Lecture 6

Titrations I

Titrations (p. 101)

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Acid and Base Titration Apparatus flask + buret

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3. Weak acid (like $HC_2H_3O_2$, $K_a = 1.8 \times 10^{-5}$) titrated by a strong base (like NaOH) – WA by SB

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4. Weak base (like $C_6H_5NH_2$, $K_b = 3.8 \times 10^{-10}$) by a strong acid (like HI) – WB by SA

Titration Definitions (p. 100)

- **Titrant** – substance in buret that is added in controlled amounts; always a strong acid or a strong base.

- **Neutralization reaction** – reaction between beaker contents and the titrant; always assumed to go to completion because a strong acid and/or strong base is reacted.

Titrant-stuff in the buret

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Example Neutralization Reactions

1. Strong acid (like HCl) titrated by a strong base (like KOH): $H^+ + OH^- \rightarrow H_2O$
2. Strong base [like $Ca(OH)_2$] titrated by a strong acid (like HNO_3): $OH^- + H^+ \rightarrow H_2O$
3. Weak acid (like $HC_2H_3O_2$, $K_a = 1.8 \times 10^{-5}$) titrated by a strong base (like NaOH):

   $HC_2H_3O_2 + OH^- \rightarrow C_2H_3O_2^- + H_2O$
4. Weak base (like $C_6H_5NH_2$, $K_b = 3.8 \times 10^{-10}$) by a strong acid (like HI):

   $C_6H_5NH_2 + H^+ \rightarrow C_6H_5NH_3^+$

More Definitions (p. 100)

- **Equivalence Point** – when enough titrant has been added to exactly neutralize (react with) all the acid or base present initially. At the equivalence point (assuming a 1:1 mol relationship in balanced equation):

  moles acid = moles base

Indicators mark the Equivalence Point

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More Definitions

To determine moles of solute, we multiply the molarity times the volume.

$$M \text{ x V} = \frac{\text{mol}}{\text{L}} \times \text{L} = \text{mol solute}$$

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$$M_A V_A = M_B V_B$$

100.0 mL of 0.500 *M* HF titrated by 1.00 *M* NaOH (p. 104)

What volume of NaOH is required to reach the equivalence point?

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$M_A V_A = M_B V_B$ (At equiv. point, mol HF = mol OH^- added)

$0.500\ M(0.1000\ L) = 1.00\ M(V_{NaOH})$

$V_{NaOH} = 0.0500\ L$

Working with mmols (p. 101)

Molarity can also be defined as mmol/mL:

molarity = *M* = mol/L = mmol/mL

$$M \times \mathrm{V} = \frac{\mathrm{mmol}}{\mathrm{mL}} \times \mathrm{mL} = \mathrm{mmol\ solute}$$

100.0 mL of 0.500 *M* HF titrated by 1.00 *M* NaOH (p. 104)

What volume of NaOH is required to reach the equivalence point?

$M_A V_A = M_B V_B$, 0.500 M(0.1000 L) = 1.00 M(V_{NaOH}),
V_{NaOH} = 0.0500 L

Using mmol/mL definition for molarity:

