Titration of weak acid with strong base

Acid and base definition

The Arrhenius Definitions

- describe the characteristics of aqueous solutions of acids and bases
- acid as a substance that releases hydrogen ions in aqueous solutions and a base as a substance that releases hydroxide ions in aqueous solutions

The Brønsted-Lowry Definitions

- defines acids and bases in terms of the mechanism by which they react
- An acid is a proton (H^+) donor.
- A base is a proton (H^+) acceptor.

Strong acid and base, weak acid and base

- **strong acids and bases** are completely ionized when dissolve in water.
- **Weak acids and bases** are only partially ionized in their solutions
- Strong acid and base like HCl, H_2SO_4, HNO_3, NaOH, KOH, LiOH
- Weak acid and base like CH_3COOH (acetic acid), HCOOH (formic acid), HF (hydrofluoric acid), NH_3 ammonia, CH_3NH_2 methylamine, C_5H_5N pyridine

K_a and pK_a

- Ka equilibrium constant for the ionization of weak acid

$$HA \leftrightarrow A^- + H^+$$

$$K_a = \frac{[A^-][H^+]}{[AH]}$$

- larger Ka, the greater ionization of the acid, the stronger of it
- Pka is the negative log of the Ka

$$pK_a = -\log K_a$$

K_b and pK_b

- Kb equilibrium constant for the ionization of weak base

$$B + H_2O \leftrightarrow BH^+ + OH^-$$

$$K_b = \frac{[BH^+][OH^-]}{[B]}$$

- larger Kb, the greater ionization of the base, the stronger of it
- Pkb is the negative log of the Kb

$$pK_b = -\log K_b$$

The relation between Ka and Kb

$$K_B \times K_A = 1.\ 10^{-14} = K_W$$

$$pK_B + pK_A = 14 = pK_W$$

pH and pOH

- The acidity of the solution depend on the conc. of H^+ or OH^-
- The chemist express the acidity by pH

$$pH = -\log [H^+]$$

$$pOH = -\log [OH^-]$$

Example

Calculate the pH and pOH of 0.1 molar Ethanoic acid (K_a= 1.8 X10^{-5})

$CH_3COOH \leftrightarrow CH_3COO^- + H^+$		
0.1	0	0
0.1-X	+X	+X

$$K_a = \frac{[CH_3COO^-][H^+]}{[CH_3COOH]}$$

$$1.8 \text{ X}10^{-5} = \frac{[X][X]}{[0.1-X]}$$

$$X = 1.34\text{x}10^{-3} = [H^+]$$

$$pH = -\log [H^+]$$

$$pH = -\log 1.34\text{x}10^{-3} = 2.87$$

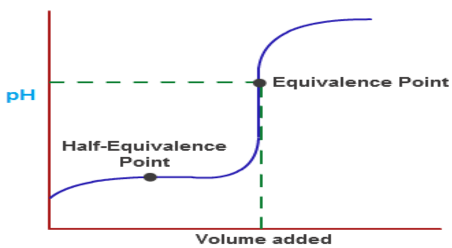
$$14 = pH + pOH$$

$$pOH = 14 - 2.87 = 11.13$$

Titration of acid and base

Strong Acid	**Strong Base**
Strong Acid	**Weak Base**
Strong Base	**Weak Acid**
Weak Acid	**Weak Base**

Titration curve of weak acid (monoprotic) with strong base



The 4 important points in titration of weak acid with strong base

- The starting point pH (only weak acid are found)
- The end point pH the strong base is excess
- The equivalence point when the amount of OH^- from the strong base is react with all weak acid ≈ zero weak acid
- half equivalence point when the [weak acid] is equal to [conjugate base]

Video 1

20.0 ml of 0.113 M ethanoic acid is titrated with 0.100 M NaOH calculate the 1est points (K_a=1.7X10^{-5})

- The starting point pH (only weak acid are found)

