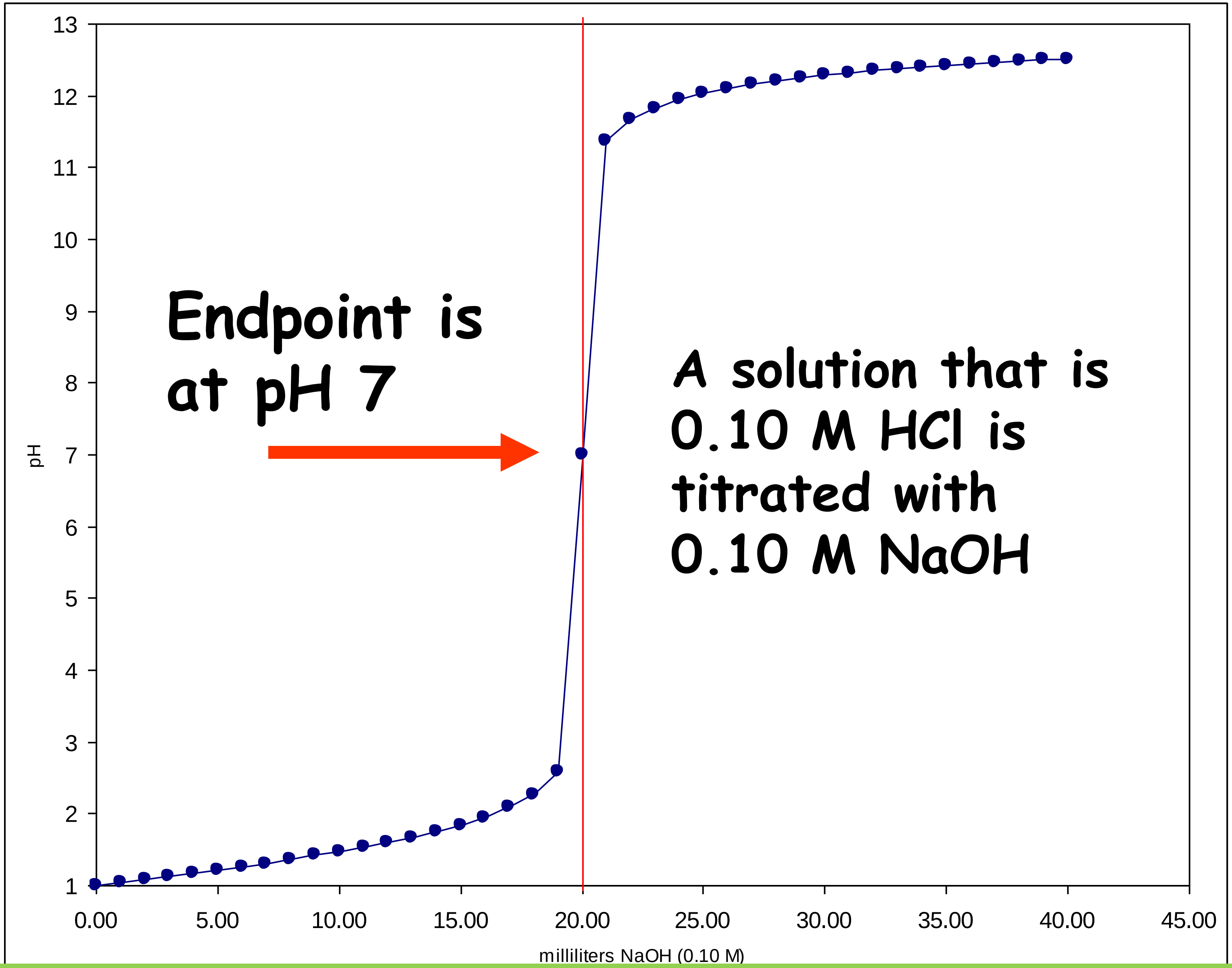
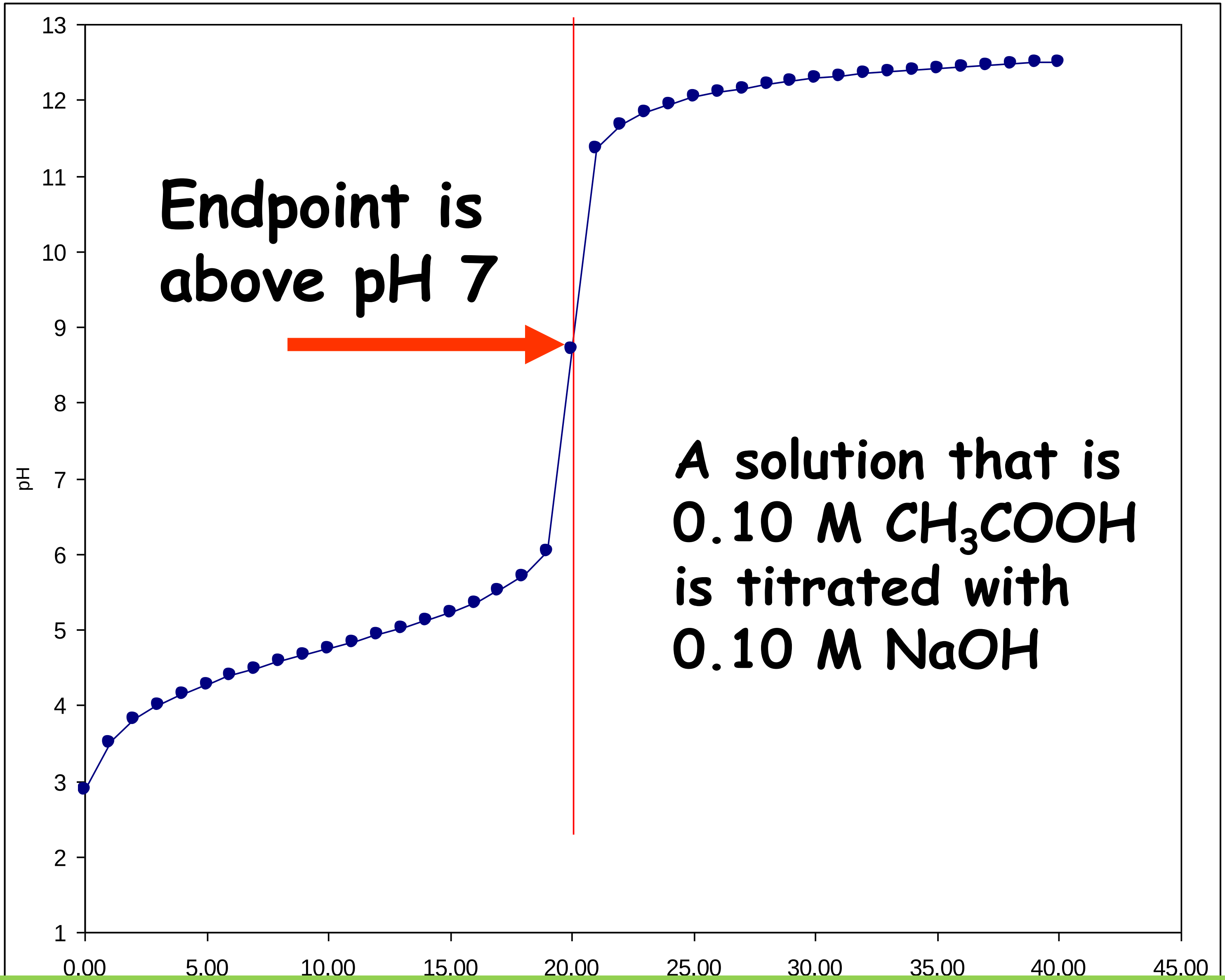
N40 – Acid Base

