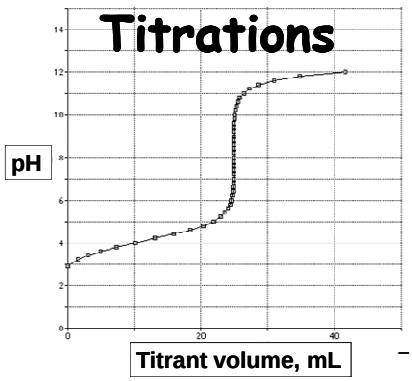
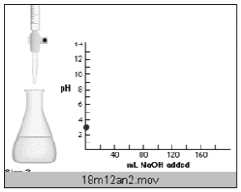
1

Titrations



2

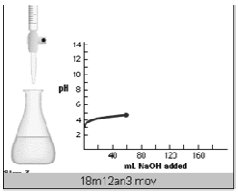
Acid-Base Titrations



Adding NaOH from the buret to acetic acid in the flask, a weak acid. In the beginning the pH increases very slowly.

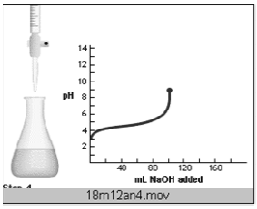
3

Acid-Base Titrations



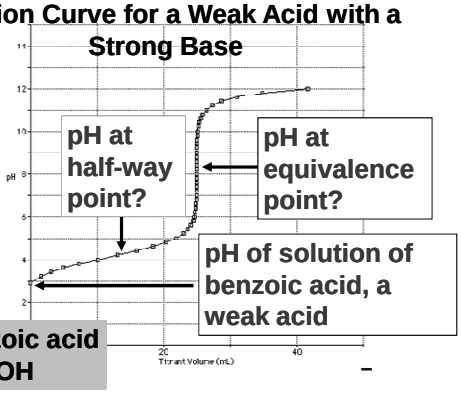
Additional NaOH is added. pH rises as equivalence point is approached.

Acid-Base Titrations



Additional NaOH is added. pH increases and then levels off as NaOH is added beyond the equivalence point.

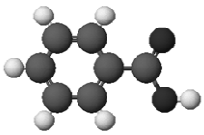
Titration Curve for a Weak Acid with a Strong Base



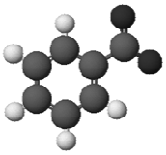
Acid-Base Titration

QUESTION: You titrate 100. mL of a 0.025 M solution of benzoic acid with 0.100 M NaOH to the equivalence point. What is the pH of the final solution?

$C_6H_5CO_2H + OH^- \rightarrow C_6H_5CO_2^- + H_2O$



$C_6H_5CO_2H$



$C_6H_5CO_2^-$

Acid-Base Titrations

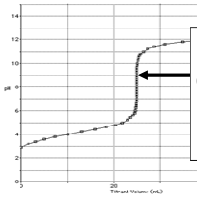
The product of the titration of benzoic acid is the benzoate ion, $C_6H_5CO_2^-$.

$C_6H_5CO_2^-$ is the conjugate base of a weak acid.

Therefore, final solution is basic.

$C_6H_5CO_2^- + H_2O \rightleftharpoons C_6H_5CO_2H + OH^-$

$K_b = 1.6 \times 10^{-10}$



pH at equivalence point is basic

Acid-Base Reactions

QUESTION: You titrate 100. mL of a 0.025 M solution of benzoic acid with 0.100 M NaOH to the equivalence point. What is the pH of the final solution?

Strategy — find the concentration of the conjugate base $C_6H_5CO_2^-$ in the solution AFTER the titration, then calculate pH.

This is a two-step problem

1. stoichiometry of acid-base reaction
2. equilibrium calculation

QUESTION: You titrate 100. mL of a 0.025 M solution of benzoic acid with 0.100 M NaOH to the equivalence point. What is the pH of the final solution?

STOICHIOMETRY PORTION

1. Calculate the moles of NaOH required

(0.100 L $C_6H_5CO_2H$)(0.025 M)

= 0.0025 mol $C_6H_5CO_2H$

(mols acid = mols base)

This requires 0.0025 mol NaOH

2. Calculate the volume of NaOH required

0.0025 mol (1 L / 0.100 mol)

= 0.025 L NaOH = 25 mL of NaOH required

QUESTION: You titrate 100. mL of a 0.025 M solution of benzoic acid with 0.100 M NaOH to the equivalence point. What is the pH of the final solution?

STOICHIOMETRY PORTION, cont.