	CH_3COOH +	H_2O	$\leftrightarrow$	CH_3COO^- +	H_3O^+
I	0.113	-		0	0
C	-X			+X	+X
E	0.113-X			+X	+X

$K_a = \frac{[CH_3COO^-][H^+]}{[CH_3COOH]}$

$1.7X10^{-5} = \frac{[X][X]}{[0.113-X]}$

X=1.4X10^{-3}

pH=-log[H_3O^+]

pH=-log[1.4X10^{-3}]

pH=2.85

On the graph X=0, Y=2.85

20.0 ml of 0.113 M ethanoic acid is titrated with 0.100 M NaOH calculate the 2nd point (K_a=1.7X10^{-5})

[weak acid]=[conjugate base]

$K_a = \frac{[CH_3COO^-][H^+]}{[CH_3COOH]}$

K_a=[H^+]

[H_3O^+]=1.7X10^{-5}

pH=-log 1.7X10^{-5}

pH= 4.76

On the graph X=????, Y=4.76

20.0 ml of 0.113 M ethanoic acid is titrated with 0.100 M NaOH calculate the 3ed point (K_a=1.7X10^{-5})

All CH_3COOH react with NaOH

	CH_3COOH +	NaOH	↔ CH_3COONa	+ H_2O
I	2.26x10^{-3}	2.26x10^{-3}	0	-
C	0	0	2.26x10^{-3}	-

Mole of acetic acid =MxV

=0.113$\frac{mole}{L}$x20mlx$\frac{1L}{1000ml}$

=2.26x10^{-3}mole of acetic acid

= mole of NaOH = mole of acetate that form

To calculate the molarity of acetate ion we have the moles but we must calculate the total volume the original one and the volume from the NaOH

Vol of NaOH =$\frac{2.26x10-3 \text{ mole}}{0.1\frac{mole}{L}}$

=0.0226 L of NaOH

Total vol = 20ml x $\frac{1L}{1000\ ml}$ + 0.0226

Total vol = 0.0426 L

[CH_3COONa]=$\frac{2.26x10-3mole}{0.0426\ L}$

=5.31x10^{-2} but it is weak base

	CH_3COONa +	H_2O	↔	CH_3COOH	+ OH^-
I	5.31x10^{-2}			0	0
C	-X			+X	+X
E					

Kb=$\frac{[CH_3COOH][OH^-]}{[CH3COO^-]}$

22.6/2=11.3 the vol of half equivalent

Kb=$\frac{1X10-14}{Ka}$

Kb= 5.88x10^{-10}

5.88x10^{-10}=$\frac{[X][X]}{5.31x10-2-X}$

X=5.58x10^{-6}

pOH=5.25

pH=14-5.25=8.74

On the graph X=22.6 , Y=8.74

20.0 ml of 0.113 M ethanoic acid is titrated with 0.100 M NaOH calculate the 4th point (K_a=1.7X10^{-5})

