[TP] $V_b = 100.$ mL of $c_b = 0.20$ M of $OH^-$ is combined with $V_a = 300.$ mL of $c_a = 0.10$ M of HA, $K_a = 1.0 \times 10^{-4}$. at 25 °C.

17% 1. $[H_3O^+] = 1.0 \times 10^{-4}$
17% 2. $[H_3O^+] = 2.0 \times 10^{-4}$
17% 3. $[H_3O^+] = 5.0 \times 10^{-4}$
17% 4. $[H_3O^+] = 1.0 \times 10^{-5}$
17% 5. $[H_3O^+] = 2.0 \times 10^{-5}$
17% 6. None of the above.

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Response Counter

10

1

# Lecture 19 CH102 A2 (MWF 11:15 am)

Friday, March 8, 2019

- Review: [H3O+] when "too little" base added
- [H3O+] when "just enough" base added

Next: $[H_3O^+]$ when "too much" base added; Practice: Too little, just enough, too much?; How much strong acid remains unreacted?; Recipe for calculating combinations of acids and bases; $[H_3O^+]$ when different amounts of "not enough" base added

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[TP] $V_b = 100.$ mL of $c_b = 0.20$ M of $OH^-$ is combined with $V_a = 300.$ mL of $c_a = 0.10$ M of HA, $K_a = 1.0 \times 10^{-4}$. at 25 °C.

17% 1. $[H_3O^+] = 1.0 \times 10^{-4}$
17% 2. $[H_3O^+] = 2.0 \times 10^{-4}$
17% 3. $[H_3O^+] = 5.0 \times 10^{-4}$
17% 4. $[H_3O^+] = 1.0 \times 10^{-5}$
17% 5. $[H_3O^+] = 2.0 \times 10^{-5}$
17% 6. None of the above.

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10

6

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## Step 2: $[H_3O^+]$ when "too little" base added

$V_b = 100.$ mL of $c_b = 0.20$ M of $OH^-$ is combined with $V_a = 300.$ mL of $c_a = 0.10$ M of HA, $K_a = 1.0 \times 10^{-4}$.

| | $HA(aq)$ | $H_3O^+(aq)$ | $A^-(aq)$ | $Q$ |
|---|---|---|---|---|
| Initial | $0.010/V$ | $10^{-7}$ | $0.020/V$ | $10^{-7} < K_a$ |
| Change | $-x$ | $+x$ | $+x$ | |
| Equilibrium | $0.010/V - x$ | $10^{-7} + x$ | $0.020/V + x$ | $K_a$ |
| Approximate | $\approx 0.010/V$ | $\approx x$ | $\approx 0.020/V$ | $K_a$ |

$$[H_3O^+] = x = \frac{K_a[HA]}{[A^-]} = \frac{1.0\times10^{-4}\times0.010/V}{0.020/V} = 5.0 \times 10^{-5}$$

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[Quiz] $V_b = 100.$ mL of $c_b = 0.20$ M of $OH^-$ is combined with $V_a = 300.$ mL of $c_a = 0.10$ M of HA, $K_a = 2.0 \times 10^{-4}$. at 25 °C.

17% 1. $[H_3O^+] = 1.0 \times 10^{-4}$
17% 2. $[H_3O^+] = 2.0 \times 10^{-4}$
17% 3. $[H_3O^+] = 5.0 \times 10^{-4}$
17% 4. $[H_3O^+] = 1.0 \times 10^{-5}$
17% 5. $[H_3O^+] = 2.0 \times 10^{-5}$
17% 6. None of the above.

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Response Counter

10





## Step 2: $[H_3O^+]$ when "too little" base added

$V_b = 100.$ mL of $c_b = 0.20$ M of $OH^-$ is combined with $V_a = 300.$ mL of $c_a = 0.10$ M of HA, $K_a = 2.0 \times 10^{-4}$.

| | $HA(aq)$ | $H_3O^+(aq)$ | $A^-(aq)$ | $Q$ |
|---|---|---|---|---|
| Initial | $0.010/V$ | $10^{-7}$ | $0.020/V$ | $10^{-7} < K_a$ |
| Change | $-x$ | $+x$ | $+x$ | |
| Equilibrium | $0.010/V - x$ | $10^{-7} + x$ | $0.020/V + x$ | $K_a$ |
| Approximate | $\approx 0.010/V$ | $\approx x$ | $\approx 0.020/V$ | $K_a$ |

$$[H_3O^+] = x = \frac{K_a[HA]}{[A^-]} = \frac{2.0\times10^{-4}\times0.010/V}{0.020/V} = 1.0 \times 10^{-4}$$

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$[H_3O^+]$ when "just enough" base added

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## Step 2: $[H_3O^+]$ when "just enough" base added

$V_b = 100.$ mL of $c_b = 0.40$ M of $OH^-$ is combined with $V_a = 100.$ mL of $c_a = 0.40$ M of HA, $K_a = 1.0 \times 10^{-5}$.

