

[TP] At 25 °C, 0.10 mol each of a weak acid HA, its conjugate base A^-, and OH^- are combined in 1.0 L of water. The pH of the solution is …

25% 1. < 7
25% 2. = 7
25% 3. > 7
25% 4. Further information needed

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Lecture 22 CH102 A2 (MWF 11:15 am)

Friday, March 22, 2019

- Postscript on titration of strong acid with strong base
- Buffers: $[H_3O^+]$ when different amounts of "not enough" base added
- Practice: Too little, just enough, too much?

Next lecture: Ch15: Five kinds of solubility equilibria problems; Practice with solubility equilibria.

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Strong acid titration: "not enough" base

Add 0.006 mol of OH^- to 1.0 L of 0.01 M HA, $K_a = 1.0 \times 10^{+5}$, at 25 °C, assuming no volume change.

Step 1 results in 0.004 mol HA and 0.006 mol A^-.

Step 2

	[HA]	$[H_3O^+]$	$[A^-]$	Q
Initial	$0.004/V$	1×10^{-7}	$0.006/V$	$\ll K_a$

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Strong acid titration: "not enough" base

Add 0.006 mol of OH^- to 1.0 L of 0.01 M HA, $K_a = 1.0 \times 10^{+5}$, at 25 °C, assuming no volume change.

Step 1 results in 0.004 mol HA and 0.006 mol A^-.

Step 2

	[HA]	$[H_3O^+]$	$[A^-]$	Q
Initial	$0.004/V$	1×10^{-7}	$0.006/V$	$\ll K_a$
Change	$\approx -0.004/V$	$\approx +0.004/V$	$\approx +0.004/V$	

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Strong acid titration: "not enough" base

Add 0.006 mol of OH^- to 1.0 L of 0.01 M HA, $K_a = 1.0 \times 10^{+5}$, at 25 °C, assuming no volume change.

Step 1 results in 0.004 mol HA and 0.006 mol A^-.

Step 2

	[HA]	$[H_3O^+]$	$[A^-]$	Q
Initial	$0.004/V$	1×10^{-7}	$0.006/V$	$\ll K_a$
Change	$\approx -0.004/V$	$\approx +0.004/V$	$\approx +0.004/V$	
Equilibrium	≈ 0	$\approx 0.004/V$	$\approx 0.010/V$	$\approx K_a$

$[H_3O^+] = 4.0 \times 10^{-3}$ and pH = 2.4

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Strong acid titration: "just enough" base

Add 0.010 mol of OH^- to 1.0 L of 0.01 M HA, $K_a = 1.0 \times 10^{+5}$, at 25 °C, assuming no volume change.

Step 1 results in 0.000 mol HA and 0.010 mol A^-.

Step 2, since $K_b = K_w/K_a \ll K_w$ ...

	$[A^-]$	[HA]	$[OH^-]$	Q
Initial	$0.010/V$	0	1×10^{-7}	$0 \ll K_b$

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Strong acid titration: "just enough" base

Add 0.010 mol of OH^- to 1.0 L of 0.01 M HA, $K_a = 1.0 \times 10^{+5}$, at 25 °C, assuming no volume change.

Step 1 results in 0.000 mol HA and 0.010 mol A^-.

Step 2, since $K_b = K_w/K_a \ll K_w$ ...

	$[A^-]$	[HA]	$[OH^-]$	Q
Initial	$0.010/V$	0	1×10^{-7}	$0 \ll K_b$
Change	$-x$	$+x$	$+x$	

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Strong acid titration: "just enough" base

Add 0.010 mol of OH^- to 1.0 L of 0.01 M HA, $K_a = 1.0 \times 10^{+5}$, at 25 °C, assuming no volume change.

Step 1 results in 0.000 mol HA and 0.010 mol A^-.

Step 2, since $K_b = K_w/K_a \ll K_w$ ...