$M_A V_A = M_B V_B$, 0.500 M(100.0 mL) = 1.00 M(V_{NaOH}),
V_{NaOH} = 50.0 mL

Titration (pH) Curve – a plot of pH of solution vs. volume of titrant added

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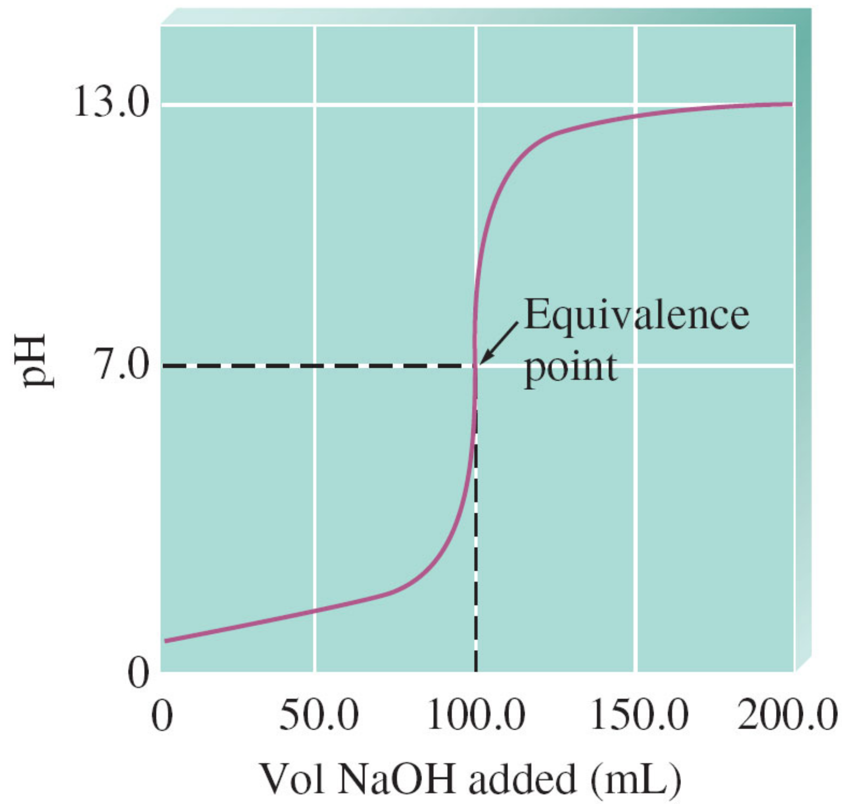
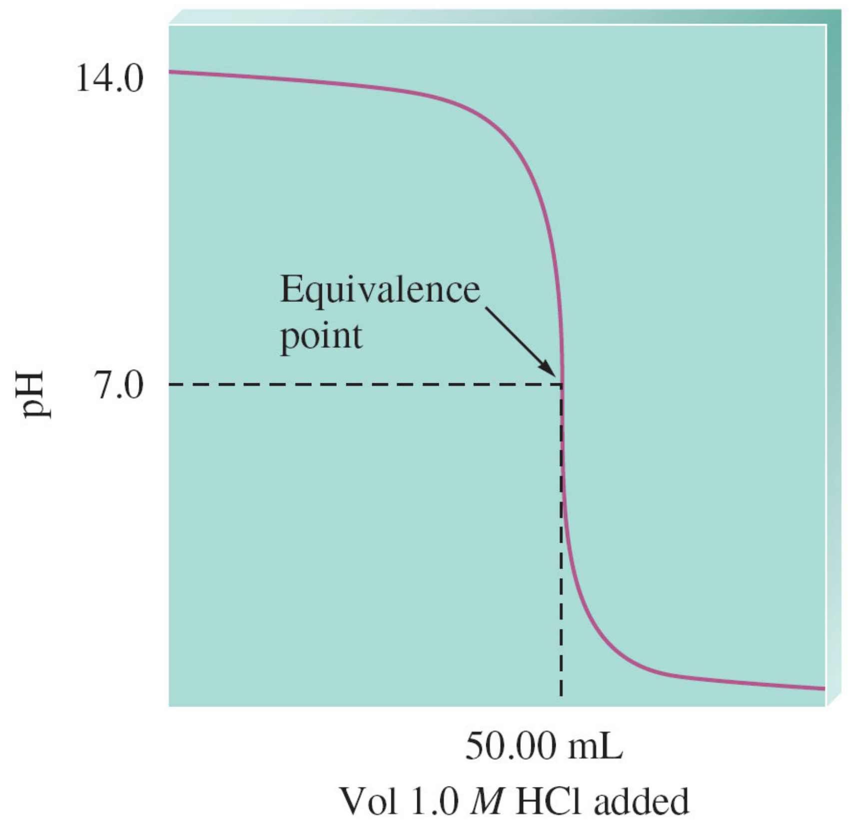
pH curve for a strong acid titrated by strong base

