

[TP] 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

BOSTON UNIVERSITY

0 of 0

Lecture 21 CH102 A1 (MWF 9:05 am)

Wednesday, March 20, 2019

- Titration: Adding successive amounts of base

Next: Buffers: $[H_3O^+]$ when different amounts of "not enough" base added; Practice: Too little, just enough, too much?; Ch15: Solubility, precipitation, and complexation

BOSTON UNIVERSITY

Titration: Adding successive amounts of base

When successive amounts of base added, for each addition carry out step 1 by "going back to the beginning."

Say 0.02 mol of OH^- is added to 0.10 mol of weak acid HA.

Then an additional 0.01 mol of OH^- is added.

The net result is 0.03 mol of OH^- added to 0.10 mol of weak acid.

BOSTON UNIVERSITY

Titration of weak acid with hydroxide

Let's see how this works "titrating" 1.0 L of 0.01 M HA, $K_a = 1.0 \times 10^{-5}$, at 25 °C.

Calculate $[H_3O^+]$ and pH.

$[H_3O^+] = 3.2 \times 10^{-4}$ and pH = 3.5

BOSTON UNIVERSITY

Titration of weak acid with hydroxide

Let's see how this works "titrating" 1.0 L of 0.01 M HA, $K_a = 1.0 \times 10^{-5}$, at 25 °C.

Now, add 0.004 mol of OH^-, and assume no volume change.

Calculate $[H_3O^+]$ and pH.

$[H_3O^+] = 1.5 \times 10^{-5}$ and pH = 4.8

BOSTON UNIVERSITY 13

Titration of weak acid with hydroxide

Let's see how this works "titrating" 1.0 L of 0.01 M HA, $K_a = 1.0 \times 10^{-5}$, at 25 °C.

Now, add another 0.001 mol of OH^-, and assume no volume change.

Calculate $[H_3O^+]$ and pH.

$[H_3O^+] = 1.0 \times 10^{-5}$ and pH = 5.0 = pKa! (half-equivalence point)

BOSTON UNIVERSITY 14

Titration of weak acid with hydroxide

Let's see how this works "titrating" 1.0 L of 0.01 M HA, $K_a = 1.0 \times 10^{-5}$, at 25 °C.

Now, add another 0.001 mol of OH^-, and assume no volume change.

Calculate $[H_3O^+]$ and pH.

$[H_3O^+] = 6.7 \times 10^{-6}$ and pH = 5.2

BOSTON UNIVERSITY 15

Titration of weak acid with hydroxide

Let's see how this works "titrating" 1.0 L of 0.01 M HA, $K_a = 1.0 \times 10^{-5}$, at 25 °C.

Now, add another 0.004 mol of OH^-, and assume no volume change.

Calculate $[H_3O^+]$ and pH.

$[H_3O^+] = 3.2 \times 10^{-9}$ and pH = 8.5 (equivalence point)

BOSTON UNIVERSITY 16

Lecture 21 CH102 A1 (MWF 9:05 am) Spring 2019

Titration of weak acid with hydroxide

Let's see how this works "titrating" 1.0 L of 0.01 M HA, $K_a = 1.0 \times 10^{-5}$, at 25 °C.

Now, add another 0.001 mol of OH^-, and assume no volume change.

Calculate $[H_3O^+]$ and pH.

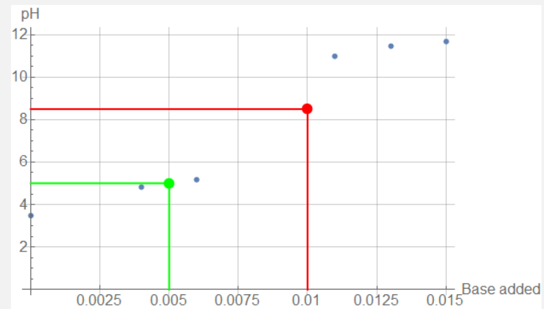
$[H_3O^+] = 1.0 \times 10^{-11}$ and pH = 11.0 (excess base)

BOSTON UNIVERSITY 17

Lecture 21 CH102 A1 (MWF 9:05 am) Spring 2019

Titration of weak acid with hydroxide

Let's see how this works "titrating" 1.0 L of 0.01 M HA, $K_a = 1.0 \times 10^{-5}$, at 25 °C.



BOSTON UNIVERSITY 18

Lecture 21 CH102 A1 (MWF 9:05 am) Spring 2019

Titration of strong acid with hydroxide

Let's see how this works "titrating" 1.0 L of 0.01 M HA, $K_a = 1.0 \times 10^{+5}$, at 25 °C.

Calculate $[H_3O^+]$ and pH.

$[H_3O^+] = 1.0 \times 10^{-2}$ and pH = 2

BOSTON UNIVERSITY 19

Lecture 21 CH102 A1 (MWF 9:05 am) Spring 2019

Titration of strong acid with hydroxide

Let's see how this works "titrating" 1.0 L of 0.01 M HA, $K_a = 1.0 \times 10^{+5}$, at 25 °C.

Now, add 0.004 mol of OH^-, and assume no volume change.

Calculate $[H_3O^+]$ and pH.

BOSTON UNIVERSITY 20

Titration of strong acid with hydroxide

Add 0.004 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 0.006 mol HA and 0.004 mol A^-.