Remember that 25 mL of NaOH are required

3. Moles of $C_6H_5CO_2^-$ produced = moles $C_6H_5CO_2H$ = 0.0025 mol (1:1 ratio)
4. Calculate the concentration of $C_6H_5CO_2^-$

There are 0.0025 mol of $C_6H_5CO_2^-$ in a TOTAL SOLUTION VOLUME of 125 mL

$[C_6H_5CO_2^-]$= 0.0025 mol / 0.125 L = 0.020 M

QUESTION: You titrate 100. mL of a 0.025 M solution of benzoic acid with 0.100 M NaOH to the equivalence point. What is the pH at equivalence point?

Equivalence Point

Most important species in solution is benzoate ion, $C_6H_5CO_2^-$

the weak conjugate base of benzoic acid, $C_6H_5CO_2H$.

$C_6H_5CO_2^- + H_2O \rightleftharpoons C_6H_5CO_2H + OH^-$

$K_b = 1.6 \times 10^{-10}$ Make an ICE chart…

	$[C_6H_5CO_2^-]$	$[C_6H_5CO_2H]$	$[OH^-]$
initial	0.020	0	0
change	- x	+x	+x
equilib	0.020 - x	x	x

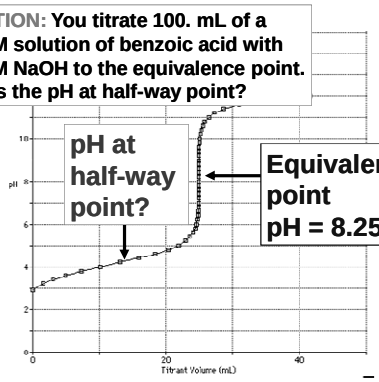
$$K_b = 1.6 \times 10^{-10} = \frac{x^2}{0.020 - x}$$

Neglect x

$x = [OH^-] = 1.8 \times 10^{-6}$

pOH = 5.75 -----> pH = 8.25

QUESTION: You titrate 100. mL of a 0.025 M solution of benzoic acid with 0.100 M NaOH to the equivalence point. What is the pH at half-way point?



Acid-Base Reactions

You titrate 100. mL of a 0.025 M solution of benzoic acid with 0.100 M NaOH.

What is the pH at the half-way point?

$C_6H_5CO_2H + H_2O \rightleftharpoons H_3O^+ + C_6H_5CO_2^-$

$K_a = 6.3 \times 10^{-5}$

Both $C_6H_5CO_2H$ and $C_6H_5CO_2^-$ are present.
This is a BUFFER!

At the half-way point, $[C_6H_5CO_2H] = [C_6H_5CO_2^-]$

$$K_a = \frac{[H_3O^+][C_6H_5CO_2^-]}{[C_6H_5CO_2H]} \qquad K_a = 6.3 \times 10^{-5}$$

Therefore, $[H_3O^+] = K_a = 6.3 \times 10^{-5}$

pH = 4.20 = pK_a of the acid

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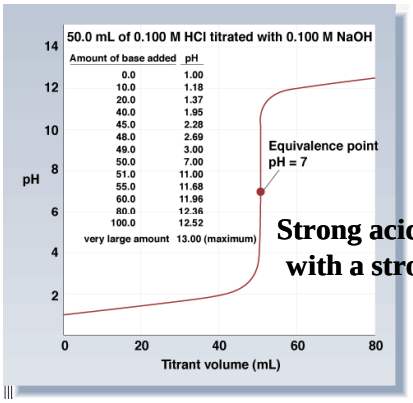


Strong acid titrated with a strong base

Figure 18.4

17

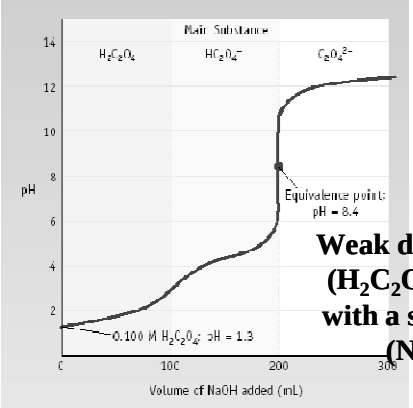
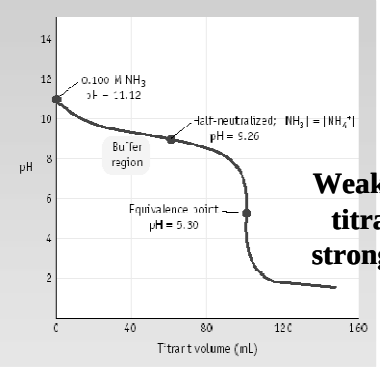


Figure 18.6

Weak diprotic acid ($H_2C_2O_4$) titrated with a strong base (NaOH)

18



Weak base (NH_3) titrated with a strong acid (HCl)

Figure 18.7