Titration

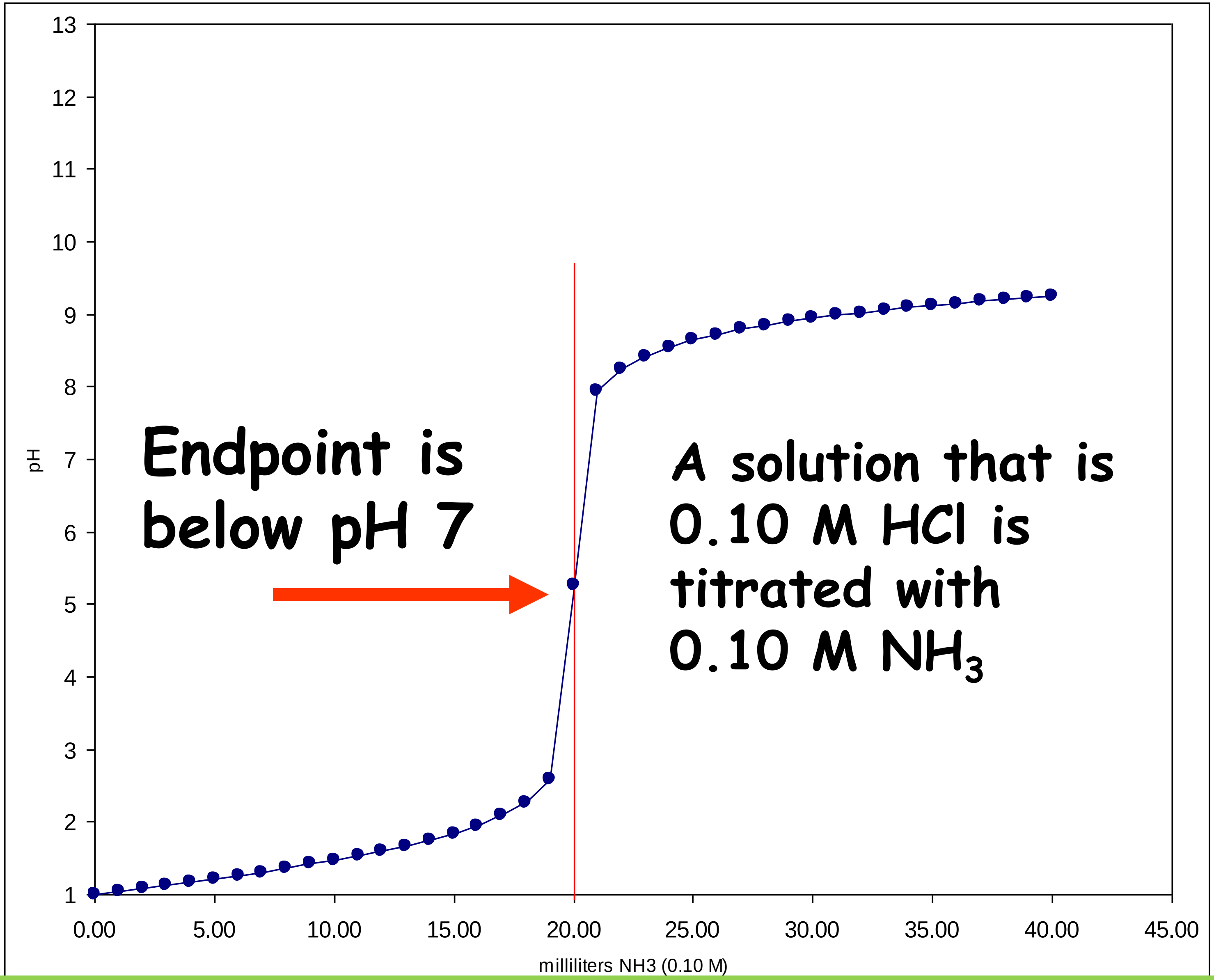
Strong Acid/Strong Base Titration



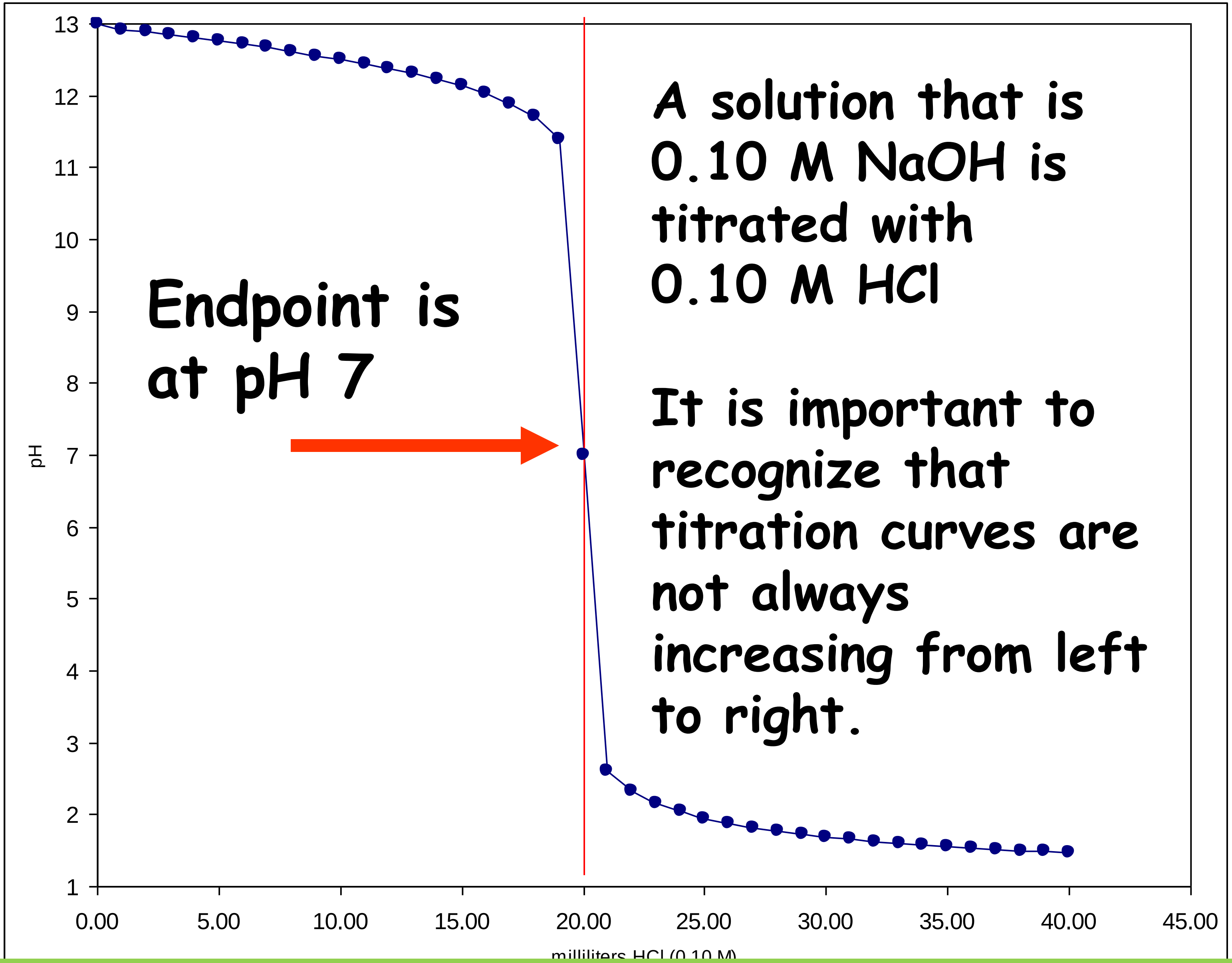
Weak Acid/Strong Base Titration



Strong Acid/Weak Base Titration



Strong Acid/Strong Base Titration



Titration Calculations…

1. **Starting pH**
   - ICE table then pH
2. **Early on during titration**
   - Stoich then He-Ha
3. **Equivalence Point**
   - mol acid = mol base
   - No more buffer! Reverse rxn
   - Calc new K value - ICE then pH
4. **½ Way Point**
   - ½ moles @ eq.pt
   - pH = pKa
5. **Towards end of titration**
   - Extra titrant left over
   - Stoich then simple pH

