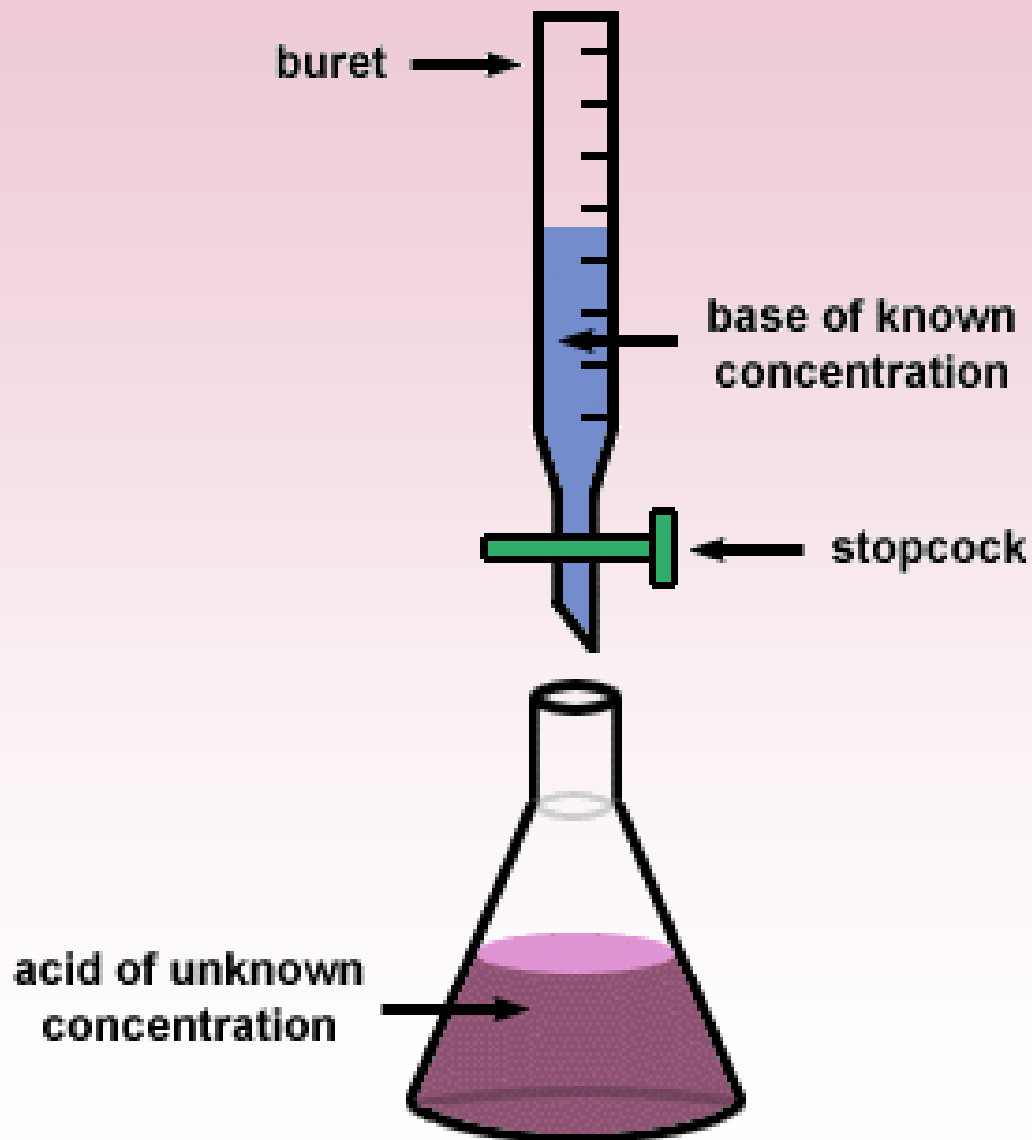


# TITRATIONS & BUFFERS

# TITRATIONS



Purpose:

To determine the unknown concentration of the acid.

# TITRATIONS

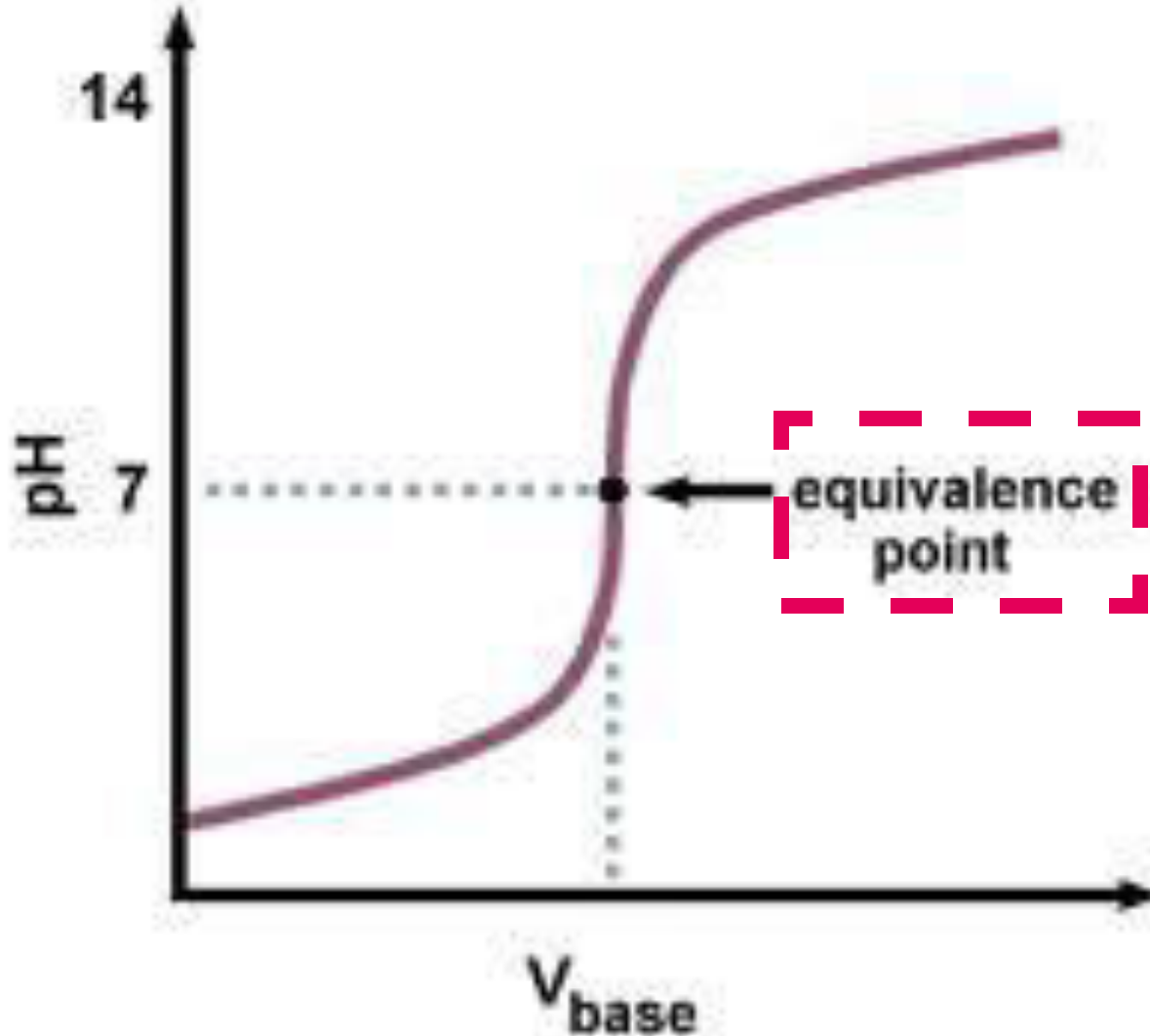
**Equivalence point:** The point (pH) in the titration when an equal number of moles of acid and base have been added