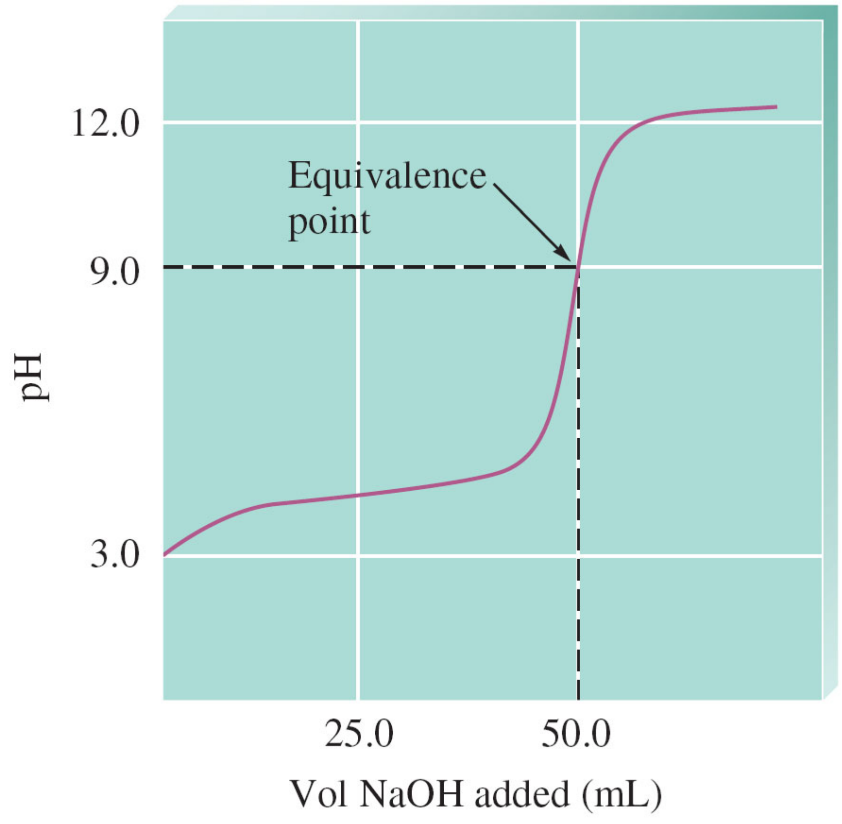


pH curve for a strong base titrated by strong acid



More Titration (pH) Curves

pH curve for a weak acid titrated by strong base



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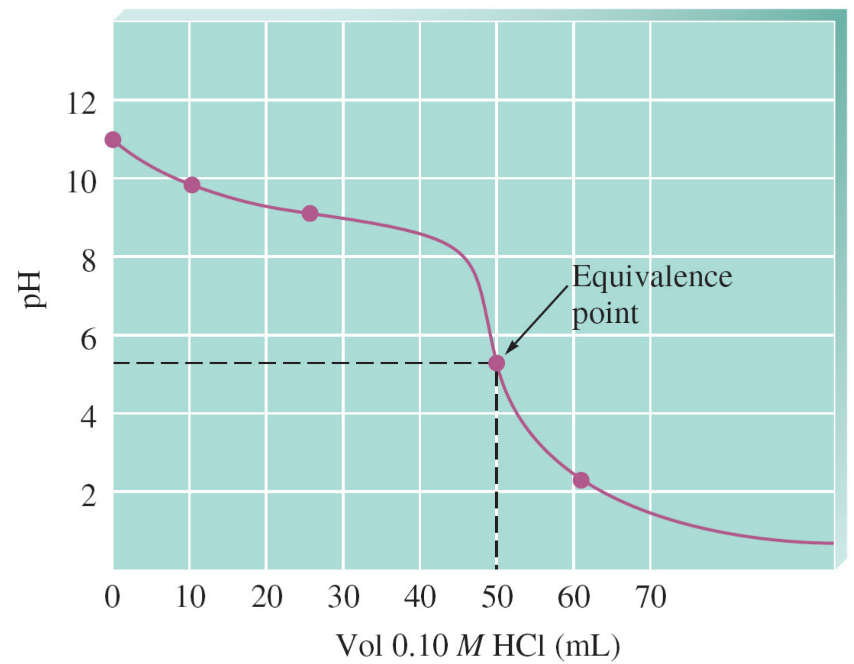


Clicker Question

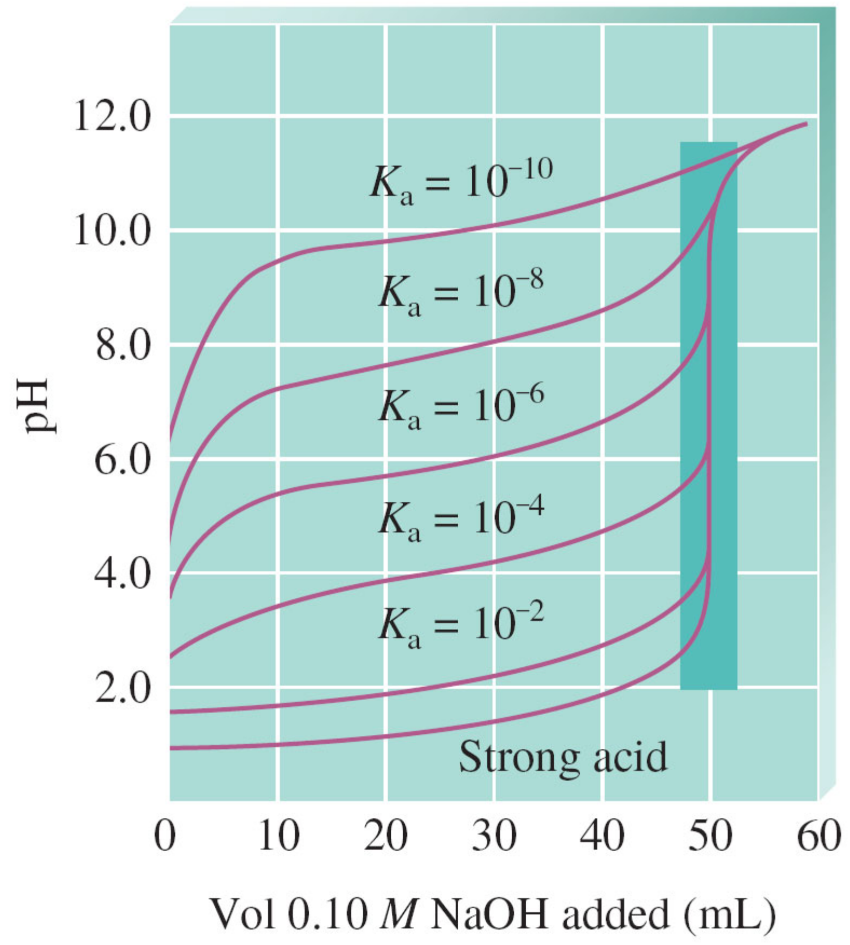
Consider the following three titrations:

I. 50.0 mL of 0.1 *M* HCO_2H ($K_a \approx 1 \times 10^{-4}$) by 0.20 *M* KOH
II. 50.0 mL of 0.1 *M* HOC_6H_5 ($K_a \approx 1 \times 10^{-10}$) by 0.20 *M* KOH
III. 50.0 mL of 0.1 *M* HNO_3 by 0.20 *M* KOH

Which of the following statements is false?

a. The HNO_3 titration has a lower pH initially before the titration begins as compared to the other titrations.
b. At 12.5 mL KOH added, the HCO_2H titration has pH ≈ 4.0.
c. At the halfway point to equivalence for the HOC_6H_5 titration, the pH is acidic.
d. The pH of the HOC_6H_5 titration has a higher pH at the equivalence point as compared to the HCO_2H titration.
e. The pH of the HNO_3 titration is 7.0 at 25.0 mL KOH added.

