

Lecture 21 CH102 A1 (MWF 9 am) Spring 2017 Copyright © 2016 Dan Dill dan@bu.edu

[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 ...

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

BOSTON UNIVERSITY

Response Counter

10

1

Lecture 21 CH102 A1 (MWF 9:05 am)
 Friday, March 17, 2017

See Overview of acid-base calculations, <https://goo.gl/GEPDqo>

- [H₃O⁺] when “too much” base added
- Practice: Too little, just enough, too much?
- More practice
- [H₃O⁺] when different amounts of “not enough” base added

Next lecture: Complete ch14; begin ch15: Solubility, precipitation, and complexation

BOSTON UNIVERSITY

Lecture 21 CH102 A1 (MWF 9 am) Spring 2017 Copyright © 2016 Dan Dill dan@bu.edu

[H₃O⁺] when “too much” base added

BOSTON UNIVERSITY

6

Lecture 21 CH102 A1 (MWF 9 am) Spring 2017 Copyright © 2016 Dan Dill dan@bu.edu

Step 2: [H₃O⁺] when “too much” base added

$V_b = 200.$ mL of $c_b = 0.30$ M of OH⁻ is combined with $V_a = 200.$ mL of $c_a = 0.20$ M of HA, $K_a = 1.0 \times 10^{-6}$ and $K_b = K_w / K_a = 1.0 \times 10^{-8}$.

BOSTON UNIVERSITY

7

Lecture 21 CH102 A1 (MWF 9 am) Spring 2017

Copyright © 2016 Dan Dill dan@bu.edu

Step 2: $[\text{H}_3\text{O}^+]$ when “too much” base added

$V_b = 200.$ mL of $c_b = 0.30$ M of OH^- is combined with $V_a = 200.$ mL of $c_a = 0.20$ M of HA, $K_a = 1.0 \times 10^{-6}$ and $K_b = K_w / K_a = 1.0 \times 10^{-8}$. Step 1 results:

Ignoring acid-base equilibrium, after the limiting reagent reaction is complete, the resulting concentrations of HA, A^- , and OH^- are ...

$$[\text{HA}] = 0$$

$$[\text{A}^-] = (c_a V_a) / (V_a + V_b) = (0.040) \text{ mol} / (0.400 \text{ L}) = 0.10 \text{ M}$$

$$[\text{OH}^-] = (c_b V_b - c_a V_a) / (V_a + V_b) = (0.060 - 0.040) \text{ mol} / (0.400 \text{ L}) = 0.020 \text{ mol} / (0.400 \text{ L}) = 0.050 \text{ M}$$



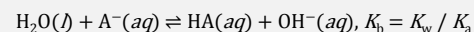
8

Lecture 21 CH102 A1 (MWF 9 am) Spring 2017

Copyright © 2016 Dan Dill dan@bu.edu

Step 2: $[\text{H}_3\text{O}^+]$ when “too much” base added

If conjugate base is present and excess $[\text{OH}^-]$, then work with



9

Lecture 21 CH102 A1 (MWF 9 am) Spring 2017

Copyright © 2016 Dan Dill dan@bu.edu

Step 2: $[\text{H}_3\text{O}^+]$ when “too much” base added

$V_b = 200.$ mL of $c_b = 0.30$ M of OH^- is combined with $V_a = 200.$ mL of $c_a = 0.20$ M of HA, $K_a = 1.0 \times 10^{-6}$ and $K_b = K_w / K_a = 1.0 \times 10^{-8}$

	$\text{A}^-(\text{aq})$	$\text{HA}(\text{aq})$	$\text{OH}^-(\text{aq})$	Q
Initial				
Change				
Equilibrium				
Approximate				

$$[\text{OH}^-] = ?$$

$$[\text{H}_3\text{O}^+] = ?$$

$$[\text{HA}] = ?$$



10

Lecture 21 CH102 A1 (MWF 9 am) Spring 2017

Copyright © 2016 Dan Dill dan@bu.edu

Step 2: $[\text{H}_3\text{O}^+]$ when “too much” base added

$V_b = 200.$ mL of $c_b = 0.30$ M of OH^- is combined with $V_a = 200.$ mL of $c_a = 0.20$ M of HA, $K_a = 1.0 \times 10^{-6}$ and $K_b = K_w / K_a = 1.0 \times 10^{-8}$

	$\text{A}^-(\text{aq})$	$\text{HA}(\text{aq})$	$\text{OH}^-(\text{aq})$	Q
Initial	0.10	0	0.050	0
Change	$-x$	$+x$	$+x$	
Equilibrium	$0.10 - x$	x	$0.050 + x$	1.0×10^{-8}
Approximate	≈ 0.10	x	≈ 0.050	1.0×10^{-8}

$$[\text{OH}^-] = 0.050 \text{ (easy!)}$$

$$[\text{H}_3\text{O}^+] = K_w / [\text{OH}^-] = (1.0 \times 10^{-14}) / (0.050) = 2.0 \times 10^{-13}$$

$$[\text{HA}] = x = K_b [\text{A}^-] / [\text{OH}^-] = 1.0 \times 10^{-8} \times 0.10 / 0.050 = 2.0 \times 10^{-8} \text{ (tiny!)}$$



11

Lecture 21 CH102 A1 (MWF 9 am) Spring 2017 Copyright © 2016 Dan Dill dan@bu.edu

Too little, just enough, too much?