**End point:** The point (pH) at which the indicator changes colour indicating an end to the titration

For a successful titration, choose an indicator that changes colour at a pH value **close to the pH at the equivalence point.**

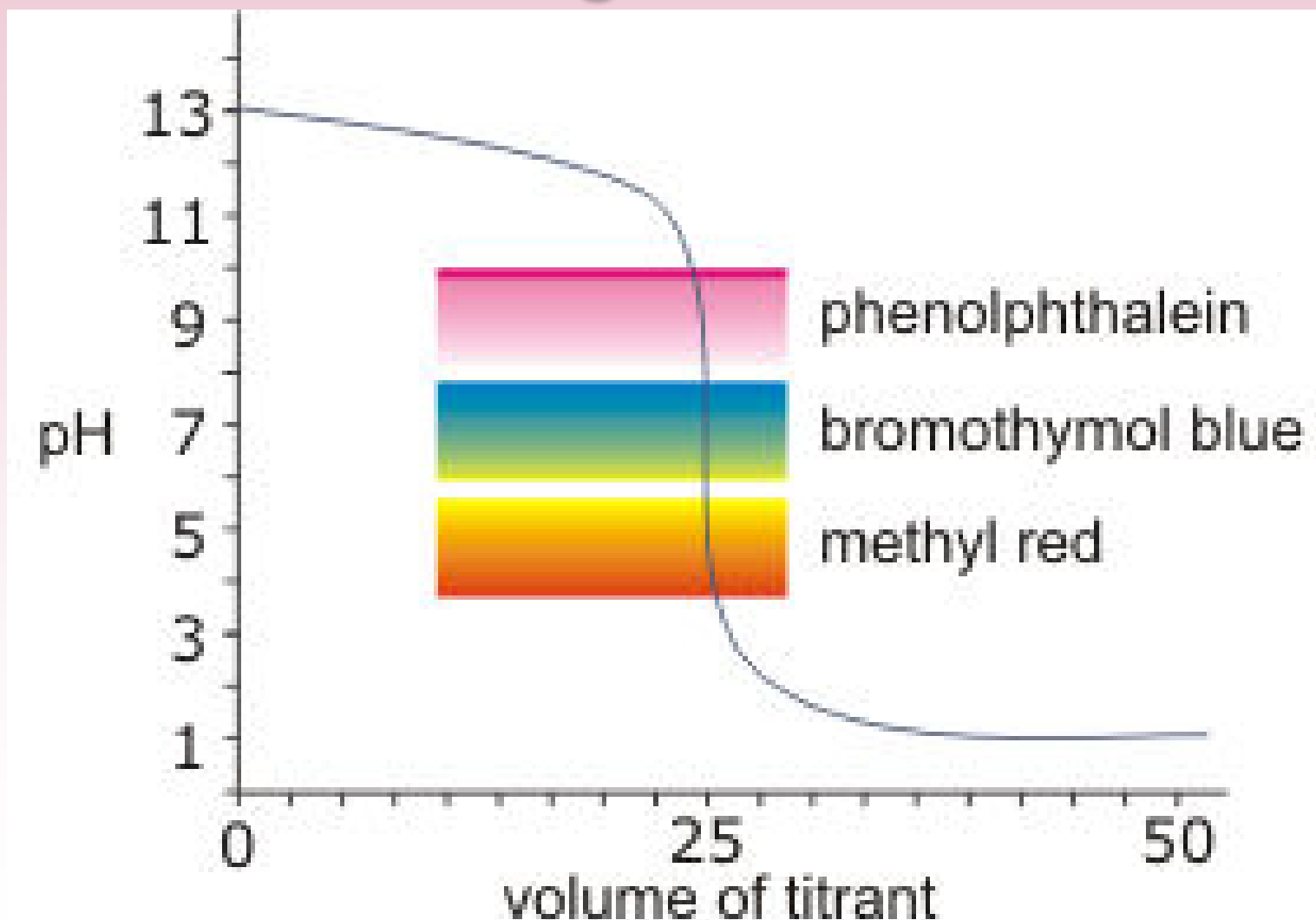
# TITRATIONS

## Titration Curve



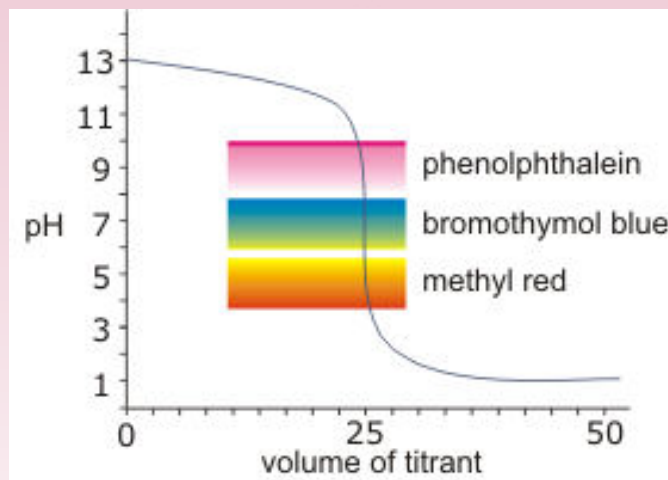
# TITRATIONS

## Indicator Ranges



# TITRATIONS

## Indicator Ranges



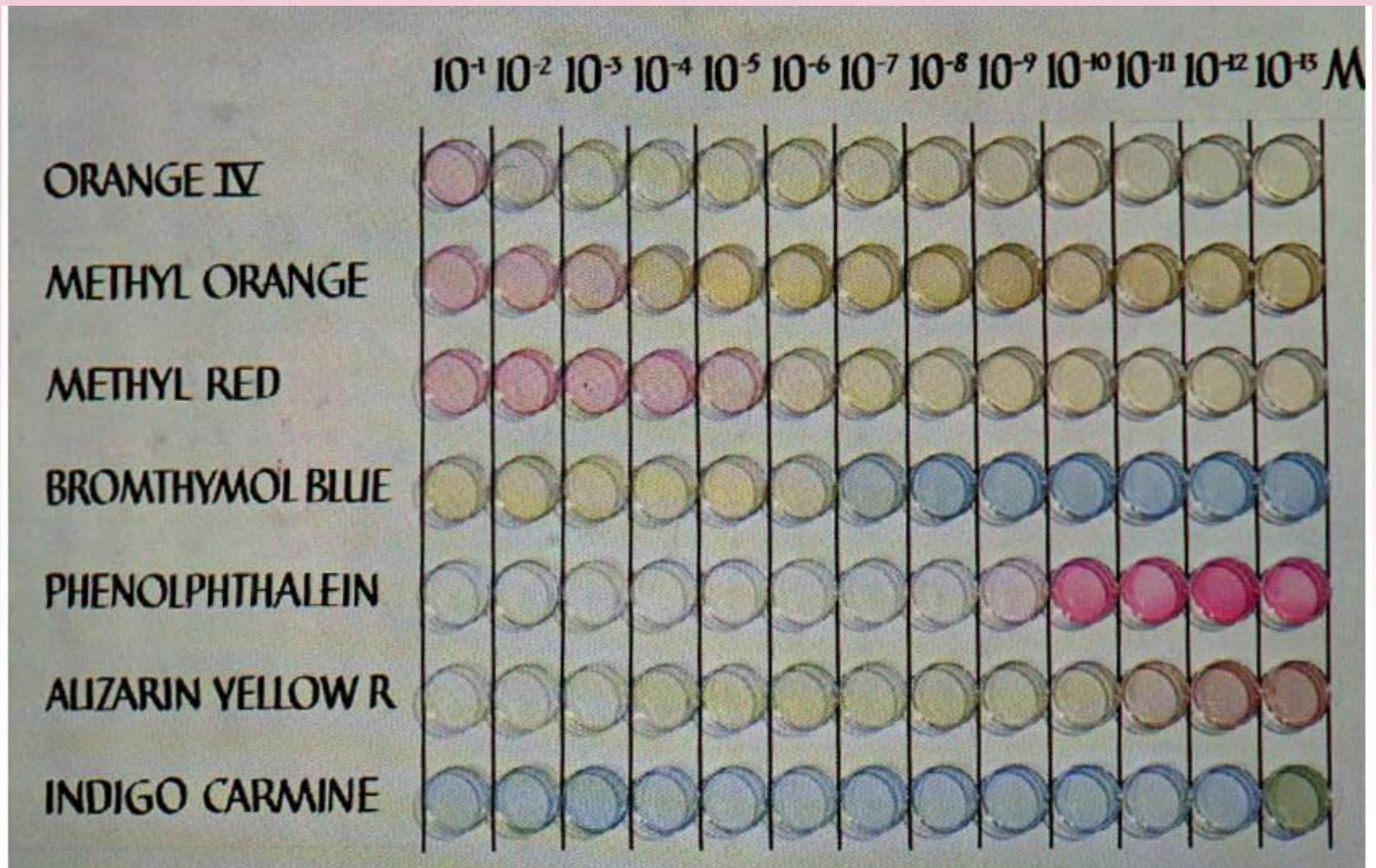