Calculations to Plot a Titration Curve

1. **Starting pH**
   - ICE table then pH
2. **Early on during titration**
   - Stoich then He-Ha
3. **Equivalence Point**
   - mol acid = mol base
   - No more buffer! Reverse rxn
   - Calc new K value - ICE then pH
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   - ½ moles @ eq.pt
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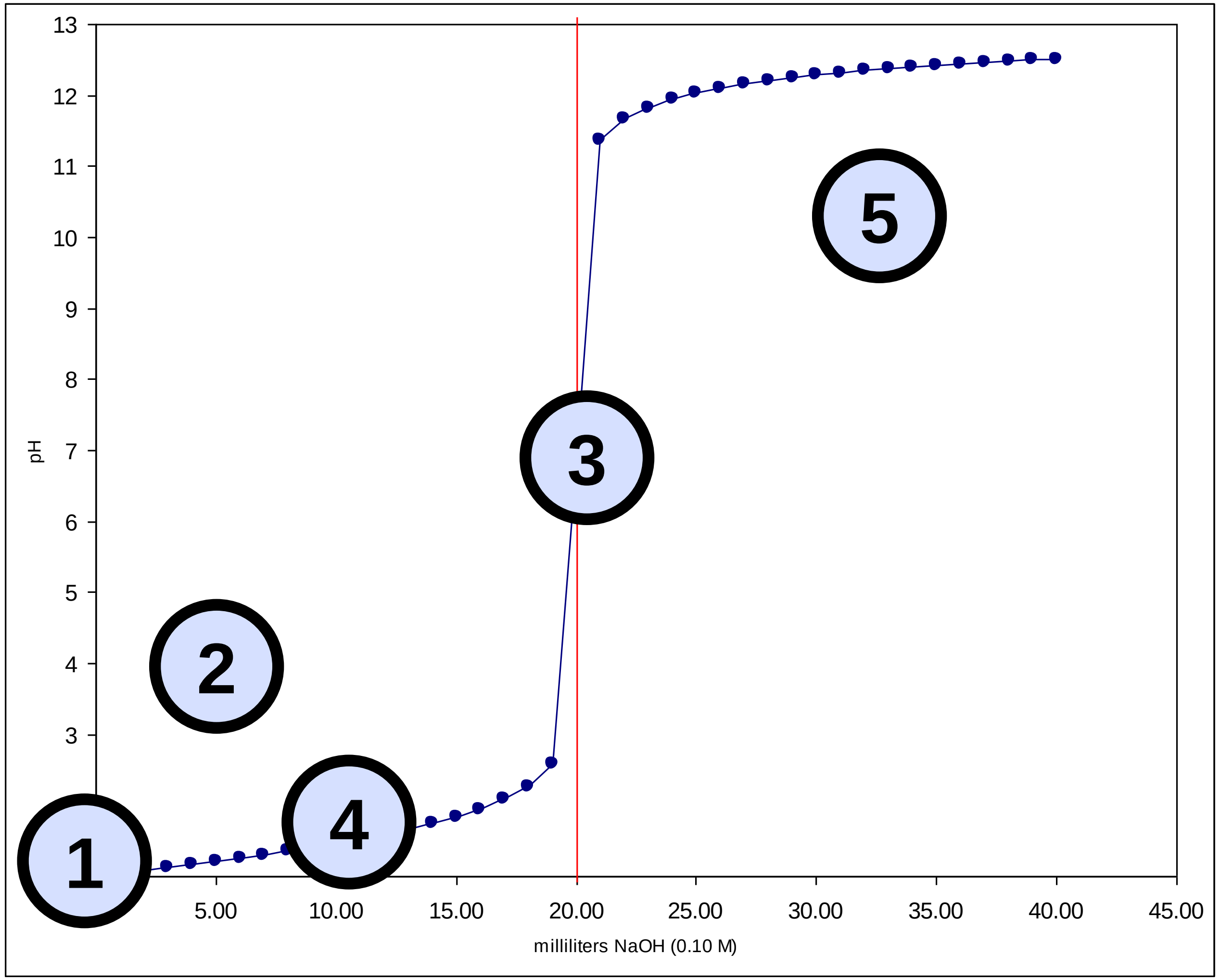
5. **Towards end of titration**
   - Extra titrant left over
   - Stoich then simple pH



Titration Calculations

1

Lets look at the titration of acetic acid w/ NaOH

BEFORE TITRATION

- **Starting point:**
  - 25 ml of 0.15M Acetic Acid ($K_a = 1.8E^{-5}$)
    - Calculate pH before any titrant is added
      - ICE TABLE! Then pH calculation

C_2H_3OH	$\leftrightarrow$ H^+	$C_2H_3O^-$
0.15 M	0 M	0 M
- x	+ x	+ x
0.15 – x	x	x
0.15	x	x

$$K = \frac{[H^+][C_2H_3O^-]}{[C_2H_3OH]}$$

$$1.8\ x\ 10^{-5} = \frac{(x)(x)}{0.15}$$

$$x = 1.64\ x\ 10^{-3}$$

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

$$pH = -log(1.64\ x\ 10^{-3})$$

$$pH\ @\ starting\ point$$

= 2.78

Titration Calculations

DURING THE TITRATION

- Add 10ml of 0.10 M NaOH
  - Determine stoichiometry
  - Notice! You have a buffer now.
    - You have a conjugate base!
    - Use He-Ha eq.

$$\frac{25\ mL}{} \Big| \frac{1\ L}{1000\ mL} \Big| \frac{0.15\ mol}{1\ L} = 3.75\times10^{-3}\ \text{mol acid}$$

$$\frac{10\ mL}{} \Big| \frac{1\ L}{1000\ mL} \Big| \frac{0.10\ mol}{1\ L} = 1.0\times10^{-3}\ \text{mol base}$$

People like to use these "mole tables" – they are NOT ICE TABLES! They have moles not concentrations. ***BE CAREFUL!***

C_2H_3OH	OH^- $\leftrightarrow$	H_2O	$C_2H_3O^-$
3.75 mmol	1 mmol	0	0
2.75 mmol	0 mmol	1mmol	1mmol

Have to convert to M before using He-Ha!

