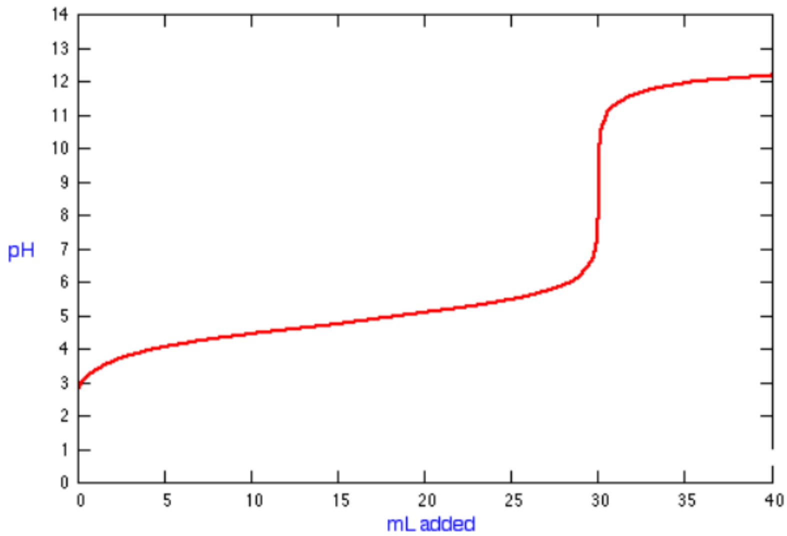
b) What volume of 1.000 M NaOH was required to attain the equivalence point?

6.7 - Titration Curves

2. A 25.0 mL solution of 0.100 M HCl is titrated with NaOH. Use the graph below to determine the concentration of the NaOH.

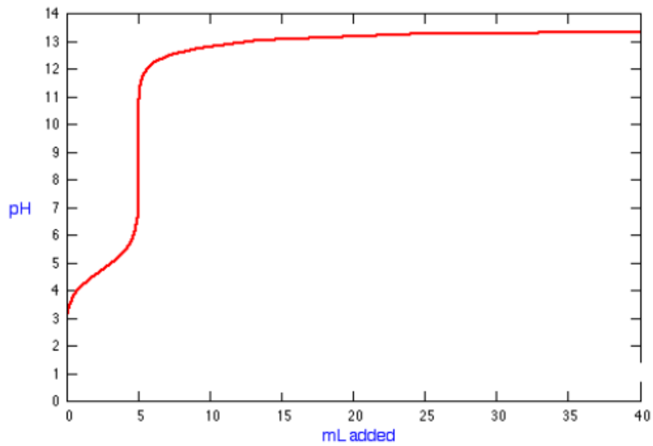


3. 20.0 mL of acetic acid is titrated with 0.100 M NaOH. What is the initial concentration of HCH_3COO?



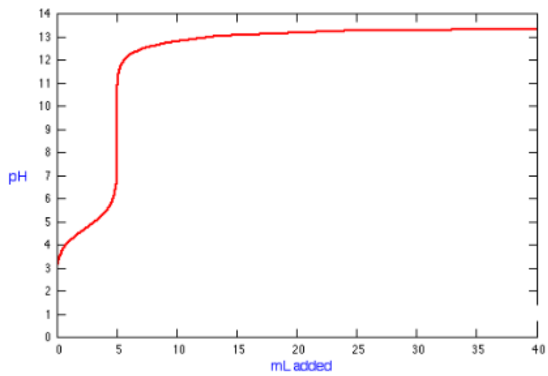
6.7 - Titration Curves

4. 20.0 mL of a weak acid, 0.100 M, is titrated with NaOH. What is the concentration of NaOH?



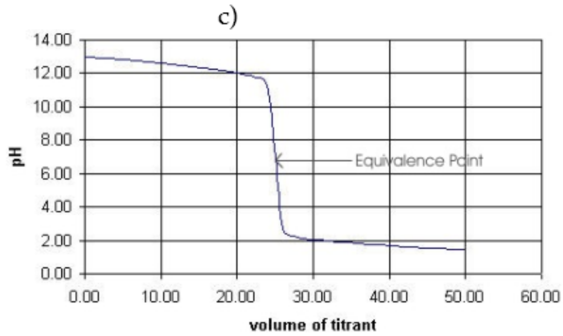
5. Which indicator would best be used for the following titrations?

a)



b) an equivalence point around 3.50

c)



6. How many equivalence points would H_2CO_3 have if you titrated it with NaOH? How do you know?