**Strong acid + Strong base titration:** resulting solution has a  $\text{pH} = 7$ , so bromothymol blue could be used (pH range is 6.0 – 7.6)

**Weak acid + Strong base titration:** resulting solution has a  $\text{pH} > 7$  so phenolphthalein could be used (pH range is 8.2 – 10.0)

**Strong acid + weak base titration:** resulting solution has a  $\text{pH} < 7$  so methyl orange could be used (pH range is 3.1 – 4.4)

# TITRATIONS

# Indicator Ranges

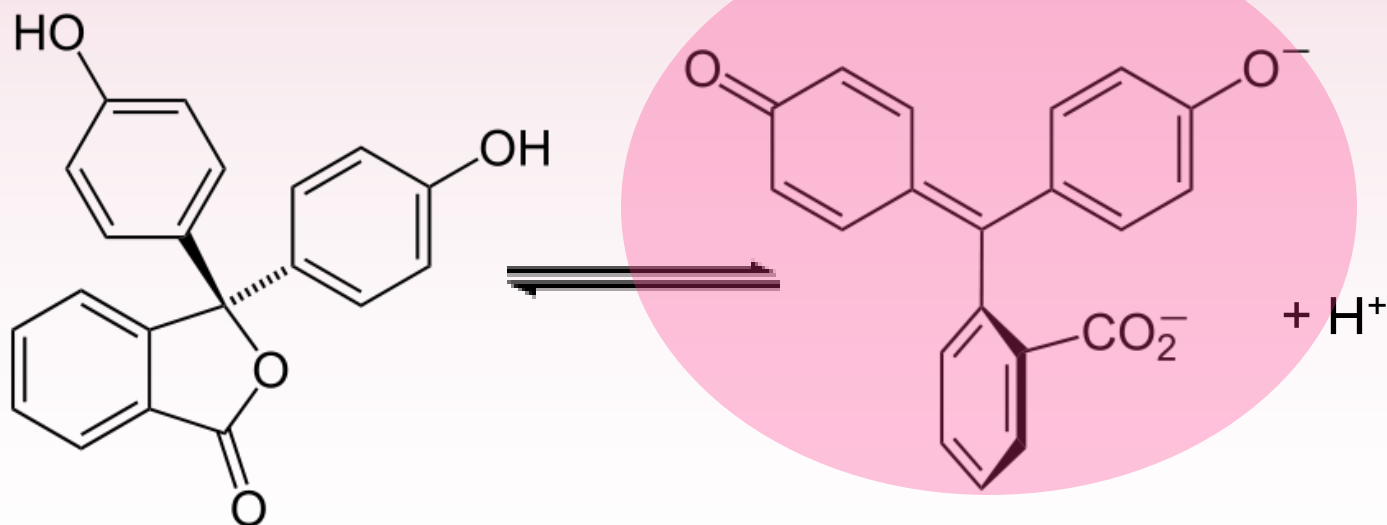


# TITRATIONS

## Indicators

How do indicators work?

Through equilibrium!