BOSTON UNIVERSITY

12

Lecture 21 CH102 A1 (MWF 9 am) Spring 2017 Copyright © 2016 Dan Dill dan@bu.edu

[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 ...

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

BOSTON UNIVERSITY

Response Counter

10

13

Lecture 21 CH102 A1 (MWF 9 am) Spring 2017 Copyright © 2016 Dan Dill dan@bu.edu

[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

BOSTON UNIVERSITY

Response Counter

10

14

Lecture 21 CH102 A1 (MWF 9 am) Spring 2017 Copyright © 2016 Dan Dill dan@bu.edu

[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 ...

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

BOSTON UNIVERSITY

Response Counter

10

15

Lecture 21 CH102 A1 (MWF 9 am) Spring 2017

Copyright © 2016 Dan Dill dan@bu.edu

[TP] At 25 °C, 0.10 mol each of a weak acid HA, a strong acid HB, 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

Response
Counter

16

Lecture 21 CH102 A1 (MWF 9 am) Spring 2017

Copyright © 2016 Dan Dill dan@bu.edu

[Quiz] An acid HA has $K_a = 1.0 \times 10^{-4}$ at 25 °C. An aqueous solution is made by combining of 0.137 moles each of HA and A^- in a total volume of 250 mL at 25 °C. The pH of the solution is ...

- 17% 1. 1
 17% 2. 4
 17% 3. 7
 17% 4. 10
 17% 5. 13
 17% 6. More information needed



17

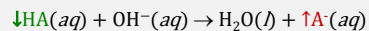
Lecture 21 CH102 A1 (MWF 9 am) Spring 2017

Copyright © 2016 Dan Dill dan@bu.edu

Different amounts of “not enough” base

At 25 °C, the pH of a 1.0 L solution of $c_a = c_b = 1.00 \text{ M}$, $K_a = 1 \times 10^{-5}$ is ...
 pH = 5.00

Add 100. mL of 0.100 M NaOH ...



HA $\rightarrow 1.00 \text{ mol} - 0.010 \text{ mol} = 0.99 \text{ mol}$

$\text{A}^- \rightarrow 1.00 \text{ mol} + 0.010 \text{ mol} = 1.01 \text{ mol}$

The pH of a 1.0 L solution of $c_a = 0.99 \text{ mol}/1.10 \text{ L}$, $c_b = 1.01 \text{ mol}/1.10 \text{ L}$ is ...

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



19

Lecture 21 CH102 A1 (MWF 9 am) Spring 2017

Copyright © 2016 Dan Dill dan@bu.edu

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 NaOH ...

$[\text{OH}^-] = 0.010 \text{ mol}/1.10 \text{ L} = 0.0091$

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



20

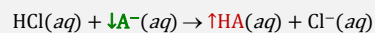
Lecture 21 CH102 A1 (MWF 9 am) Spring 2017

Copyright © 2016 Dan Dill dan@bu.edu

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 HCl ...



$$\text{HA} \rightarrow 1.00 \text{ mol} + 0.010 \text{ mol} = 1.01 \text{ mol}$$

$$\text{A}^- \rightarrow 1.00 \text{ mol} - 0.010 \text{ mol} = 0.99 \text{ mol}$$

The pH of a 1.0 L solution of $c_a = 1.01 \text{ mol}/1.10 \text{ L}$, $c_b = 0.99 \text{ mol}/1.10 \text{ L}$...

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



21

Lecture 21 CH102 A1 (MWF 9 am) Spring 2017

Copyright © 2016 Dan Dill dan@bu.edu

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 ...

$$[\text{H}_3\text{O}^+] = 0.010 \text{ mol}/1.10 \text{ L} = 0.0091$$

$$\text{pH} = 2.04 \text{ (huge change!)}$$



22

Lecture 21 CH102 A1 (MWF 9 am) Spring 2017

Copyright © 2016 Dan Dill dan@bu.edu

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**.



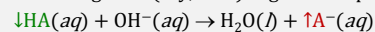
23

Lecture 21 CH102 A1 (MWF 9 am) Spring 2017

Copyright © 2016 Dan Dill dan@bu.edu

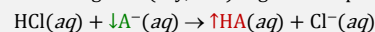
Buffers resist change in pH

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



$$c_a \text{ lowered, } c_b \text{ raised, } c_a/c_b \text{ lowered}$$

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



$$c_b \text{ lowered, } c_a \text{ raised, } c_a/c_b \text{ raised}$$



26