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## Step 2: $[H_3O^+]$ when "just enough" base added

$V_b = 100.$ mL of $c_b = 0.40$ M of $OH^-$ is combined with $V_a = 100.$ mL of $c_a = 0.40$ M of HA, $K_a = 1.0 \times 10^{-5}$. Step 1 results:

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

$[HA] =$

$[A^-] =$

$[OH^-] =$





## Step 2: $[H_3O^+]$ when "just enough" base added

$V_b = 100.$ mL of $c_b = 0.40$ M of $OH^-$ is combined with $V_a = 100.$ mL of $c_a = 0.40$ M of HA, $K_a = 1.0 \times 10^{-5}$. Step 1 results:

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

$[HA] = \frac{c_a V_a - c_b V_b}{V_a + V_b} = 0$ ("just enough" base added)

$[A^-] = \frac{c_b V_b}{V_a + V_b} = \frac{0.040 \text{ mol}}{0.200 \text{ L}} = 0.20$ M

$[OH^-] = 0$ ("just enough" base added)





## Step 2: $[H_3O^+]$ when "just enough" base added

We get $[H_3O^+]$ by equilibrating the limiting reagent reaction (step 1) outcome.

$[HA] = 0$ ("just enough" base added)

$[A^-] = 0.20$ M

$[OH^-] = 0$ ("just enough" base added)

When "just enough" base is added, only the conjugate base will be present after the limiting reagent reaction.

So what equilibrium do we work with?





## Step 2: $[H_3O^+]$ when "just enough" base added

If only conjugate base is present, then always work with

$A^-(aq) + H_2O(l) \rightleftarrows HA(aq) + OH^-(aq), K_b = K_w/K_a$

[TP] Which of the following is true about the a weak base?

0% 1. $K_b \ll 1$
0% 2. $K_b \approx 1$
0% 3. $K_b \gg 1$
0% 4. $K_b \gg K_w$
0% 5. $K_b \ll K_w$
0% 6. 1 and 4
0% 7. 1 and 5
0% 8. 1, 4, and 5





[Quiz] Which of the following is true about the conjugate base $A^-$ of the weak acid HA?

0% 1. $A^-$ is a strong base
0% 2. $A^-$ is a weak base
0% 3. Not a base, since $K_b \ll K_w$
0% 4. Further information needed





## Step 2: $[H_3O^+]$ when "just enough" base added

$V_b = 100.$ mL of $c_b = 0.40$ M of $OH^-$ is combined with $V_a = 100.$ mL of $c_a = 0.40$ M of HA, $K_a = 1.0 \times 10^{-6}$ and $K_b = K_w / K_a = 1.0 \times 10^{-8}$

| | $A^-(aq)$ | $HA(aq)$ | $OH^-(aq)$ | Q |
|---|---|---|---|---|
| Initial | | | | |
| Change | | | | |
| Equilibrium | | | | |
| Approximate | | | | |

$[OH^-] = ?$

$[H_3O^+] = ?$





## Step 2: $[H_3O^+]$ when "just enough" base added

$V_b = 100.$ mL of $c_b = 0.40$ M of $OH^-$ is combined with $V_a = 100.$ mL of $c_a = 0.40$ M of HA, $K_a = 1.0 \times 10^{-6}$ and $K_b = K_w / K_a = 1.0 \times 10^{-8}$

| | $A^-(aq)$ | $HA(aq)$ | $OH^-(aq)$ | $Q$ |
|---|---|---|---|---|
| Initial | 0.20 | 0 | $10^{-7}$ | $0 < K_b$ |
| Change | $-x$ | $+x$ | $+x$ | |
| Equilibrium | $0.20 - x$ | $x$ | $10^{-7} + x$ | $K_b$ |
| Approximate | $\approx 0.20$ | $x$ | $\approx x$ | $K_b$ |

$[OH^-] = x = \sqrt{K_b \times [A^-]} = \sqrt{1.0 \times 10^{-8} \times 0.20} = 4.5 \times 10^{-5}$

$[H_3O^+] = K_w / [OH^-] = \frac{1.0 \times 10^{-14}}{4.5 \times 10^{-5}} = 2.2 \times 10^{-10}$



 