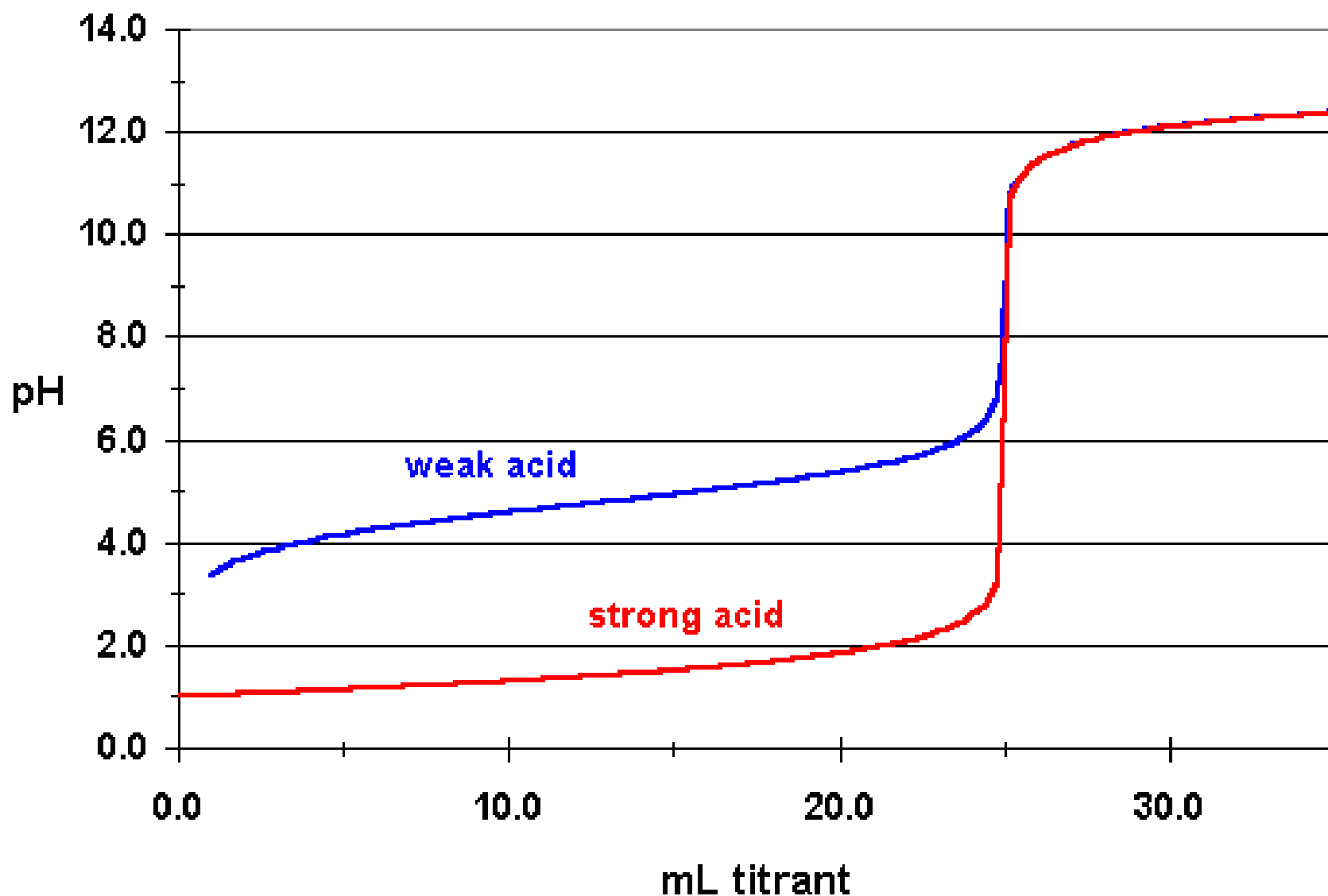


Phenolphthalein



# **STRONG-WEAK TITRATIONS & BUFFERS**

# Strong-Weak Titration Curves



# Buffers

Buffer solutions contain a mixture of an acid and its conjugate base or a base with its conjugate acid.

Due to the presence of the conjugate acid-base pair, the addition of more acid or base will not cause the pH to drastically change.

# Buffers

Buffers are important in biological systems where large changes in pH could be detrimental to the organism.

Almost all organic substances in our body act as a buffer.



Weak acid  
(CO<sub>2</sub> controlled by lungs)

Weak base  
(Controlled by kidneys)

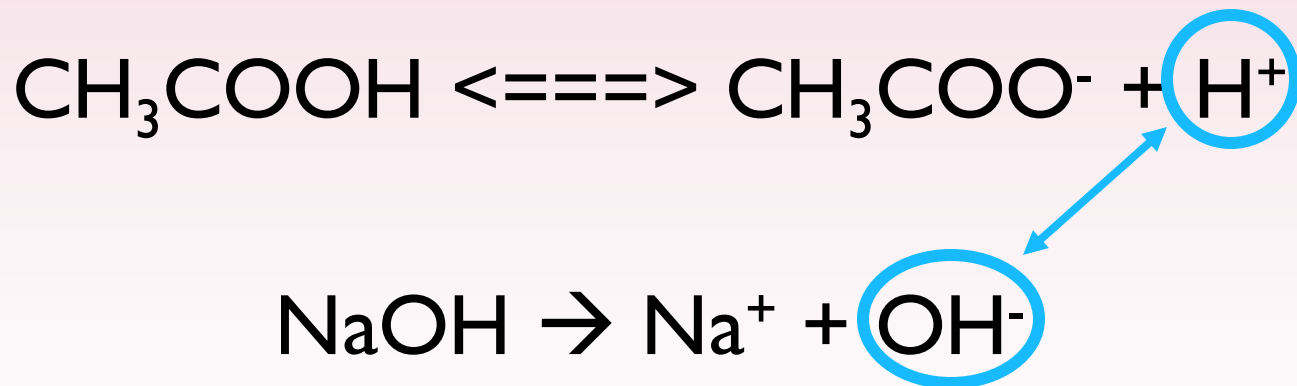
# Buffers

## Buffers in Food, Drink & Medicines

- Sodium citrate + citric acid : buffer in food that acts like a preservative
- Citric acid + calcium citrate: buffer that deters bacterial growth
- Aspartame: decomposition is pH dependent
- Medicines: coating reduces the risk of upset stomach

# Strong-Weak Titrations

What happens when you add a strong base to a weak acid?



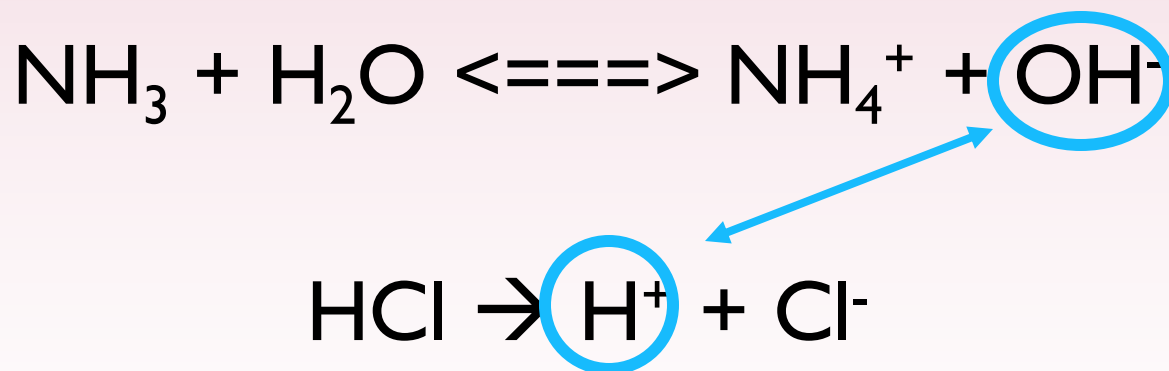
# Strong-Weak Titrations

Two-step process:

1. All  $\text{OH}^-$  ions from the strong base will react with  $\text{H}^+$  to produce  $\text{H}_2\text{O}$ .
2. Equilibrium is shifted to the .
3. pH is then calculated from the new equilibrium based on the remaining  $[\text{H}^+]$ .