Step 2

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

BOSTON UNIVERSITY 21

Lecture 21 CH102 A1 (MWF 9:05 am) Spring 2019 Copyright © 2019 Dan Dill dan@bu.edu

Titration of strong acid with hydroxide

Add 0.004 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 0.006 mol HA and 0.004 mol A^-.

Step 2

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

BOSTON UNIVERSITY 22

Lecture 21 CH102 A1 (MWF 9:05 am) Spring 2019 Copyright © 2019 Dan Dill dan@bu.edu

Titration of strong acid with hydroxide

Add 0.004 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 0.006 mol HA and 0.004 mol A^-.

Step 2

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

$[H_3O^+] = 6.0 \times 10^{-3}$ and pH = 2.2

BOSTON UNIVERSITY 23

Lecture 21 CH102 A1 (MWF 9:05 am) Spring 2019 Copyright © 2019 Dan Dill dan@bu.edu

Titration of strong acid with hydroxide

Let's see how this works "titrating" 1.0 L of 0.01 M HA, $K_a = 1.0 \times 10^{+5}$, at 25 °C.

Now, add another 0.001 mol of OH^-, and assume no volume change.

Calculate $[H_3O^+]$ and pH.

$[H_3O^+] = 5.0 \times 10^{-3}$ and pH = 2.3 (half-equivalence point)

BOSTON UNIVERSITY 24

Titration of strong acid with hydroxide

Let's see how this works "titrating" 1.0 L of 0.01 M HA, $K_a = 1.0 \times 10^{+5}$, at 25 °C.

Now, add another 0.001 mol of OH^-, and assume no volume change.

Calculate $[H_3O^+]$ and pH.

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

BOSTON UNIVERSITY

Titration of strong acid with hydroxide

Let's see how this works "titrating" 1.0 L of 0.01 M HA, $K_a = 1.0 \times 10^{+5}$, at 25 °C.

Now, add another 0.004 mol of OH^-, and assume no volume change.

Calculate $[H_3O^+]$ and pH.

BOSTON UNIVERSITY

Strong acid titration: Equivalence point

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}	$\ll K_b$

BOSTON UNIVERSITY

Strong acid titration: Equivalence point

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	$-x$	$+x$	$+x$	

BOSTON UNIVERSITY

Lecture 21 CH102 A1 (MWF 9:05 am) Spring 2019

Strong acid titration: Equivalence point

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}	$\ll K_b$
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 (equivalence point)

BOSTON UNIVERSITY 29

Lecture 21 CH102 A1 (MWF 9:05 am) Spring 2019 Copyright © 2019 Dan Dill dan@bu.edu

Titration of strong acid with hydroxide

Let's see how this works "titrating" 1.0 L of 0.01 M HA, $K_a = 1.0 \times 10^{+5}$, at 25 °C.

Now, add another 0.001 mol of OH^-, and assume no volume change.

Calculate $[H_3O^+]$ and pH.

BOSTON UNIVERSITY 30

Lecture 21 CH102 A1 (MWF 9:05 am) Spring 2019 Copyright © 2019 Dan Dill dan@bu.edu

Strong acid titration: Excess 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	$0.001/V$	$\ll K_b$
Change	$-x$	$+x$	$+x$	
Equilibrium	$\approx 0.010/V$	x	$\approx 0.001/V$	$\approx K_b$

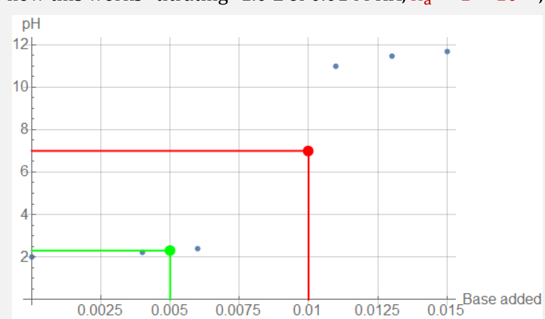
$[H_3O^+] = \frac{K_w}{0.001/V} = 1.0 \times 10^{-11}$ and pH = 11.0 (excess base)

BOSTON UNIVERSITY 31

Lecture 21 CH102 A1 (MWF 9:05 am) Spring 2019 Copyright © 2019 Dan Dill dan@bu.edu

Titration of strong acid with hydroxide

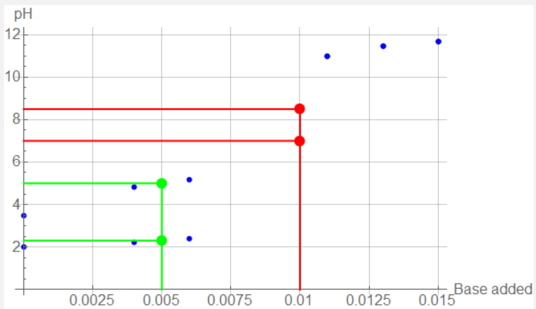
Let's see how this works "titrating" 1.0 L of 0.01 M HA, $K_a = 1 \times 10^{+5}$, at 25 °C.



BOSTON UNIVERSITY 32

Titration of strong and weak acid with hydroxide

Let's see how this works "titrating" 1.0 L of 0.01 M HA, $K_a = 1 \times 10^{+5}$, at 25 °C.



BOSTON UNIVERSITY

33

[TP] 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

BOSTON UNIVERSITY

0 of 0

34