Multiple Acid Titration (pH) Curves



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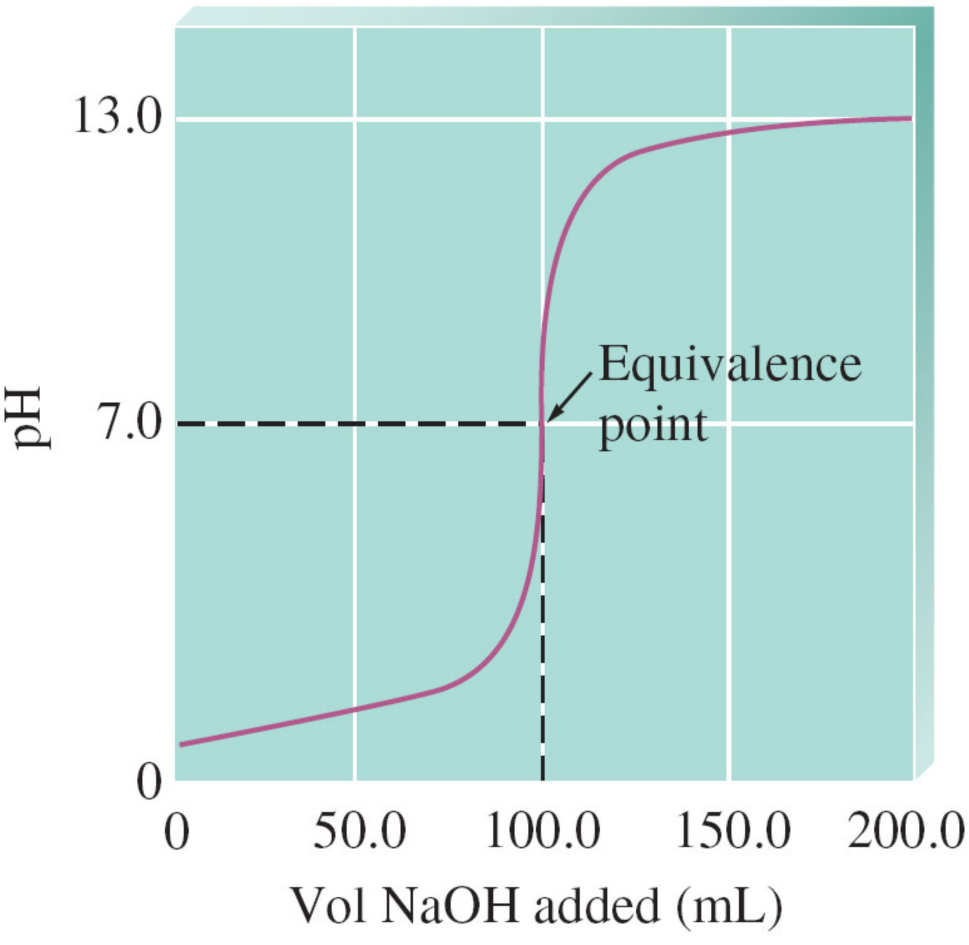
Strong Acid – Strong Base Titrations



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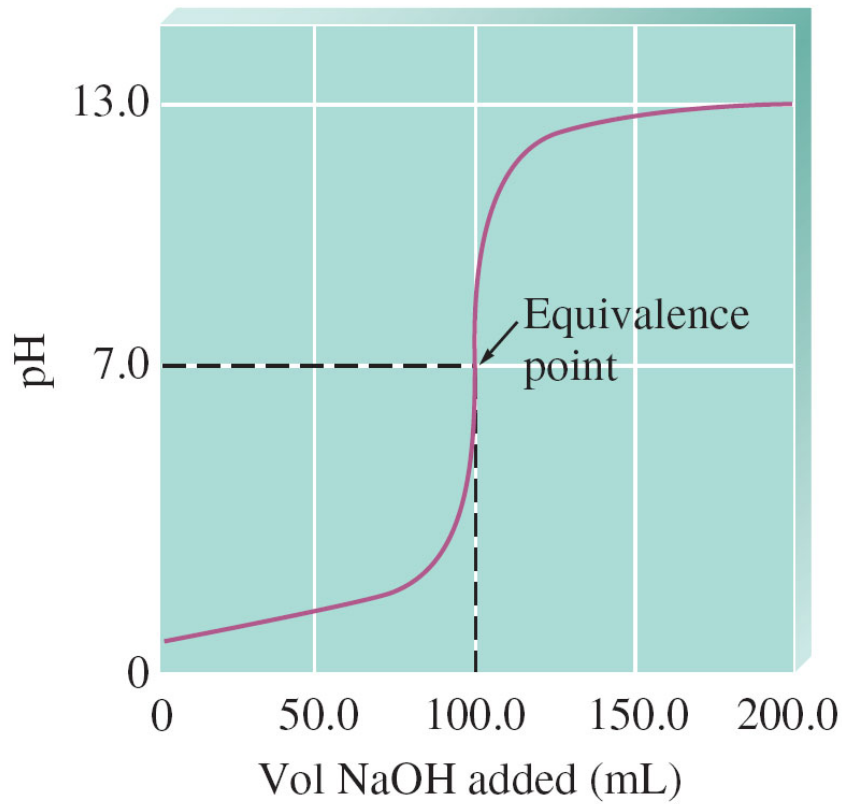
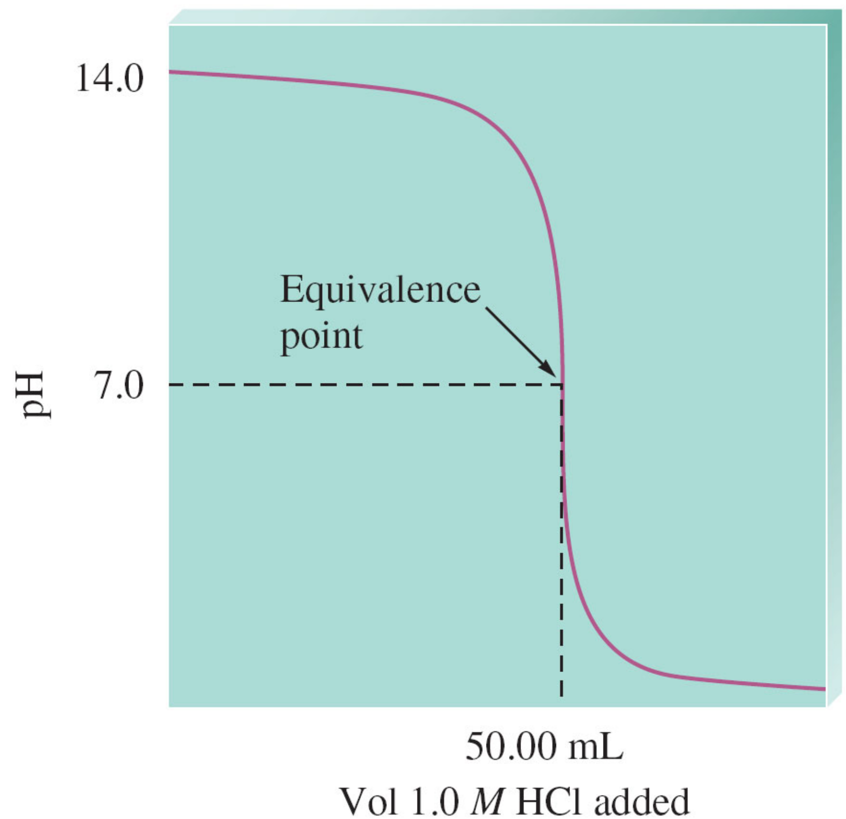