# Strong Weak Titrations

What happens when you add a strong acid to a weak base?





# Strong-Weak Titrations

Two-step process:

1. All  $\text{H}^+$  ions from the strong acid will react with  $\text{OH}^-$  to produce  $\text{H}_2\text{O}$ .
2. Equilibrium is shifted to the .
3. pH is then calculated from the new equilibrium based on the remaining  $[\text{H}^+]$ .

# Buffers

Too much acid = **acidosis**



## Respiratory (Lungs) Acidosis:

### RESPIRATORY ACIDOSIS

- Hypoventilation → Hypoxia

- Rapid, Shallow Respirations

- ↓ BP with Vasodilation

- Dyspnea

- Headache

- Hyperkalemia

- Dysrhythmias (↑K)

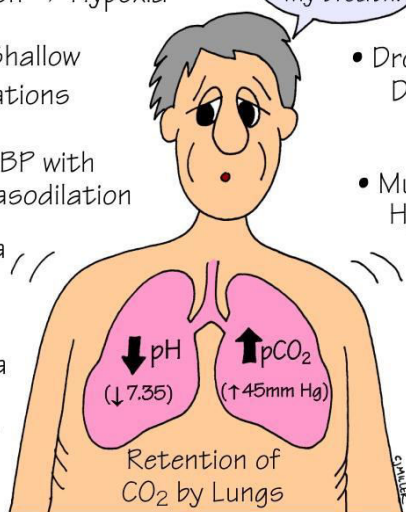
I can't catch my breath.

- Drowsiness, Dizziness, Disorientation

- Muscle Weakness, Hyperreflexia

- Causes:

↓ Respiratory Stimuli  
(Anesthesia, Drug Overdose)  
COPD  
Pneumonia  
Atelectasis



## Metabolic (Kidneys) Acidosis:

### METABOLIC ACIDOSIS

- Headache

- Decreased BP

- Hyperkalemia

- Muscle Twitching

- Warm, Flushed Skin (Vasodilation)

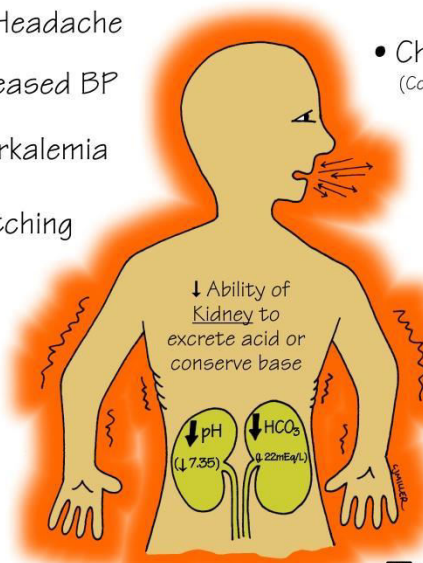
- Nausea, Vomiting, Diarrhea

- Changes in LOC (Confusion, ↑ drowsiness)

- Kussmaul Respirations (Compensatory Hyperventilation)

- Causes:

DKA  
Severe Diarrhea  
Renal Failure  
Shock



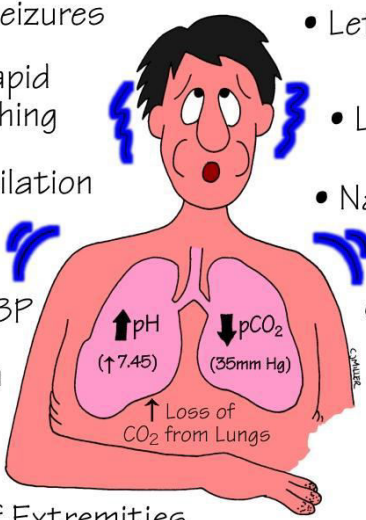
# Buffers

Too much base = **alkalosis**



## Respiratory (Lungs) Alkalosis:

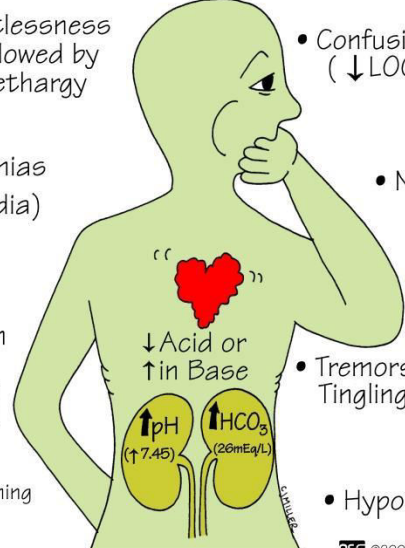
### RESPIRATORY ALKALOSIS



- Seizures
- Deep, Rapid Breathing
- Hyperventilation
- Tachycardia
- ↓ or Normal BP
- Hypokalemia
- Numbness & Tingling of Extremities
- Lethargy & Confusion
- Light Headedness
- Nausea, Vomiting
- Causes:
  - Hyperventilation (Anxiety, PE, Fear)
  - Mechanical Ventilation

## Metabolic (Kidneys) Alkalosis:

### METABOLIC ALKALOSIS



- Restlessness Followed by Lethargy
- Dysrhythmias (Tachycardia)
- Compensatory Hypoventilation
- Causes:
  - Severe Vomiting
  - Excessive GI Suctioning
  - Diuretics
  - Excessive  $\text{NaHCO}_3$
- Confusion (↓ LOC, Dizzy, Irritable)
- Nausea, Vomiting, Diarrhea
- Tremors, Muscle Cramps, Tingling of Fingers & Toes
- Hypokalemia

# Buffer Equations

The following can be used to determine ion concentrations in buffers:

## Acid Buffer:

$$[\text{H}^+] = K_a \times \frac{[\text{HA}]}{[\text{A}^-]}$$

HA = acid

A<sup>-</sup> = conjugate base

## Base Buffer:

$$[\text{OH}^-] = K_b \times \frac{[\text{B}]}{[\text{HB}^+]}$$

B = base

HB<sup>+</sup> = conjugate acid

# Buffer Equations

Alternatively, you can use moles instead of concentration to get the same answer:

