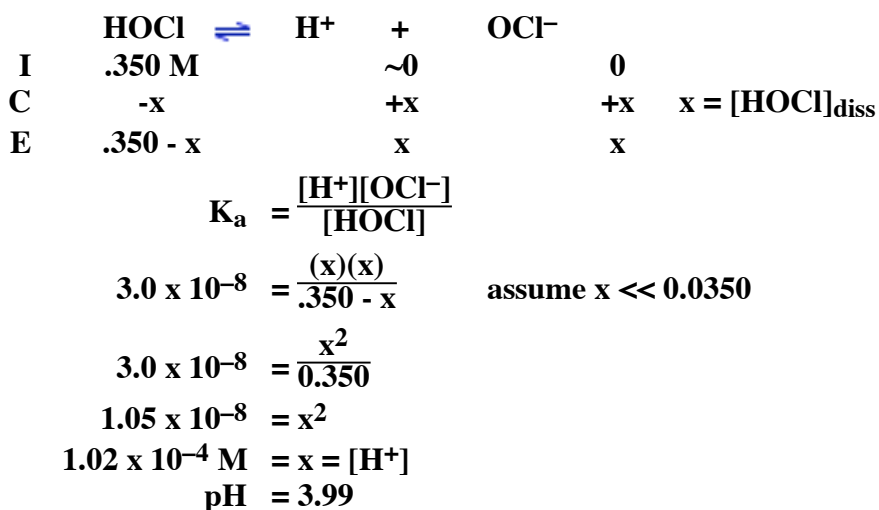


1. Qualitatively, describe how the pH of a solution of a weak acid changes when a solution of strong base is added to it.

The pH of a solution of a weak acid will increase when a solution containing a strong base is added to it.

- a. A titration is performed by adding 0.200 M NaOH to 24 mL of 0.350 M HOCl.

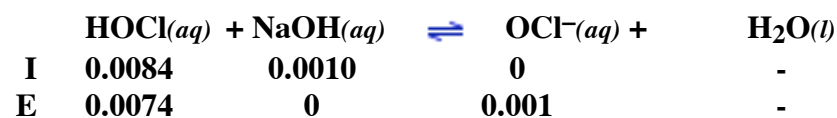
i) Calculate the pH before addition of any NaOH.



ii) Calculate the pH after the addition of 5.0 mL of the base.
Add 5.0 mL of NaOH

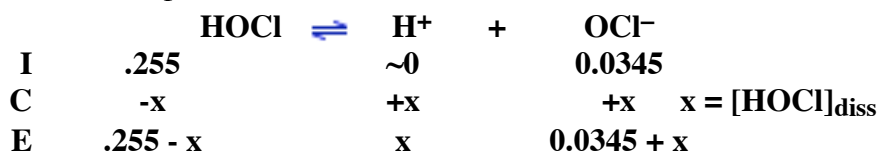
$$5.0 \text{ mL} \left(\frac{1 \text{ L}}{1000 \text{ mL}} \right) \left(\frac{0.200 \text{ mol}}{1 \text{ L}} \right) = 0.0010 \text{ mol NaOH}$$

$$24.0 \text{ mL} \left(\frac{1 \text{ L}}{1000 \text{ mL}} \right) \left(\frac{0.350 \text{ mol}}{1 \text{ L}} \right) = 0.0084 \text{ mol HCl}$$



$$[\text{HOCl}] = \frac{0.0074 \text{ mol}}{0.029 \text{ L}} = 0.255 \text{ M} \quad [\text{OCl}^-] = \frac{0.001 \text{ mol}}{0.029 \text{ L}} = 0.0345 \text{ M}$$

ii) Calculate the pH after the addition of 5.0 mL of the base. (Continued)



$$K_a = \frac{[\text{H}^+][\text{OCl}^-]}{[\text{HOCl}]}$$

$$3.0 \times 10^{-8} = \frac{(x)(0.0345 + x)}{0.255 - x} \quad \text{assume } x \ll 0.0345$$

