thymol blue: red: pH 1-3; yellow: pH 3-8; blue: 8-14

Buffers Exploration

$K_a(HC_2H_3O_2) = 1.8E\text{-}5$

$\Rightarrow pK_a = -\log(1.8E\text{-}5) = 4.74$

Procedure (Teacher Demo):

1. Obtain two beakers] 50mL, using ~20 mL sol'n
2. Add water to one and the 0.10 M $HC_2H_3O_2/C_2H_3O_2^-$ buffer system to the other
3. Add thymol blue indicator to each. (2 drops)
4. Add 0.10 M HCl dropwise to the water.
   a. Students: Predict how many drops of acid it will take to change the color of the water solution
5. Add 0.10 M HCl dropwise to the buffer.
   a. Students: Predict how many drops of acid it will take to change the color of the buffer solution
6. Repeat Steps 1-5 with the same solutions, but adding 0.10 M NaOH dropwise

Data Table: water color = yellow | 1:1 buffer color = yellow

Solution	# of drops predicted to change color	# of drops actually to change color	Relevant Reaction
Water + HCl		5-10	$H^+_{(aq)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)}$
Buffer + HCl		50+	$H^+_{(aq)} + C_2H_3O_2^-{}_{(aq)} \rightarrow HC_2H_3O_{2(aq)}$
Water + NaOH		1	$OH^-_{(aq)} + H_2O_{(l)} \rightleftharpoons H_2O_{(l)} + OH^-_{(aq)}$
Buffer + NaOH		50+	$OH^-_{(aq)} + HC_2H_3O_{2(aq)} \rightarrow H_2O_{(l)} + C_2H_3O_2^-{}_{(aq)}$

$HC_2H_3O_{2(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} +$

Analysis:

1. Describe how a buffer system is effective at maintaining a constant pH when strong acid/base is added (use relevant chemical reactions as part of your explanation).

A buffer contains both a weak acid + its conjugate base, so if a strong acid is added, the conjugate base will neutralize the acid, maintaining the pH. And if a strong base is added, the weak acid will neutralize it.

Added SA: $H^+_{(aq)} + C_2H_3O_2^-{}_{(aq)} \rightarrow HC_2H_3O_{2(aq)}$

Added SB: $OH^-_{(aq)} + HC_2H_3O_2 \rightarrow H_2O_{(l)} + C_2H_3O_2^-{}_{(aq)}$

2. Describe buffer capacity. (What does it mean to exceed the buffer capacity? How can we increase the buffer capacity?)

↑ how much weak acid/conjugate base are present in the buffer + able to neutralize added base/acid

→ Exceeding the capacity means adding more strong base than the amount of acid present in the buffer (or vice versa, adding more strong acid than base present).

→ To increase buffer capacity, add more of the weak acid and/or conjugate base to your buffer system!

3. The buffer is made from equal volumes 0.10 M acetic acid and 0.10 M sodium acetate. Given this, the $HC_2H_3O_2/C_2H_3O_2^-$ ratio is equal to 1. What color was the solution at this point in time?

$$\frac{HC_2H_3O_2}{C_2H_3O_2^-} = 1 \Rightarrow pH = pK_a = -\log(1.8E\text{-}5) = 4.74$$

Color = yellow

4. When strong acid is added to the buffer, is the $HC_2H_3O_2/C_2H_3O_2^-$ ratio greater than, less than, or equal to 1? What color is the solution? → color = red

pH < pKa

$\frac{HC_2H_3O_2}{C_2H_3O_2^-} > 1$, b/c $C_2H_3O_{2(aq)}^-$ neutralized the strong acid, producing more $HC_2H_3O_2$ and using up some $C_2H_3O_2^-$.

5. When strong base is added to the buffer, is the $HC_2H_3O_2/C_2H_3O_2^-$ ratio greater than, less than, or equal to 1? What color is the solution? → color = blue

pH > pKa

$\frac{HC_2H_3O_2}{C_2H_3O_2^-} < 1$, b/c $HC_2H_3O_{2(aq)}$ neutralized the strong base, producing more $C_2H_3O_2^-$ and using up some $HC_2H_3O_2$.

6. Given a solution of only acetic acid ($K_a = 1.8 \times 10^{-5}$), is the $HC_2H_3O_2/C_2H_3O_2^-$ ratio greater than, less than, or equal to 1? What color is the solution? → color = red

$\frac{HC_2H_3O_2}{C_2H_3O_2^-} >> 1$, b/c $HC_2H_3O_2$ is a weak acid and thus only a small % dissociates in sol'n (b/c $K_a << 1$)