## Acid Buffer:

$$[\text{H}^+] = K_a \times \frac{\text{moles of HA}}{\text{moles of A}^-}$$

HA = acid

A<sup>-</sup> = conjugate base

## Base Buffer:

$$[\text{OH}^-] = K_b \times \frac{\text{moles of B}}{\text{moles of HB}^+}$$

B = base

HB<sup>+</sup> = conjugate acid

# Buffer Equations

A 1.00 L sample of an aqueous solution contains 0.200 mol of acetic acid and 0.100 mol of acetate. Calculate:

- a) The pH of the solution
- b) The pH of the solution after adding 1.00 mL of 12.0 M HCl

## Buffer Equations

A 1.00 L sample of an aqueous solution contains 0.200 mol of acetic acid and 0.100 mol of acetate. Calculate:

- The pH of the solution
- The pH of the solution after adding 1.00 mL of 12.0 M HCl



$$[\text{H}^+] = K_a \times \frac{[\text{moles HA}]}{[\text{moles A}^-]}$$

$$[\text{H}^+] = (1.8 \times 10^{-5}) \times \frac{(0.200 \text{ mol})}{(0.100 \text{ mol})}$$

$$[\text{H}^+] = 0.000036 \text{ mol/L}$$

$$\text{pH} = -\log [\text{H}^+] \text{ } 0.000036 \text{ mol/L}$$

$$\text{pH} = -\log (0.000036 \text{ mol/L})$$

$$\text{pH} = 4.44$$

$$\therefore \text{pH} = 4.44$$

## Buffer Equations

A 1.00 L sample of an aqueous solution contains 0.200 mol of acetic acid and 0.100 mol of acetate. Calculate:

- The pH of the solution
- The pH of the solution after adding 1.00 mL of 12.0 M HCl

b) moles HCl:  $n = C \times V$

$$n = (12 \text{ M})(0.001 \text{ L})$$

$$n = 0.012 \text{ mol}$$

Assume this produces 0.012 mol of acetic acid and uses up 0.012 mol of acetate

moles acetic acid:  $0.200 + 0.012 = 0.212 \text{ mol}$

moles acetate:  $0.100 - 0.012 = 0.088 \text{ mol}$

$$[\text{H}^+] = K_a \times \frac{\text{mols HC}_2\text{H}_3\text{O}_2}{\text{mols C}_2\text{H}_3\text{O}_2^-}$$

$$[\text{H}^+] = (1.8 \times 10^{-5}) \times \frac{(0.212 \text{ mol})}{(0.088 \text{ mol})}$$

$$[\text{H}^+] = 4.3363 \times 10^{-5}$$

$$\text{pH} = -\log [\text{H}^+]$$

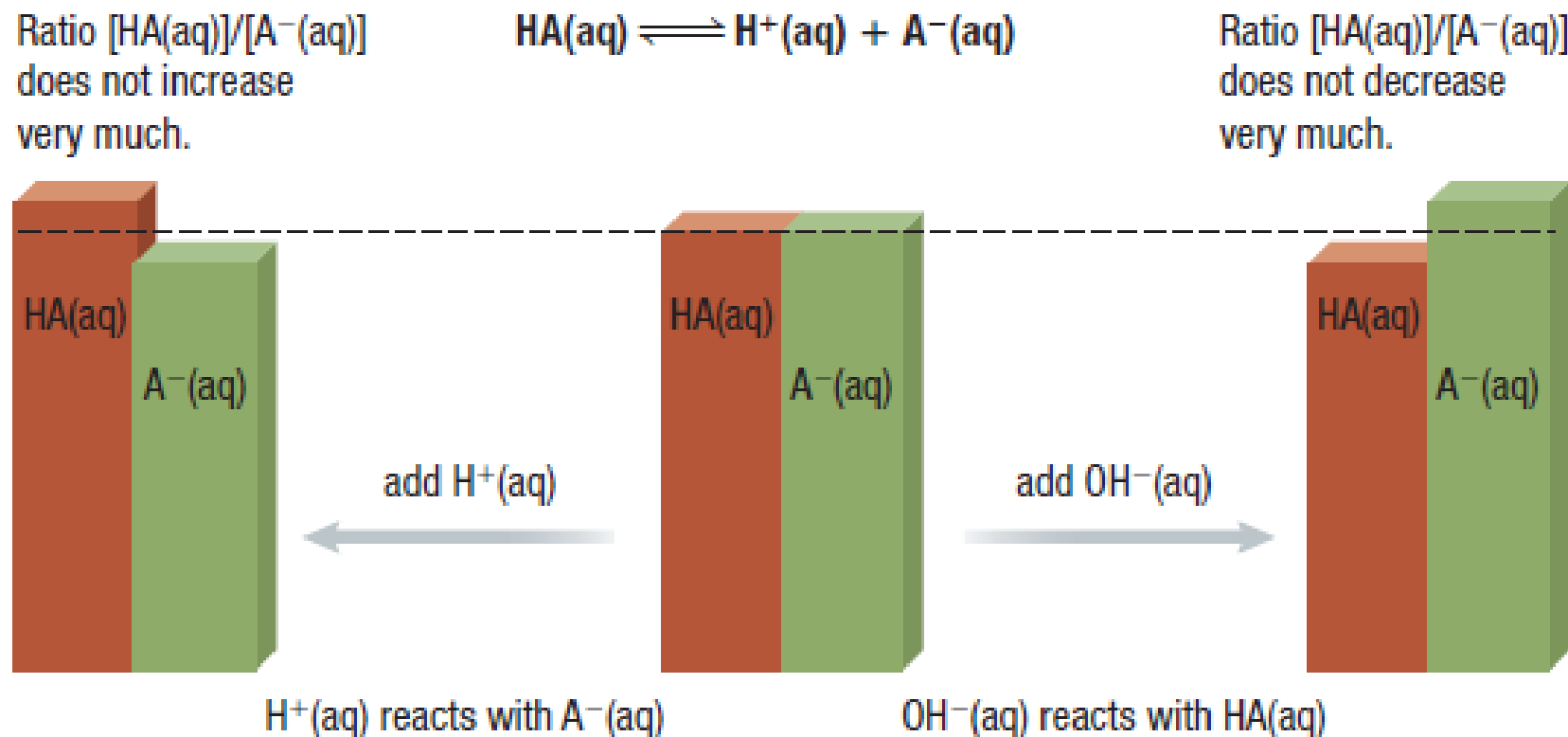
$$\text{pH} = -\log (4.3363 \times 10^{-5})$$