pH curve for a strong base titrated by strong acid

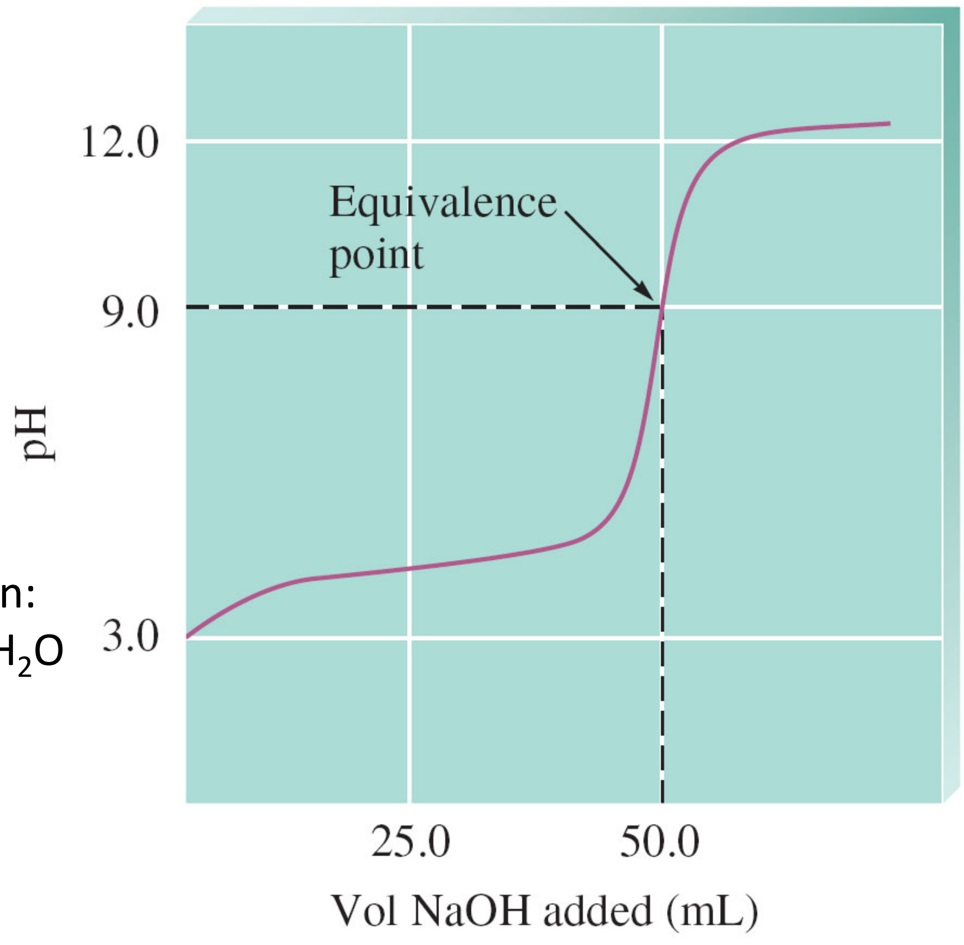


Weak Acid-Strong Base Titrations

100.0 mL of 0.50 M HF titrated by 1.0 M NaOH

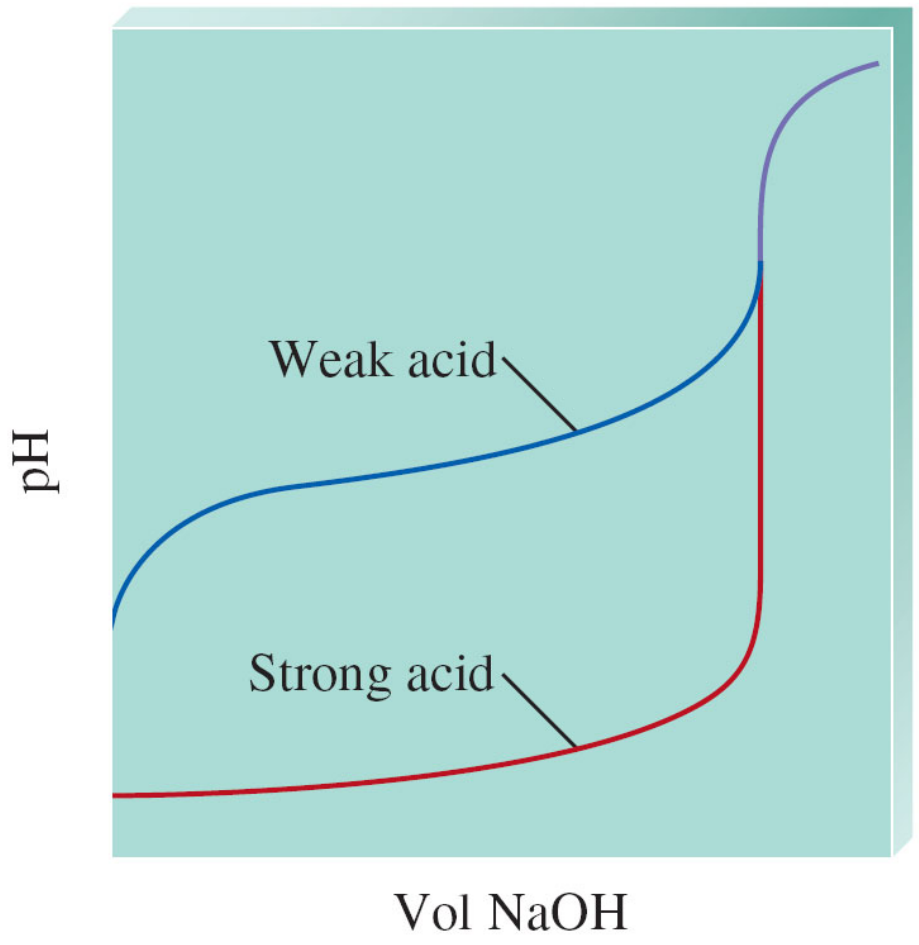
