POST-LAB/EQUILIBRIUM/ANSWER KEY

1. The equivalence point is the point in a titration when enough titrant has been added to react completely with the substance being titrated.

2a. 
\[ K_a = \frac{[H^+][CH_3COO^-]}{[CH_3COOH]} = \frac{x(x)}{0.100-x} = \frac{x^2}{0.100} = 1.8 \times 10^5 \quad x <= 0.100 \]

\[ x = 1.3 \times 10^{-3} \quad [H^+] = 1.3 \times 10^{-3} \quad pH = -\log(1.3 \times 10^{-3}) = 2.89 \]

2b. 
Moles NaOH to react: 20.0 mL(0.100 mol/1000mL) = 2.00 x 10^{-3} mol NaOH
Moles CH_3COOH before reaction: 100.0 mL(0.100 mol/1000 mL) = 0.100 mol CH_3COOH

\[ K_a = \frac{[H^+][CH_3COO^-]}{[CH_3COOH]} = \frac{x(2.00 \times 10^{-3}/0.120 \text{ L})}{((0.100-2.00 \times 10^{-3})/0.120 \text{ L})} = 1.8 \times 10^5 \]

\[ x = 7.2 \times 10^{-5} \text{ M} \quad pH = -\log(7.2 \times 10^{-5}) = 4.14 \]

2c. 
40.0 mL (0.100 mol/1000mL) = 4.00 x 10^{-3} mol NaOH 
0.010 mol CH_3COOH

\[ K_a = \frac{x(4.00 \times 10^{-3}/0.140 \text{ L})}{((0.010-4.00 \times 10^{-3})/0.140 \text{ L})} = 1.8 \times 10^5 \]

\[ x = 2.7 \times 10^{-5} \text{ M} \quad pH = -\log(2.7 \times 10^{-5}) = 4.57 \]

2d. 
50.0 mL(0.100 mol/1000mL) = 5.00 x 10^{-3} mol NaOH 
0.010 mol CH_3COOH

\[ K_a = \frac{x(5.00 \times 10^{-3}/0.150 \text{ L})}{((0.010-5.00 \times 10^{-3})/0.150 \text{ L})} = 1.8 \times 10^5 \]

\[ x = 1.8 \times 10^{-5} \text{ M} \quad pH = 4.74 \]

2e. 
60.0 mL(0.100 mol/1000mL) = 6.00 x 10^{-3} mol NaOH 
0.010 mol CH_3COOH

\[ K_a = \frac{x(6.00 \times 10^{-3}/0.160 \text{ L})}{((0.010-6.00 \times 10^{-3})/0.160 \text{ L})} = 1.8 \times 10^5 \]

\[ x = 1.2 \times 10^{-5} \text{ M} \quad pH = 4.92 \]
2f. 
\[ K_a = \frac{(x)(9.90 \times 10^{-3}/0.199 \text{ L})}{((0.010-9.90 \times 10^{-3})/0.199 \text{ L})} = 1.8 \times 10^{-5} \]

\[ x = 1.8 \times 10^{-7} \text{ M} \quad \text{pH} = 6.74 \]

2g. 
**Equivalence point**

\[ K_b =\frac{K_w}{K_a} = 1.0 \times 10^{-14}/1.8 \times 10^{-5} = 5.6 \times 10^{-10} = [OH^-][CH_3COOH]/[CH_3COO^-] \]

\[ \frac{(x^2)}{(0.010 \text{ M} - x)/0.01} = 5.6 \times 10^{-10} \]

\[ x = 2.4 \times 10^{-6} \quad \text{pH} = 14.00 - 5.63 = 8.37 \quad \text{pOH} = -\log(2.4 \times 10^{-6}) = 5.63 \]

2h. 
101.0 mL (0.100 mol/1000 mL) = 0.0101 mol NaOH

OH\(^-\) from H\(_2\)O will be negligible

0.0101 mol - 0.0100 mol = 0.0001 mol OH\(^-\) excess

\[ [OH^-] = 0.0001 \text{ mol/0.201 L} = 5.0 \times 10^{-4} \text{ M} \]

\[ pOH = 3.3 \quad \text{pH} = 10.7 \]

2i. 
110.0 (0.100 mol/1.0 L) = 0.011 mol NaOH

Again, OH\(^-\) from H\(_2\)O will be negligible

0.0110 - 0.0100 mol = 0.001 mol OH\(^-\) excess

\[ [OH^-] = 0.001 \text{ mol/0.210 L} = 4.8 \times 10^{-3} \]

\[ pOH = 2.32 \quad \text{pH} = 11.7 \]
4. \( \text{pH} = 8.37 \)

5. \( \text{pH} = 4.57 \)

6. It changes color to let you know you are near the equivalence point.

7. They are weak acids or bases that change slightly and this alters their optical properties.

8. The pH of the equivalence point should fall in the range for the color change of an indicator.

9. The endpoint is where the indicator changes color. The equivalence point is where equal amounts of acid and base have been added. (With proper selection of indicators the error between the two will be small.)