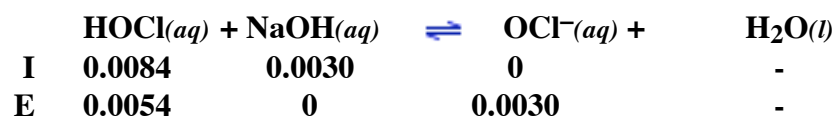
$$3.0 \times 10^{-8} = \frac{(x)(0.0345)}{0.255}$$

$$2.22 \times 10^{-7} = x = [\text{H}^+] \quad \text{pH} = 6.65$$

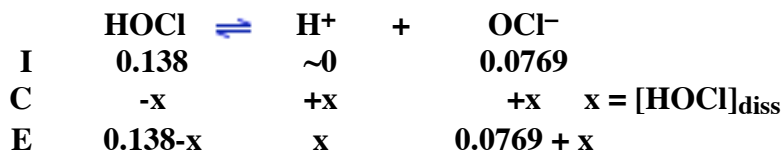
Calculate the pH after the addition of 15.0 mL of the base.

Add 15.0 mL of NaOH

$$15.0 \text{ mL} \left(\frac{1 \text{ L}}{1000 \text{ mL}} \right) \left(\frac{0.200 \text{ mol}}{1 \text{ L}} \right) = 0.0030 \text{ mol NaOH}$$



$$[\text{HOCl}] = \frac{.0054 \text{ mol}}{0.039 \text{ L}} = 0.138 \text{ M} \quad [\text{OCl}^-] = \frac{.003 \text{ mol}}{0.039 \text{ L}} = 0.0769 \text{ M}$$



$$K_a = \frac{[\text{H}^+][\text{OCl}^-]}{[\text{HOCl}]}$$

$$3.0 \times 10^{-8} = \frac{(x)(0.0769 + x)}{0.138 - x} \quad \text{assume } x \ll 0.0769$$

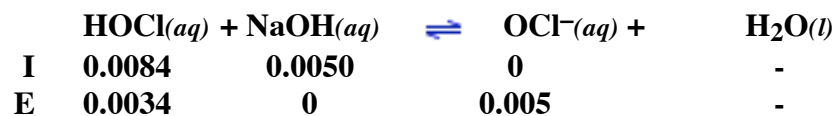
$$3.0 \times 10^{-8} = \frac{(x)(0.0769)}{0.138}$$

$$5.38 \times 10^{-8} = x = [\text{H}^+] \quad \text{pH} = 7.27$$

Calculate the pH after the addition of 25.0 mL of the base.

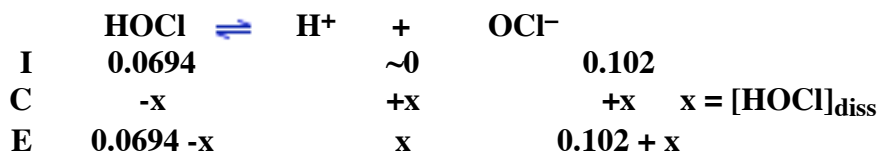
Add 25.0 mL of NaOH

$$25.0 \text{ mL} \left(\frac{1 \text{ L}}{1000 \text{ mL}} \right) \left(\frac{0.200 \text{ mol}}{1 \text{ L}} \right) = 0.0050 \text{ mol NaOH}$$



$$[\text{HOCl}] = \frac{.0034 \text{ mol}}{0.049 \text{ L}} = 0.0694 \text{ M} \quad [\text{OCl}^-] = \frac{.005 \text{ mol}}{0.049 \text{ L}} = 0.102 \text{ M}$$

Calculate the pH after the addition of 25.0 mL of the base. (Continued)



$$K_a = \frac{[\text{H}^+][\text{OCl}^-]}{[\text{HOCl}]}$$

$$3.0 \times 10^{-8} = \frac{(x)(0.102 + x)}{0.0694 - x} \quad \text{assume } x \ll 0.0694$$