Neutralization rxn:

$HF + OH^- \rightarrow F^- + H_2O$



Weak Acid vs. Strong Acid Titration

$$HA + OH^{-} \rightarrow A^{-} + H_2O$$



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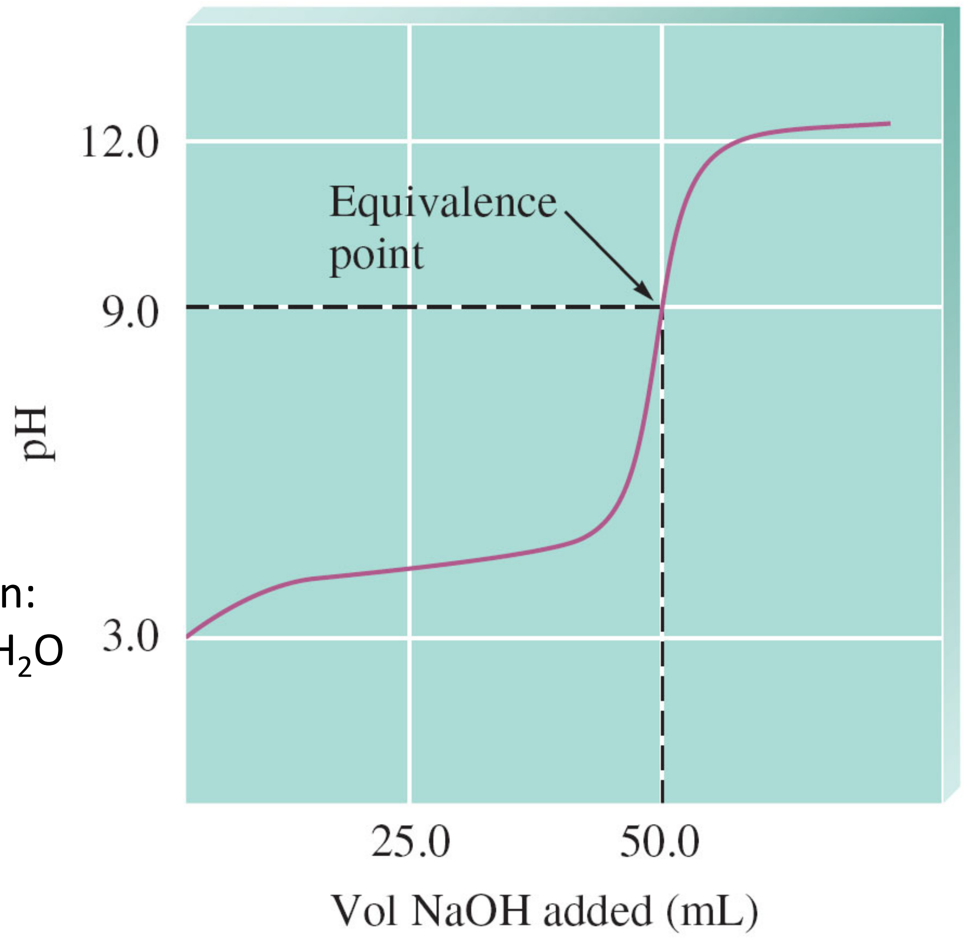