$$[C_2H_3OH] = \frac{2.75\ x\ 10^{-3} mol}{(0.025\ L + 0.010\ L)} = 0.0786\ M$$

$$[C_2H_3O^-] = \frac{1.00\ x\ 10^{-3} mol}{(0.025\ L + 0.010\ L)} = 0.0286\ M$$

NOW you can use He-Ha

Titration Calculations

DURING THE TITRATION

- Add 10ml of 0.10 M NaOH
  - Determine stoichiometry
  - Notice! You have a buffer now.
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$$[C_2H_3OH] = \frac{2.75\ x\ 10^{-3} mol}{(0.025\ L + 0.010\ L)} = 0.0786\ M$$

$$[C_2H_3O^-] = \frac{1.00\ x\ 10^{-3} mol}{(0.025\ L + 0.010\ L)} = 0.0286\ M$$

$$pH = pKa + log\left(\frac{[A^-]}{[HA]}\right)$$

$$pH = -log(1.8x10^{-5}) + log\left(\frac{0.0286\ M}{0.0786\ M}\right)$$

pH = 4.31

Titration Calculations

2

DURING THE TITRATION AGAIN

- Add 25ml of 0.10 M NaOH
  - Determine stoichiometry
  - Notice! You have a buffer now.
    - You have a conjugate base!
    - Use He-Ha eq.

People like to use these "mole tables" – they are NOT ICE TABLES! They have moles not concentrations. ***BE CAREFUL!***

C_2H_3OH	OH^- $\leftrightarrow$	H_2O	$C_2H_3O^-$
3.75 mmol	2.5 mmol	0	0
1.25 mmol	0 mmol	2.5 mmol	2.5 mmol

Have to convert to M before using He-Ha!

$$\frac{25\ mL \mid 1\ L \mid 0.15\ mol}{\mid 1000\ mL \mid 1\ L} = 3.75\times10^{-3}\ \text{mol acid}$$

$$\frac{25\ mL \mid 1\ L \mid 0.10\ mol}{\mid 1000\ mL \mid 1\ L} = 2.5\ \times10^{-3}\ \text{mol base}$$

$$[C_2H_3OH] = \frac{1.25\ x\ 10^{-3} mol}{(0.025\ L + 0.025\ L)} = 0.025\ M$$

$$[C_2H_3O^-] = \frac{1.00\ x\ 10^{-3} mol}{(0.025\ L + 0.025\ L)} = 0.050\ M$$

NOW you can use He-Ha

Titration Calculations

2

DURING THE TITRATION AGAIN

- Add 25ml of 0.10 M NaOH
  - Determine stoichiometry
  - Notice! You have a buffer now.
    - You have a conjugate base!
    - Use He-Ha eq.

$$[C_2H_3OH] = \frac{1.25\ x\ 10^{-3} mol}{(0.025\ L + 0.025\ L)} = 0.025\ M$$

$$[C_2H_3O^-] = \frac{1.00\ x\ 10^{-3} mol}{(0.025\ L + 0.025\ L)} = 0.050\ M$$

$$pH = pKa + log\left(\frac{[A^-]}{[HA]}\right)$$

$$pH = -log(1.8x10^{-5}) + log\left(\frac{0.050\ M}{0.025\ M}\right)$$

pH = 5.05

Titration Calculations

AT EQUIVALENCE POINT

- Add 37.5 ml of 0.10 M NaOH
  - Determine stoichiometry
  - Notice! You have NO BUFFER LEFT!
    - You have NO weak acid left!!

People like to use these "mole tables" – they are NOT ICE TABLES! They have moles not concentrations. ***BE CAREFUL!***

C_2H_3OH	OH^- $\leftrightarrow$	H_2O	$C_2H_3O^-$
3.75mmol	3.75mmol	0	0
0 mmol	0 mmol	3.75mmol	3.75mmol

Have to Reverse the Rxn, new ICE table!

$$\frac{25\ \text{mL}}{} \left| \frac{1\ \text{L}}{1000\ \text{mL}} \right| \frac{0.15\ \text{mol}}{1\ \text{L}} = 3.75\text{x}10^{-3}\ \text{mol acid}$$

$$\frac{37.5\text{mL}}{} \left| \frac{1\ \text{L}}{1000\ \text{mL}} \right| \frac{0.10\ \text{mol}}{1\ \text{L}} = 3.75\ \text{x}10^{-3}\ \text{mol base}$$

Titration Calculations

AT EQUIVALENCE POINT

- Add 37.5 ml of 0.10 M NaOH
  - Determine stoichiometry
  - Notice! You have NO BUFFER LEFT!
    - You have NO weak acid left!!

People like to use these "mole tables" – they are NOT ICE TABLES! They have moles not concentrations. ***BE CAREFUL!***

C_2H_3OH	OH^- ⟷	H_2O	$C_2H_3O^-$
3.75mmol	3.75mmol	0	0
0 mmol	0 mmol	3.75mmol	3.75mmol

Have to Reverse the Rxn, new ICE table!

Remember to use M in ICE Table not moles!

$$[C_2H_3O^-] = \frac{3.75 \, x \, 10^{-3} mol}{(0.025 \, L + 0.0375 \, L)} = 0.060 \, M$$

$C_2H_3O^-$	H_2O ⟷	C_2H_3OH	OH^-
0.06 M	-	0	0
- x	-	+ x	+ x
0.06	-	x	x

Titration Calculations

3

AT EQUIVALENCE POINT

- Add 37.5 ml of 0.10 M NaOH
  - Determine stoichiometry
  - Notice! You have NO BUFFER LEFT!
    - You have NO weak acid left!!