$$\text{pH} = 4.36$$

$$\therefore \text{pH} = 4.36$$



# The Effect of Adding a Strong Acid or Base to a Buffer

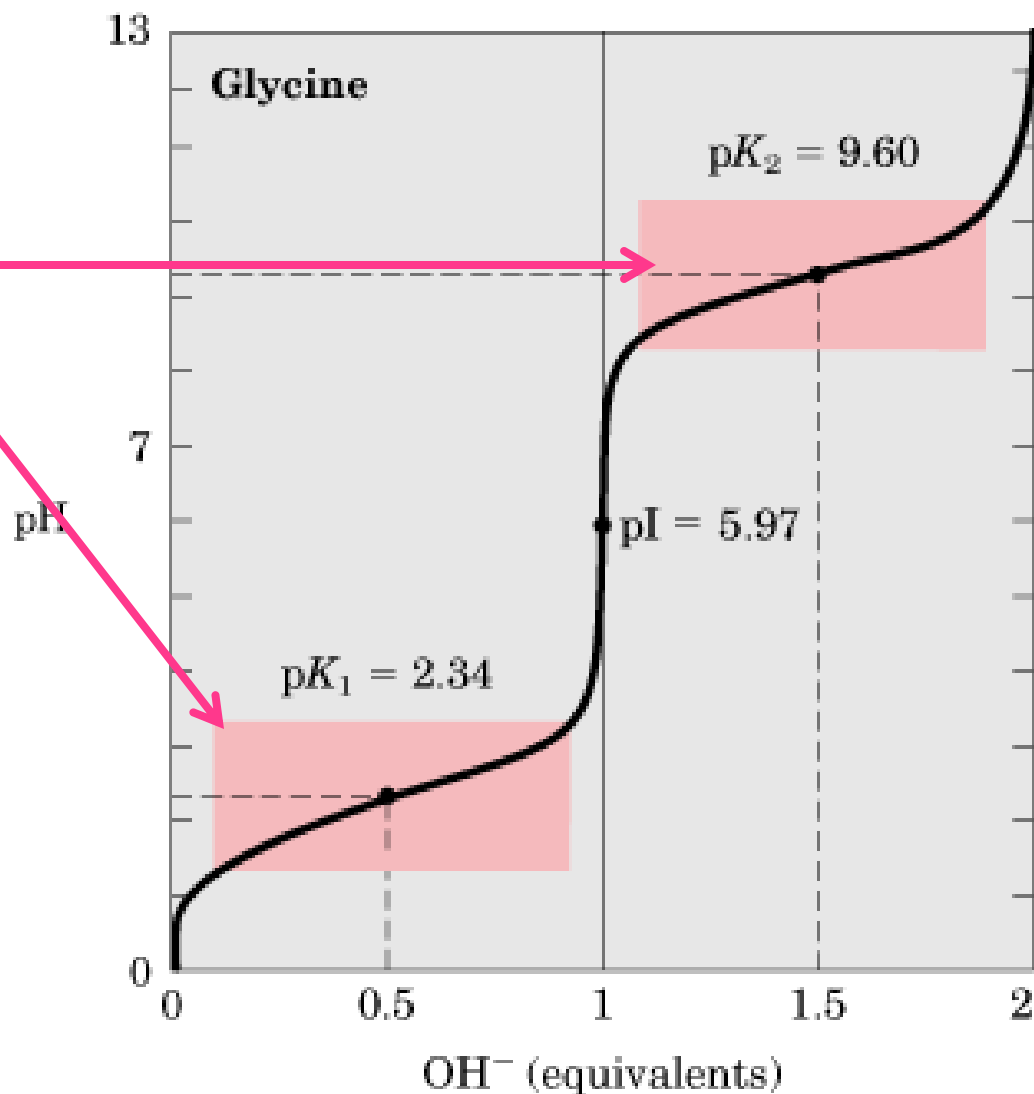
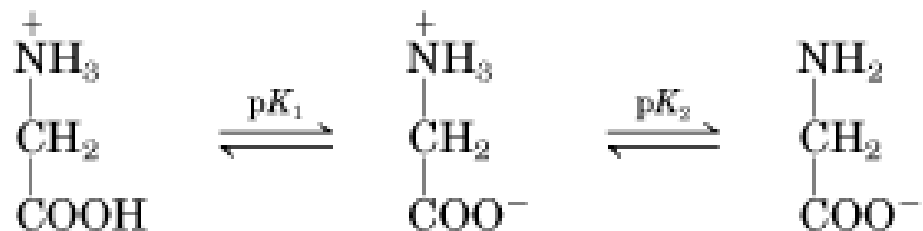


**Figure 7** The effect of adding a strong acid or base to a buffer system

# Buffers

Notice the buffer prevents the pH from rising too quickly at these two ranges

*(slope of the curve is decreased at these points)*



# Buffers

Also notice that the  $pK_a$  of the buffer matches the pH that the buffer works best in.