	$[A^-]$	[HA]	$[OH^-]$	Q
Initial	$0.010/V$	0	1×10^{-7}	$0 \ll K_b$
Change	$-x$	$+x$	$+x$	
Equilibrium	$\approx 0.010/V$	x	$\approx 1 \times 10^{-7}$	$\approx K_b$

$[H_3O^+] = [OH^-] = 1.0 \times 10^{-7}$ and pH = 7.0

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Strong acid titration: "too much" base

Add 0.011 mol of OH^- to 1.0 L of 0.01 M HA, $K_a = 1.0 \times 10^{+5}$, at 25 °C, assuming no volume change.

Step 1 results in 0.000 mol HA. 0.001 mol OH^-, and 0.010 mol A^-.

Step 2, since $K_b = K_w/K_a \ll K_w$ ...

	$[A^-]$	[HA]	$[OH^-]$	Q
Initial	$0.010/V$	0	$0.001/V$	$0 \ll K_b$

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Strong acid titration: "too much" base

Add 0.011 mol of OH^- to 1.0 L of 0.01 M HA, $K_a = 1.0 \times 10^{+5}$, at 25 °C, assuming no volume change.

Step 1 results in 0.000 mol HA. 0.001 mol OH^-, and 0.010 mol A^-.

Step 2, since $K_b = K_w/K_a \ll K_w$ ...

	$[A^-]$	[HA]	$[OH^-]$	Q
Initial	$0.010/V$	0	$0.001/V$	$0 \ll K_b$
Change	$-x$	$+x$	$+x$	

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Strong acid titration: "too much" base

Add 0.011 mol of OH^- to 1.0 L of 0.01 M HA, $K_a = 1.0 \times 10^{+5}$, at 25 °C, assuming no volume change.

Step 1 results in 0.000 mol HA. 0.001 mol OH^-, and 0.010 mol A^-.

Step 2, since $K_b = K_w/K_a \ll K_w$ ...

	$[A^-]$	[HA]	$[OH^-]$	Q
Initial	$0.010/V$	0	$0.001/V$	$0 \ll K_b$
Change	$-x$	$+x$	$+x$	
Equilibrium	$\approx 0.010/V$	x	$\approx 0.001/V$	$\approx K_b$

$[H_3O^+] = \frac{K_w}{0.001/V} = 1.0 \times 10^{-11}$ and pH = 11.0 (excess base)

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[Quiz] At 25 °C, titration of 1.0 L of 0.010 M weak acid with OH^- has pH = 8.5 at the equivalence point, whereas titration of 1.0 L of 0.010 M strong acid with OH^- has pH = 7.0 at the equivalence point. This means that, compared to the moles of OH^- needed to reach equivalence in the weak acid titration, the moles of OH^- needed in the strong acid titration must be ...

25% 1. less
25% 2. the same
25% 3. more
25% 4. Further information needed

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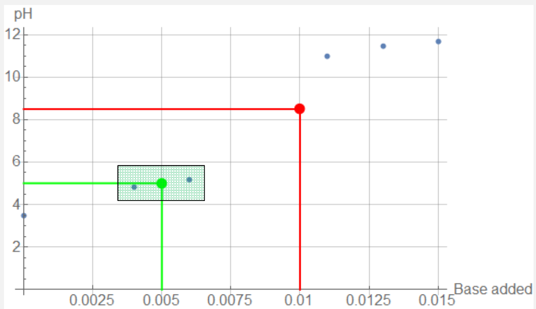
Different amounts of “not enough” base

Near half-equivalence, pH changes very little.



Different amounts of “not enough” base

At 25 °C, the pH of a 1.0 L solution of $c_a = c_b = 1.00$ M, $K_a = 1 \times 10^{-5}$ is …

pH = 5.00

Add 100. mL of 0.100 M NaOH …

HA → 1.00 mol – 0.010 mol = 0.99 mol

A^- → 1.00 mol + 0.010 mol = 1.01 mol

↓$HA(aq) + OH^-(aq) \rightarrow H_2O(l) +$ ↑$A^-(aq)$

The pH of a 1.0 L solution of c_a = 0.99 mol/1.10 L, c_b = 1.01 mol/1.10 L is …

$c_a/c_b = 1.00 \rightarrow 0.99/1.01$, pH → 5.01 (tiny change!)