People like to use these "mole tables" – they are NOT ICE TABLES! They have moles not concentrations. ***BE CAREFUL!***

C_2H_3OH	OH^- $\leftrightarrow$	H_2O	$C_2H_3O^-$
3.75mmol	3.75mmol	0	0
0 mmol	0 mmol	3.75mmol	3.75mmol

Remember to use Kb this time!

$$Kw = Ka\ x\ Kb \qquad Kb = \frac{Kw}{Ka}$$

$$Kb = \frac{(1\ x\ 10^{-14})}{(1.8\ x\ 10^{-5})} = 5.56\ x\ 10^{-10}$$

Have to Reverse the Rxn, new ICE table!

$C_2H_3O^-$	H_2O $\leftrightarrow$	C_2H_3OH	OH^-
0.06 M	-	0	0
- x	-	+ x	+ x
0.06	-	x	x

Titration Calculations

3

AT EQUIVALENCE POINT

- Add 37.5 ml of 0.10 M NaOH
  - Determine stoichiometry
  - Notice! You have NO BUFFER LEFT!
    - You have NO weak acid left!!

$C_2H_3O^-$	$H_2O \leftrightarrow$	C_2H_3OH	OH-
0.06 M	-	0	0
- x	-	+ x	+ x
0.06	-	x	x

Remember to use Kb this time!

$$Kw = Ka\ x\ Kb \qquad Kb = \frac{Kw}{Ka}$$

$$Kb = \frac{(1\ x\ 10^{-14})}{(1.8\ x\ 10^{-5})} = 5.56\ x\ 10^{-10}$$

$$5.56\ x\ 10^{-10} = \frac{(x)(x)}{0.06}$$

$$x = 5.77\ x\ 10^{-6} = [OH^-]$$

Now you can do pH calculation!

Titration Calculations

AT EQUIVALENCE POINT

- Add 37.5 ml of 0.10 M NaOH
  - Determine stoichiometry
  - Notice! You have NO BUFFER LEFT!
    - You have NO weak acid left!!

Stop and check that it makes sense!

Weak Acid + Strong Base
Equivalence Point
should be Basic
Yes, 8.76 makes sense!

Now you can do pH calculation!

$$x = 5.77\ x\ 10^{-6} = [OH^-]$$

$$pOH = -log(5.77\ x\ 10^{-6}) = 5.24$$

$$pH = 14 - pOH$$

$$pH = 14 - 5.24$$

pH = 8.76

Titration Calculations

AT ½ WAY POINT

- It took 37.5 ml of NaOH to get to eq.pt
  - So half way to eq. pt. would be 18.75 mL of NaOH

@ ½ way point pH = pKa

$$pH = -log(1.8\,x\,10^{-5})$$

pH = 4.74

Why calculate pH at the ½ way point? It is a nice point to plot on a graph to help get the curve. Also - when doing a titration, you can figure out the Ka by finding the pH at the halfway point.

Titration Calculations

5

AT THE END OF TITRATION

- Add 50mL of 0.10 M NaOH
  - Still no buffer anymore…used up all the weak acid.
  - BUT…you are past the equivalence point!
  - Now you have excess OH-

$$\frac{50\text{mL}}{} \left| \frac{1\text{ L}}{1000\text{ mL}} \right| \frac{0.10\text{ mol}}{1\text{ L}} = 5 \times 10^{-3} \text{ mol base}$$

Do stoich to find how much left

C_2H_3OH	OH^- $\leftrightarrow$	H_2O	$C_2H_3O^-$
3.75mmol	5 mmol	0	0
0 mmol	5 – 3.75 = 1.25 mmol	3.75mmol	3.75mmol

Remember to use M in pH calculations!