- Excess amount of NaOH were added

	NaOH	→	Na^+	+	OH^-
I	0.1 M				
F	0		0.1M		0.1M

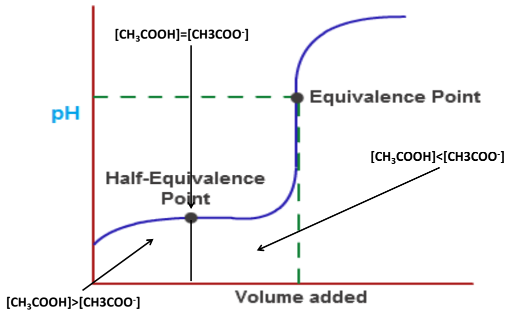
pOH=-log 0.1

pOH =1

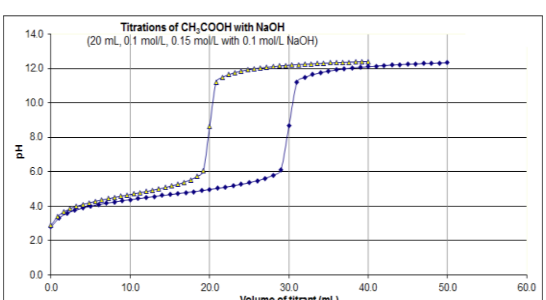
pH=13

On the graph X=∞ , Y=13

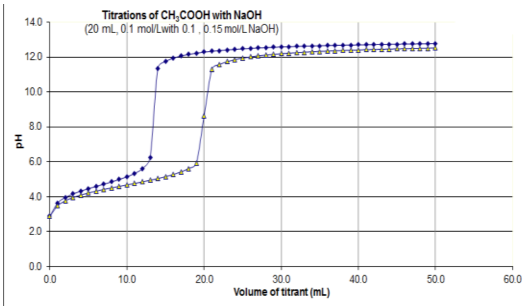
Composition of the solution during titration monoprotic acid



Virtual experiment



[CH_3COOH]		Starting Point	half equivalence point	equivalence point
0.1	pH	2.881	4.757	8.726
	vol	0	10	20
0.15	pH	2.793	4.757	8.766
	vol	0	15	30



[NaOH]		Starting Point	half equivalence point	equivalence point
0.1	pH	2.881	4.757	8.726
	vol	0	10	20
0.15	pH	2.881	4.757	7.753
	vol	0	6.66	13.32

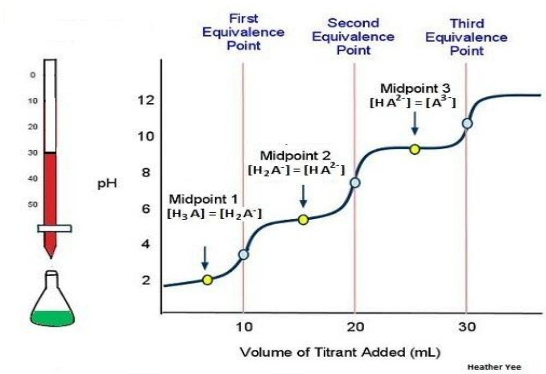
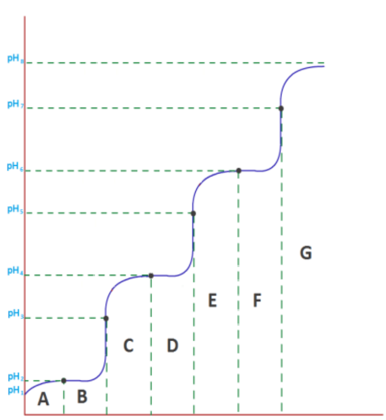


Figure 3.3 Titration of a Weak Polyprotic Acid. The final equivalence point is attained by adding another 10 mL, or a total of 30 mL, of the titrant to the weak polyprotic acid. Image created by Heather Yee.



pH_1 Starting point pH
pH_2 pKa_1
pH_3 $[H_3A]$≈zero
pH_4 pKa_2
pH_5 $[H_2A^-]$≈zero
pH_6 pKa_3
pH_7 $[HA^{-2}]$≈zero
pH_8 End point pH

A $[H_3A]>[H_2A^{-1}]$
B $[H_3A]<[H_2A^{-1}]$
C $[H_2A^{-1}]>[HA^{-2}]$
D $[H_2A^{-1}]<[HA^{-2}]$
E $[HA^{-2}]>[A^{-3}]$
F $[HA^{-2}]<[A^{-3}]$
G $[A^{-3}]$

After this lecture u must know

- Calculate the 4 points of the titration curve
- Determination of 4 points of the graph
- Know the solution composition
- Effect of solution conc on the graph
- Estimation of the Pk_a of an acid

Home work

Plot the titration curve of 30 ml, 0.16 M Propionic acid with 0.15M KOH (pK_a 1.34 x 10^{-5}), 4 points , composition