This is because

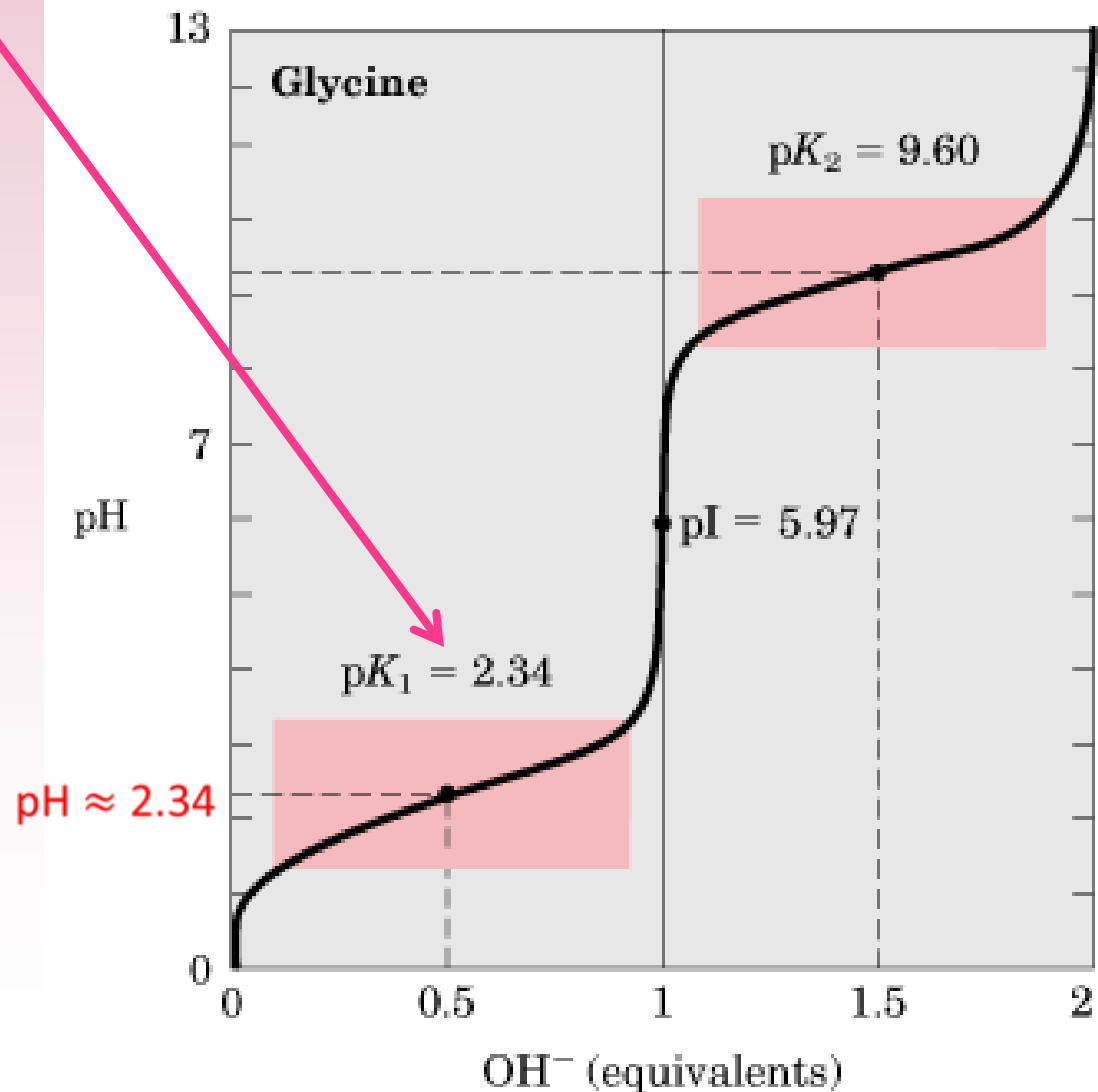
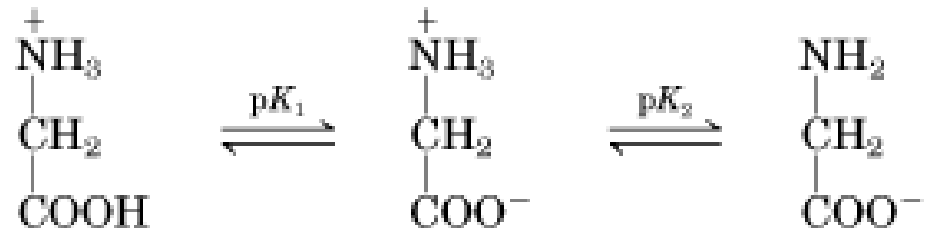
$$pH \approx pK_a + \log \frac{[Base]}{[Acid]}$$

and when the concentration of base and acid are equal (i.e. in a buffer system), it becomes

$$pH \approx pK_a + \log[1]$$

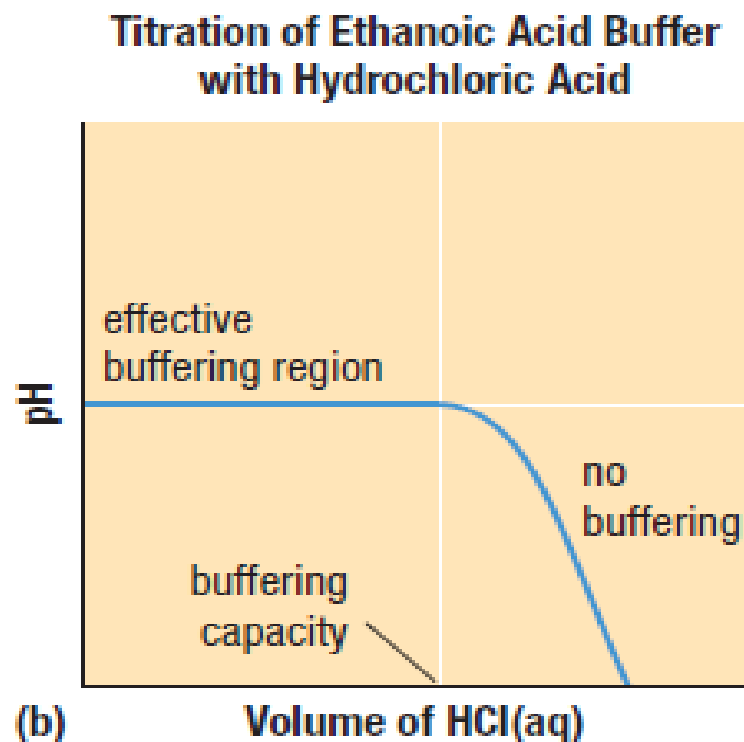
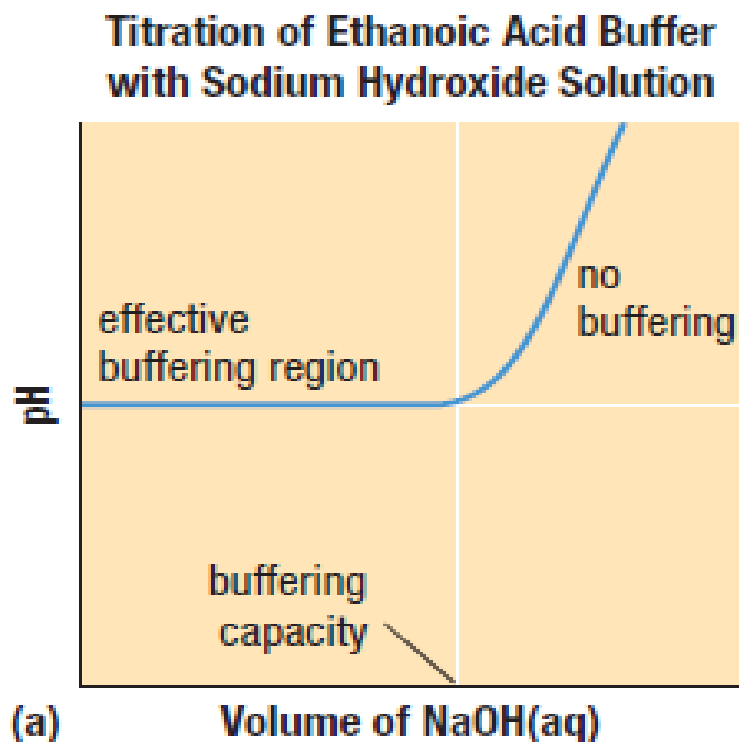
$$pH \approx pK_a + 0$$

$$pH \approx pK_a$$



# The Capacity of a Buffer

- The amount of added  $\text{H}_3\text{O}^+$  or  $\text{OH}^-$  that a buffer can absorb without a significant change in pH



**Figure 6** (a) Ethanoic acid buffer with a strong base added (b) Ethanoic acid buffer with a strong acid added. The pH changes quickly once all of the available buffer is depleted.

# The Capacity of a Buffer

- To calculate the buffer region, find the equivalence point volume and divide that by 2.