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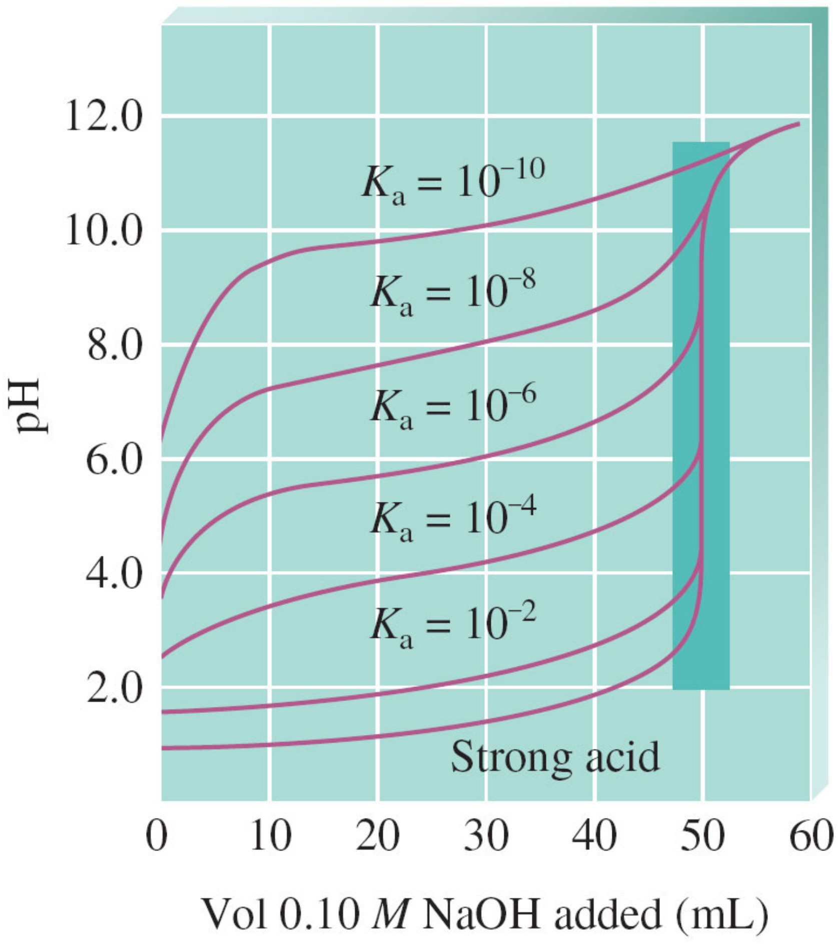

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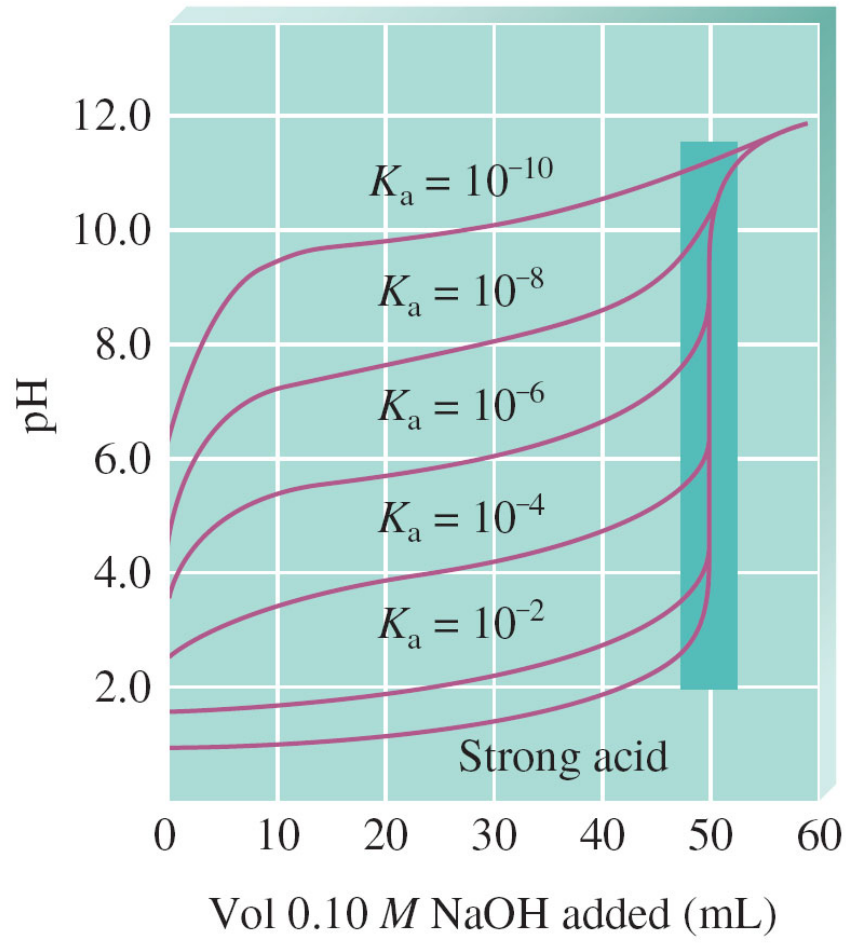