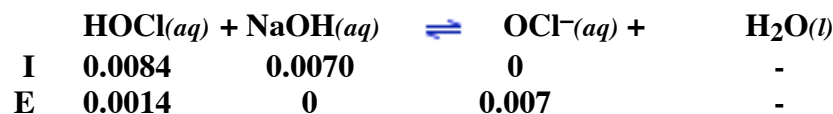
$$3.0 \times 10^{-8} = \frac{(x)(0.102)}{0.0694}$$

$$2.04 \times 10^{-8} = x = [\text{H}^+] \quad \text{pH} = 7.69$$

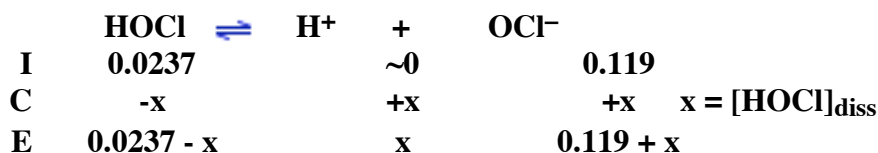
Calculate the pH after the addition of 35.0 mL of the base.

Add 35.0 mL of NaOH

$$35.0 \text{ mL} \left(\frac{1 \text{ L}}{1000 \text{ mL}} \right) \left(\frac{0.200 \text{ mol}}{1 \text{ L}} \right) = 0.0070 \text{ mol NaOH}$$



$$[\text{HOCl}] = \frac{.0014 \text{ mol}}{0.059 \text{ L}} = 0.0237 \text{ M} \quad [\text{OCl}^-] = \frac{.007 \text{ mol}}{0.059 \text{ L}} = 0.119 \text{ M}$$



$$K_a = \frac{[\text{H}^+][\text{OCl}^-]}{[\text{HOCl}]}$$

$$3.0 \times 10^{-8} = \frac{(x)(0.119 + x)}{0.0237 - x} \quad \text{assume } x \ll 0.0237$$

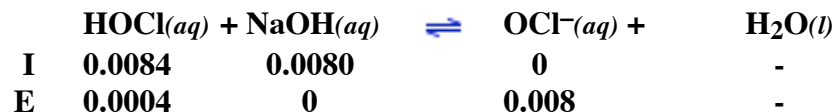
$$3.0 \times 10^{-8} = \frac{(x)(0.119)}{0.0237}$$

$$5.97 \times 10^{-9} = x = [\text{H}^+] \quad \text{pH} = 8.22$$

Calculate the pH after the addition of 40.0 mL of the base.

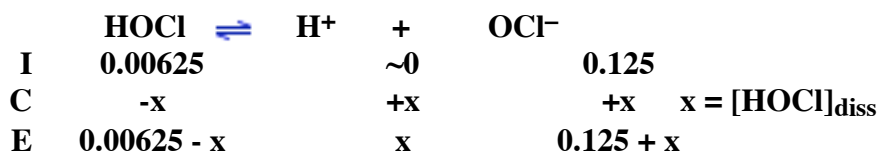
Add 40.0 mL of NaOH

$$40.0 \text{ mL} \left(\frac{1 \text{ L}}{1000 \text{ mL}} \right) \left(\frac{0.200 \text{ mol}}{1 \text{ L}} \right) = 0.0080 \text{ mol NaOH}$$



$$[\text{HOCl}] = \frac{.0004 \text{ mol}}{0.064 \text{ L}} = 0.00625 \text{ M} \qquad [\text{OCl}^-] = \frac{.008 \text{ mol}}{0.064 \text{ L}} = 0.125 \text{ M}$$

Calculate the pH after the addition of 40.0 mL of the base. (Continued)



$$K_a = \frac{[\text{H}^+][\text{OCl}^-]}{[\text{HOCl}]}$$

$$3.0 \times 10^{-8} = \frac{(x)(0.125 + x)}{0.00625 - x} \text{ assume } x \ll 0.00625$$

$$3.0 \times 10^{-8} = \frac{(x)(0.125)}{0.00625}$$

$$1.5 \times 10^{-9} = x = [\text{H}^+] \qquad \text{pH} = 8.82$$

iii) Calculate the volume of base needed to reach the equivalence point.

