BCH 312
Experiment (3)

Titration of a weak acid with strong base

+
Objectives

1) To study titration curves.
2) To determine the pKa value of a weak acid.
3) To reinforce the understanding of buffers.

Weak Acid

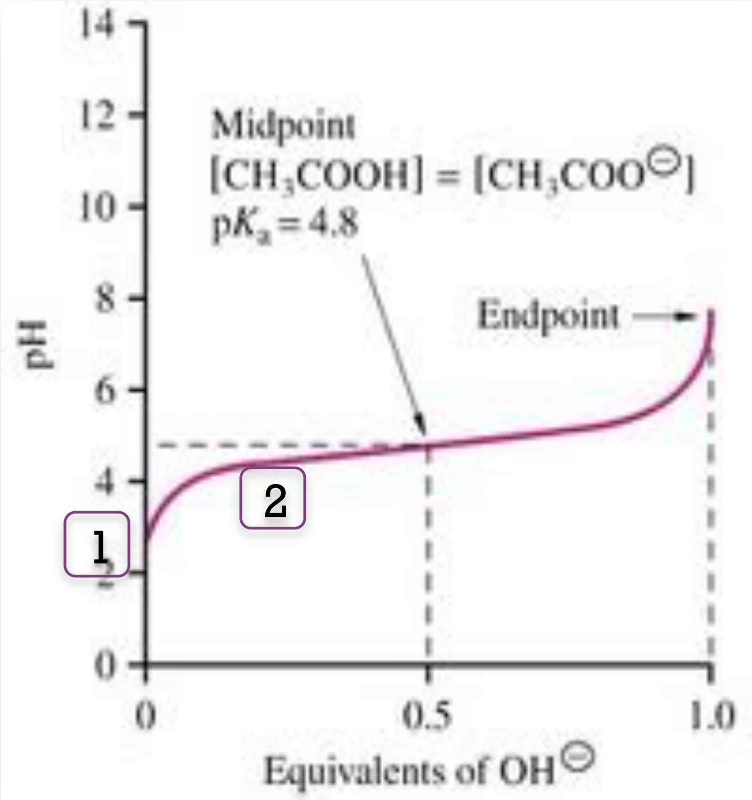
- Weak acids or bases do not dissociate completely, therefore an equilibrium expression with Ka must be used.
- The Ka is **a quantitative measure of the strength of an acid in solution.**
- Ka is usually expressed as pKa.
  - ***pKa = -log Ka***
- As an acid gets weaker, its Ka gets smaller and pka gets larger and vise versa***, for example:***
  - HCl is a strong acid , it has a large value of Ka (low pKa)
  - CH3COOH is a weak acid , it has low value of Ka (high pKa)
- pKa values of weak acids can be determined mathematically or practically by the use of titration curves.

Titration curves

- There are many uses of titration, one of them is to indicate the pKa value of the weak acid by using the titration curve.
- Titration Curves are produced by monitoring the pH of a given volume of a sample solution after successive addition of acid or alkali.
- The curves are usually **plots of pH against the volume of titrant added.**

+ How to calculate the pH at each point of the titration curve

- **[1] Before any addition of strong base the (starting point):**
  - The weak acid is in the full protonation form [CH3COOH] (electron donor) .
  - In this point pH of weak acid < pKa
  - We can calculate the pH from:
    - **pH=(pKa+$P[HA]$) /2**



- **[2] When certain amount of strong base added (any point before the middle of titration):**
  - The weak acid is starting to dissociate , [CH3COOH]>[CH3COO-] (Donor > Acceptor).
  - In this point the pH of weak acid < pKa
  - We can calculate the pH from:
    - **pH=pKa+ log[A-]/[HA]**

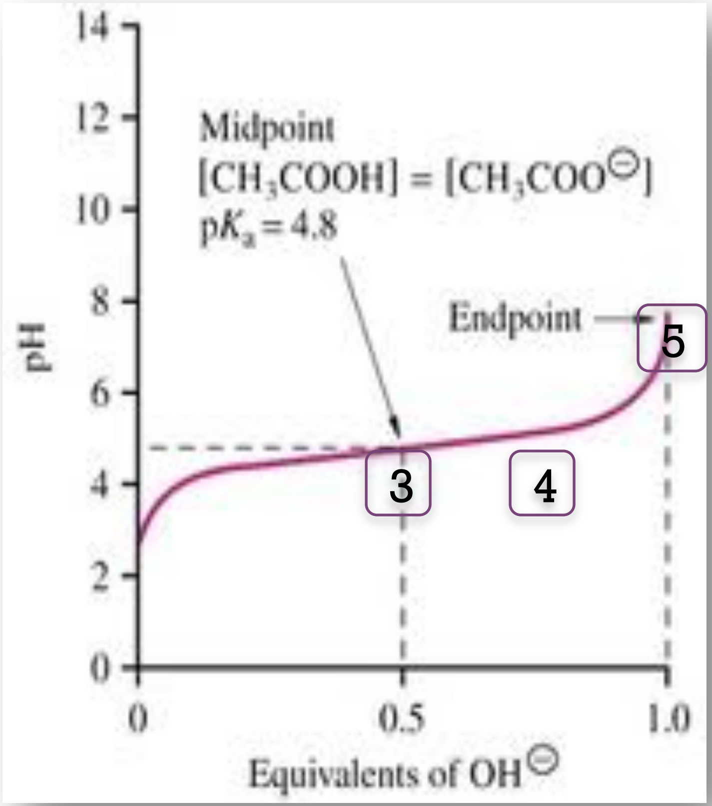
+Continue

- **[3] At middle of titration:**
  - [CH3COOH]=[CH3COO-] (Donor=Acceptor) ,
  - **PH=Pka .**
  - The component of weak acid work as a **Buffer** (A solution that can resistant the change of PH) .
  - Buffer capacity= pKa ± 1

Note: pKa is defined as the pH value at middle of titration at which they will be [donor]=[acceptor].