$$[OH^-] = \frac{1.25\ x\ 10^{-3}\ mol}{(0.025\ L + 0.050\ L)}$$

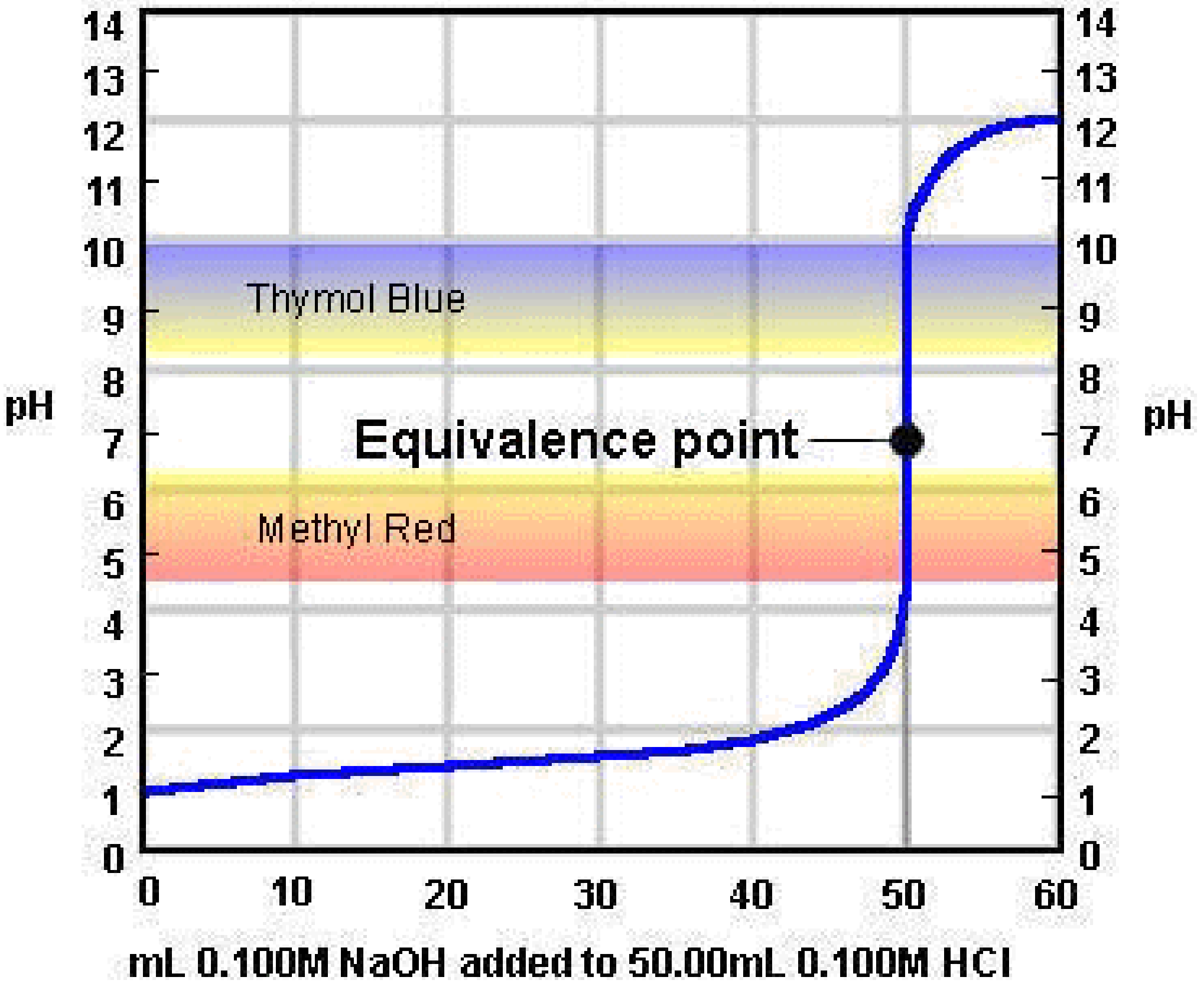
$$[OH^-] = 0.0167\ M$$

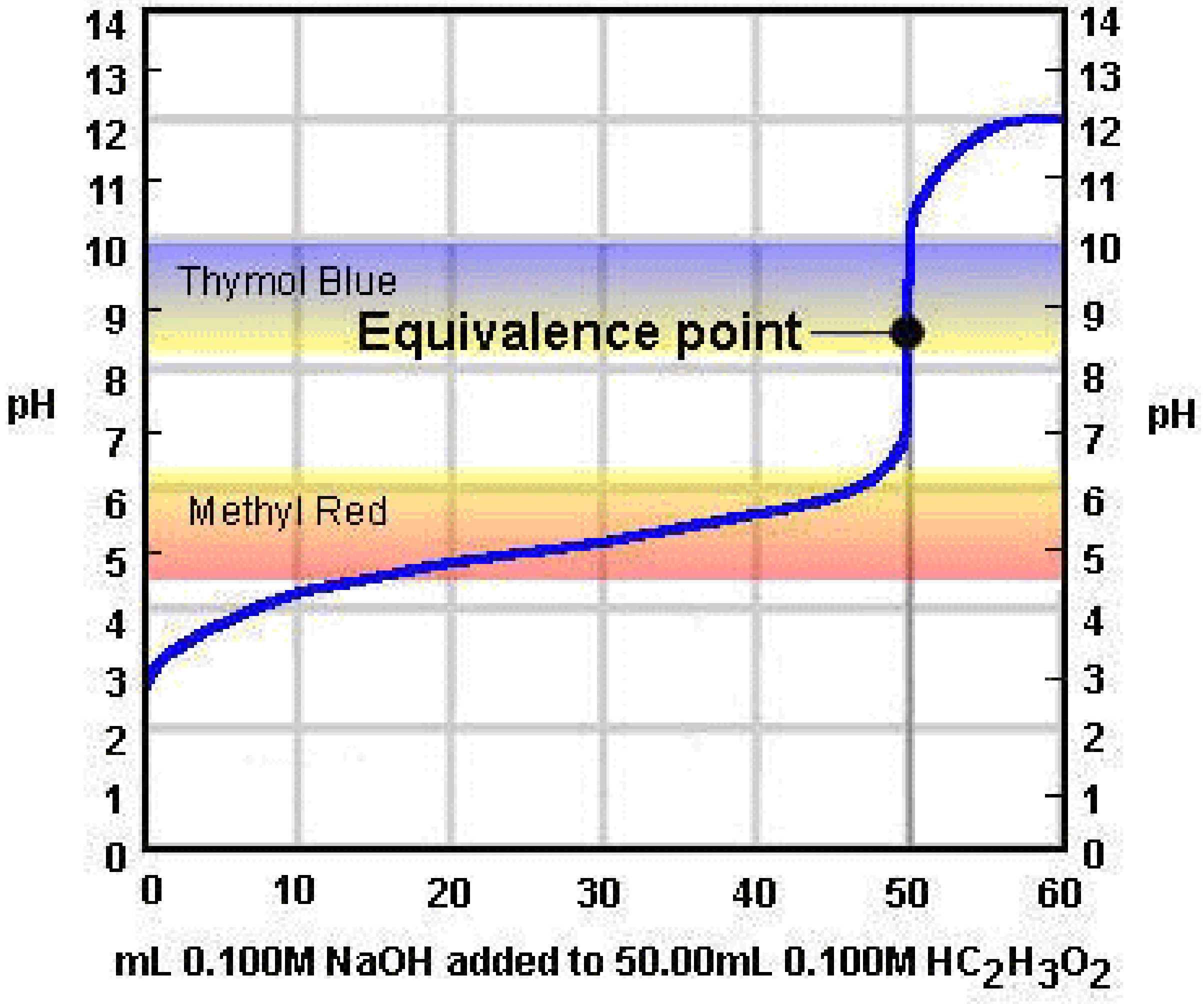
$$pOH = -log(0.0167) = 1.78$$

$$pH = 14 - pOH \quad = 14 - 1.78$$

pH = 12.22

Selection of Indicators



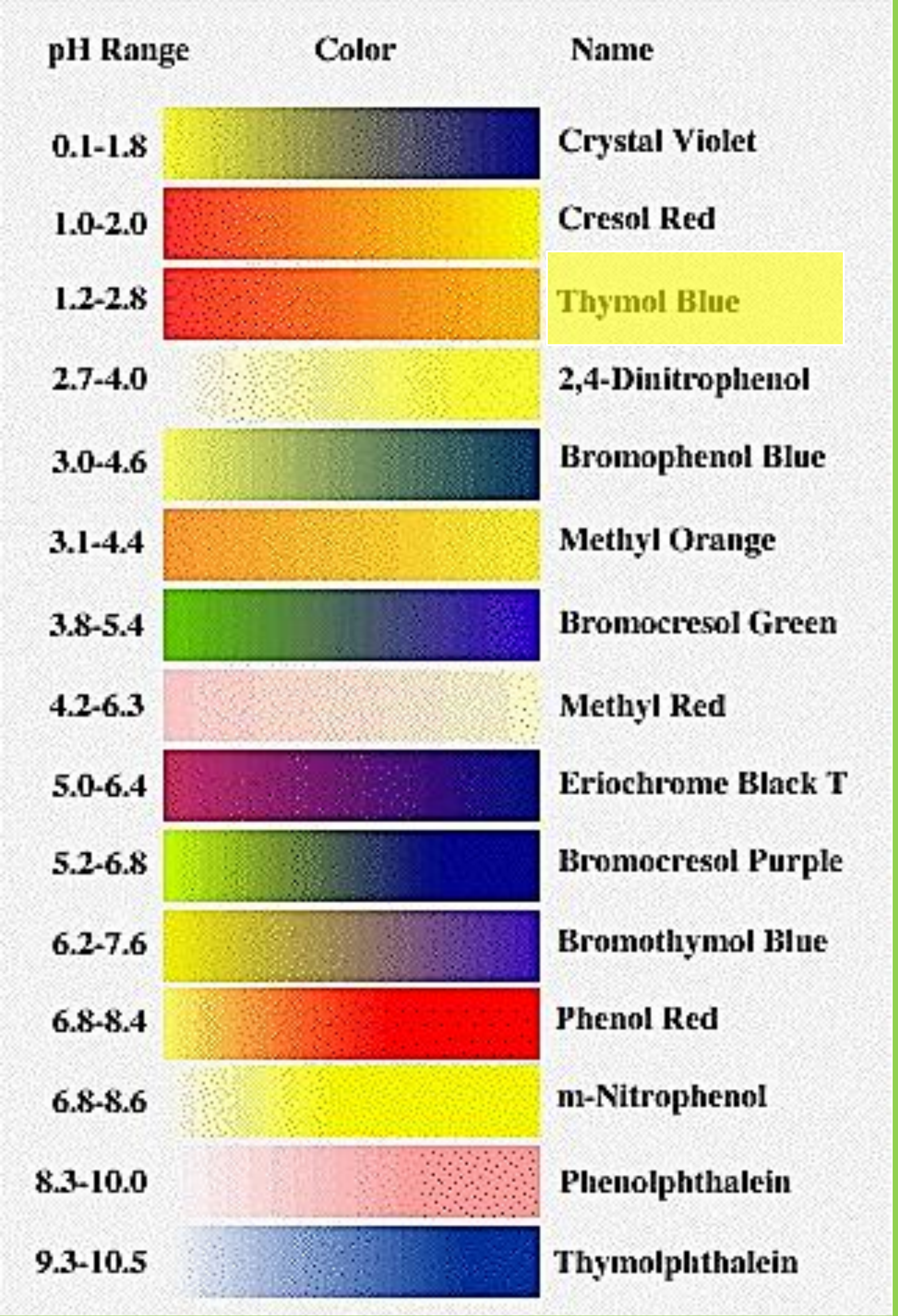


pH Indicators and Ranges

How do you know which indicator to pick for a reaction?

Pick the one that changes color in a pH range that is +/- 1 from the pKa of the reaction you are doing.

Example: pKa 2
Choose something that changes in the 1 – 3 range.



Some Acid-Base Indicators

Indicator	pH Range in which Color Change Occurs	Color Change as pH Increases
Crystal violet	0.0 - 1.6	yellow to blue
Thymol blue	1.2 - 2.8	red to yellow
Orange IV	1.4 - 2.8	red to yellow
Methyl orange	3.2 - 4.4	red to yellow
Bromcresol green	3.8 - 5.4	yellow to blue
Methyl red	4.8 - 6.2	red to yellow
Chlorophenol red	5.2 - 6.8	yellow to red
Bromthymol blue	6.0 - 7.6	yellow to blue
Phenol red	6.6 - 8.0	yellow to red
Neutral red	6.8 - 8.0	red to amber
Thymol blue	8.0 - 9.6	yellow to blue
Phenolphthalein	8.2 - 10.0	colourless to pink
Thymolphthalein	9.4 - 10.6	colourless to blue
Alizarin yellow	10.1 - 12.0	yellow to blue
Indigo carmine	11.4 - 13.0	blue to yellow