$$M_{\text{acid}}V_{\text{acid}} = M_{\text{base}}V_{\text{base}}$$

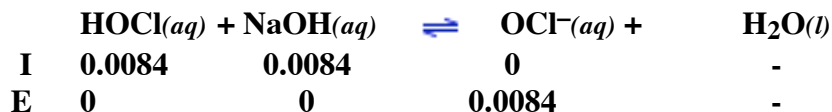
$$0.350 \text{ M} \cdot 24.0 \text{ mL} = 0.200 \text{ M} \cdot V_{\text{base}}$$

$$\frac{0.350 \text{ M} \cdot 24.0 \text{ mL}}{0.200 \text{ M}} = V_{\text{base}} = 42.0 \text{ mL}$$

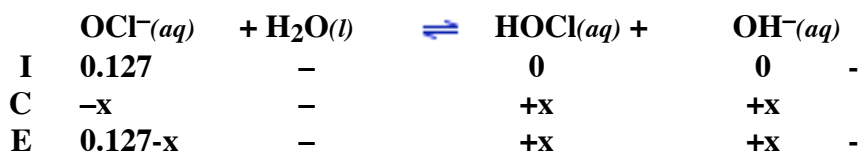
iv) What is the pH at the equivalence point?

Add 42.0 mL of NaOH

$$42.0 \text{ mL} \left(\frac{1 \text{ L}}{1000 \text{ mL}} \right) \left(\frac{0.200 \text{ mol}}{1 \text{ L}} \right) = 0.0084 \text{ mol NaOH}$$



$$[\text{OCl}^-] = \frac{0.0084 \text{ mol}}{0.066 \text{ L}} = 0.127 \text{ M}$$



$$K_b = \frac{K_w}{K_a} = \frac{1 \times 10^{-14}}{3.0 \times 10^{-8}} = \frac{[\text{OH}^-][\text{HOCl}]}{[\text{OCl}^-]}$$

$$3.33 \times 10^{-7} = \frac{(x)(x)}{0.127-x} \quad \text{assume } x \ll 0.127$$

$$3.33 \times 10^{-7} = \frac{(x^2)}{0.127}$$

$$2.06 \times 10^{-4} = x = [\text{OH}^-]$$

$$\text{pOH} = 3.69$$

$$\text{pH} = 10.31$$

v) Calculate the pH after adding 5.00 mL of NaOH past the equivalence point.

Add 47.0 mL of NaOH

$$47.0 \text{ mL} \left(\frac{1 \text{ L}}{1000 \text{ mL}} \right) \left(\frac{0.200 \text{ mol}}{1 \text{ L}} \right) = 0.0094 \text{ mol NaOH}$$



$$[\text{OCl}^-] = \frac{0.0084 \text{ mol}}{0.071 \text{ L}} = 0.118 \text{ M}$$

$$[\text{OH}^-] = \frac{0.0010 \text{ mol}}{0.071 \text{ L}} = 0.0141 \text{ M}$$



$$K_b = \frac{K_w}{K_a} = \frac{1 \times 10^{-14}}{3.0 \times 10^{-8}} = \frac{[\text{OH}^-][\text{HOCl}]}{[\text{OCl}^-]}$$

$$3.33 \times 10^{-7} = \frac{(.0141 + x)(x)}{.118 - x} \quad \text{assume } x \ll 0.0141$$

$$3.33 \times 10^{-7} = \frac{(.0141)(x)}{.118}$$

$$2.79 \times 10^{-6} = x$$

$$[\text{OH}^-] = 0.0141 + x = 0.0141 \text{ M}$$

$$\text{pOH} = 1.85 \quad \text{pH} = 12.15$$

6. Using the designated space below, draw the titration curve for each of the following cases. **See Appendix III for recommended demonstration, video, or computer resources.**
- 50.0 mL of 1.00 M HC₂H₃O₂ and 1.00 M NaOH
 - 50.0 mL of 0.0100 M HC₂H₃O₂ and 0.0100 M NaOH