- **[4] any point after mid of titration:**
  - [CH3COOH]< [CH3COO-] , (Donor< Acceptor) .
  - In this point the pH > pKa
  - We can calculate the pH from:
    - **pH= pKa + log[A-]/[HA]**

- **[5] At the end point**
  - The weak acid is fully dissociated [CH3COO-] (electron acceptor) .
  - pH of weak acid >pka
  - Approximatly, all the solution contains CH3COONa so we first must calculate pOH, then the pH:
    - **pOH= (pKb+p[A-]) /2**
    - **pH= pKw- pOH**



Notes:

The pH calculated by different way :

- **[1] At starting point** pH= (pKa+p[HA]) /2
- **[2] At any point within the curve (after , in or after middle titration)**

  pH=pKa+ log[A-]/[HA] ***(Henderson-Hasselbalch equation)***

- **[3] At end point** pOH=(pKb+p[A-]) /2

  pH=pKw – pOH

Henderson-Hasselbalch equation is an equation that is often used to :

- To calculate the pH of the buffer
- Used in buffer preparation.
- To calculate the pH in any point within the **titration curve** (Except starting and ending point)

Example

- **Determine the pH value of 500 ml weak acid (0.1M) , titrated with 0.1M KOH (Pka=5) ?**

After addition 100 ml , 250 ml , 375 and 500 ml of KOH??

[1] pH after the addition of 100 ml of KOH?

- pH=pKa+ logA^- /HA

HA + KOH → KA + H2O

- No. of moles of HA remaining = No. of moles of HA originally –No. of moles of KOH
- No. of moles of KOH = M x V (in L)= 0.1 X 0.1 = **0.01 moles** = **No. of moles of A^-**
- No. of moles of HA originally = M x V (in L) = 0.1 X 0.5 = 0.05 moles
- No. of moles of HA remaining = 0.05 – 0.01 = **0.04 moles**
- pH = 5 + log 0.01 / 0.04
- pH = 4.4

+

[2] pH after the addition of 250 ml of KOH??

- No. of moles of HA remaining = No. of moles of HA originally – No. of moles of KOH
- No. of moles of KOH = 0.1 X 0.25 = **0.025 moles** = **No. of moles of A^-**
- No. of moles of HA originally = 0.1 X 0.5 = 0.05 moles
- No. of moles of HA remaining = 0.05 – 0.025 = **0.025 mole**
- pH = 5 + log 0.025/0.025
- **pH= 5 = Pka (at mid point , The component of weak acid work as a Buffer , has a buffering capacity 5 ± 1)**

[3] pH after the addition of 375 ml of KOH??

- No. of moles of HA remaining = No. of moles of HA originally – No. of moles of KOH
- No. of moles of KOH = 0.1 X 0.375 = **0.0375 moles** = **No. of moles of A^-**
- No. of moles of HA originally = = 0.1 X 0.5 = 0.05 moles
- No. of moles of HA remaining= 0.05 – 0.0375 = **0.0125 mole**
- pH = 5 + log 0.0375/0.0125
- pH= 5.48

[4] pH after the addition of 500 ml of KOH??

Note: *500 ml the same volume of weak acid that mean the all weak acid as [CH3COO]*

- pOH = (pKb + p[A^-]) /2 **pKb= pKw-pKa →pKb =14-5 = 9**
- p[A-]= - log [A^-] → [A^-]=??
- No of moles of KOH = 0.1 X 0.5 = 0.05 moles = **No. of moles of A^-**
- Total volume = 500 + 500 = 1000 = 1L
- [A^-] = 0.05/1 =0.05 M
- p[A^-]= - log 0.05 = 1.3
- pOH= (9 +1.3) / 2 = 5.15
- pH=pKw-pOH
- PH = 14 – 5.15 = **8.85 (at end point)**

Method

- You are provided with 10 ml of a 0.1M CH_3COOH weak acid solution, titrate it with 0.1m NaOH adding the base drop wise mixing, and recording the pH after each 0.5 ml NaOH added until you reach a pH=10.

Volume of 0.1 NaOH (ml)	pH
0	
0.5	
1	
1.5	

Discussion:

1- Plot a Curve of pH versus ml of NaOH added, determine the pKa value from the curve.

2- Calculate the pH of the weak acid HA solution after the addition of 3ml, 5ml, and 10ml of NaOH.

3- Compare your calculated pH values with those obtained from Curve.

4- At what pH-range did the acid show buffering behavior? What are the chemical species at that region, what are their proportions?