Different amounts of “not enough” base

At 25 °C, the pH of a 1.0 L solution pure water, $K_a = 1 \text{ x } 10^{-14}$ is …

pH = 7.00

Add 100. mL of 0.100 M NaOH …

$[OH^-]$ = 0.010 mol/1.10 L = 0.0091

pOH = 2.04, pH = 11.96 (huge change!)

Different amounts of “not enough” base

At 25 °C, the pH of a 1.0 L solution of $c_a = c_b = 1.00$ M, $K_a = 1 \text{ x } 10^{-5}$ is …

pH = 5.00

Add 100. mL of 0.100 M HCl …

HA → 1.00 mol + 0.010 mol = 1.01 mol

A^- → 1.00 mol – 0.010 mol = 0.99 mol

$HCl(aq) +$ ↓$A^-(aq) \rightarrow$ ↑$HA(aq) + Cl^-(aq)$

The pH of a 1.0 L solution of c_a = 1.01 mol/1.10 L, c_b = 0.99 mol/1.10 L …

$c_a/c_b = 1.00 \rightarrow 1.01/0.99$, pH → 4.99 (tiny change!)

Different amounts of “not enough” base

At 25 °C, the pH of a 1.0 L solution pure water, $K_a = 1 \times 10^{-14}$ is ...

pH = 7.00

Add 100. mL of 0.100 M HCl ...

$[H_3O^+] = 0.010 \text{ mol}/1.10 \text{ L} = 0.0091$

pH = 2.04 (huge change!)

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Buffers

Mixtures of a weak acid and its conjugate base (or weak base and its conjugate acid) exhibit the special property that they resist changes to pH.

For this reason such mixtures are known as buffers.

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Buffers resist change in pH

Added strong base (say, OH^-) is gobbled up ...

↓$HA(aq) + OH^-(aq) \rightarrow H_2O(l) +$ ↑$A^-(aq)$

c_a lowered, c_b raised, c_a/c_b lowered

Added strong acid (say, HCl) is gobbled up ...

$HCl(aq) +$ ↓$A^-(aq) \rightarrow$ ↑$HA(aq) + Cl^-(aq)$

c_b lowered, c_a raised, c_a/c_b raised

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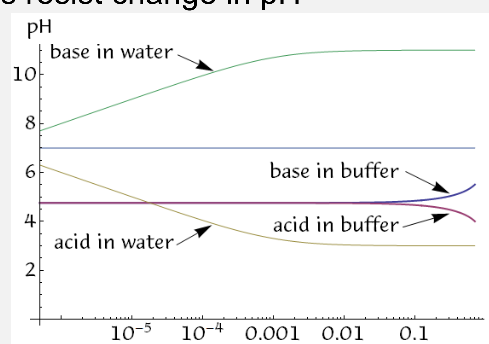
Buffers resist change in pH



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Too little, just enough, too much?

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[TP] At 25 °C, 0.10 mol each of a strong acid and OH^- are combined in 1.0 L of water. The pH of the solution is ...

0% 1. < 7
0% 2. = 7
0% 3. > 7
0% 4. Further information needed

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[TP] At 25 °C, 0.10 mol each of a weak acid HA, its conjugate base A^-, and OH^- are combined in 1.0 L of water. The pH of the solution is ...

1. < 7
2. = 7
3. > 7
4. Further information needed

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[Quiz] At 25 °C, 0.10 mol each of a weak acid HA and a strong acid HB, and 0.20 mol of OH^- are combined in 1.0 L of water. The pH of the solution is ...

0% 1. < 7
0% 2. = 7
0% 3. > 7
0% 4. Further information needed

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