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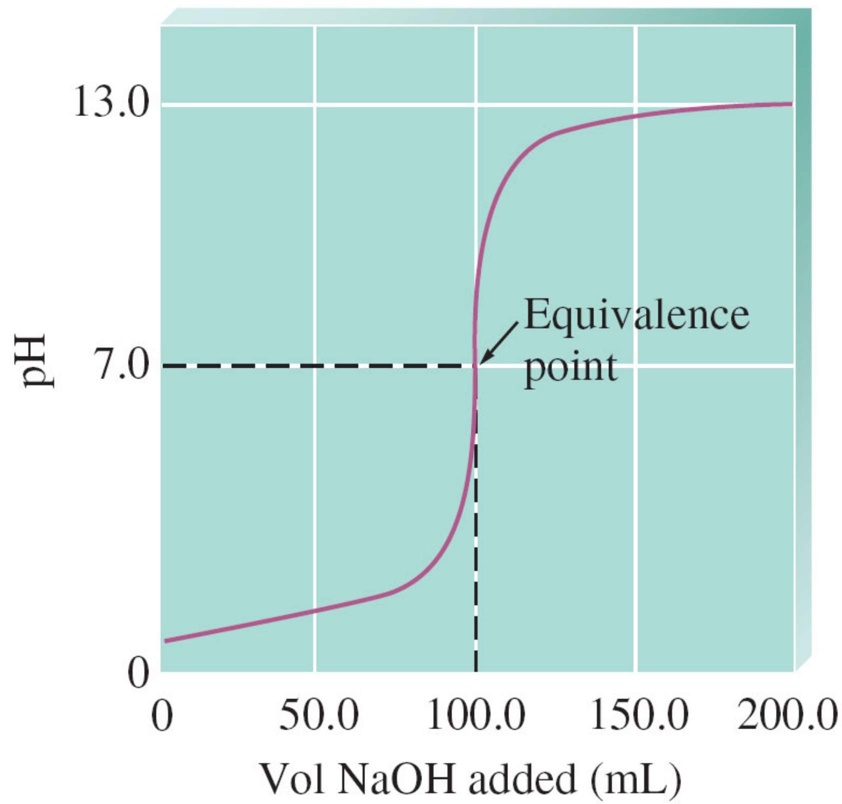
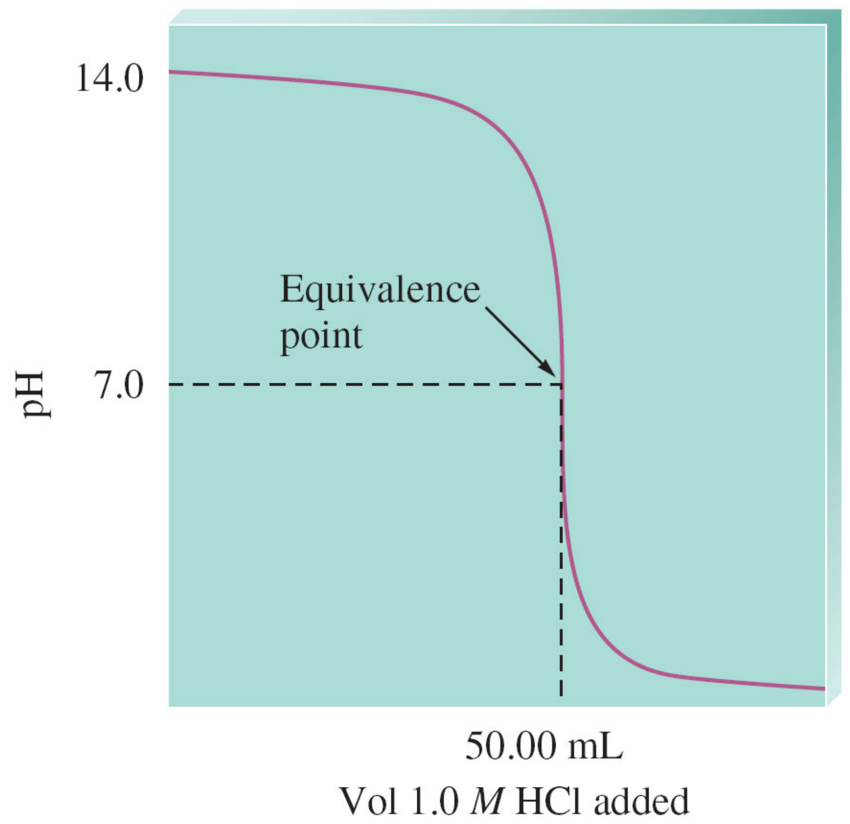


pH curve for a strong base titrated by strong acid



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$M_A V_A = M_B V_B$
mmol acid = mmol base
with M in mmol/mL and V in mL

At equivalence point.