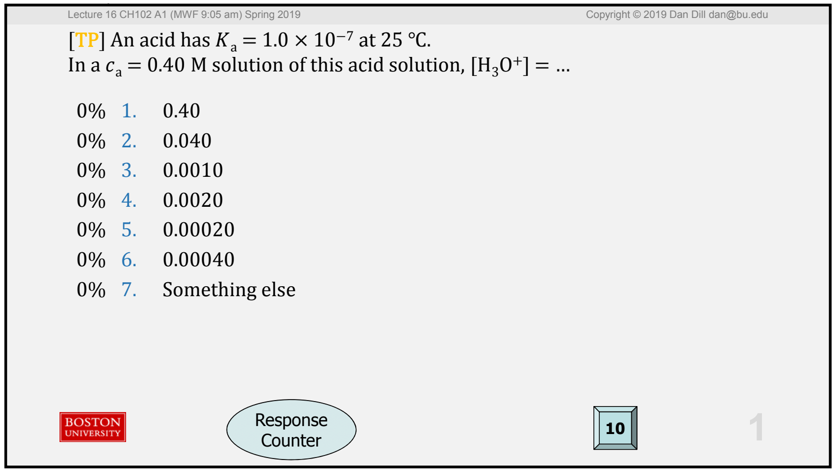
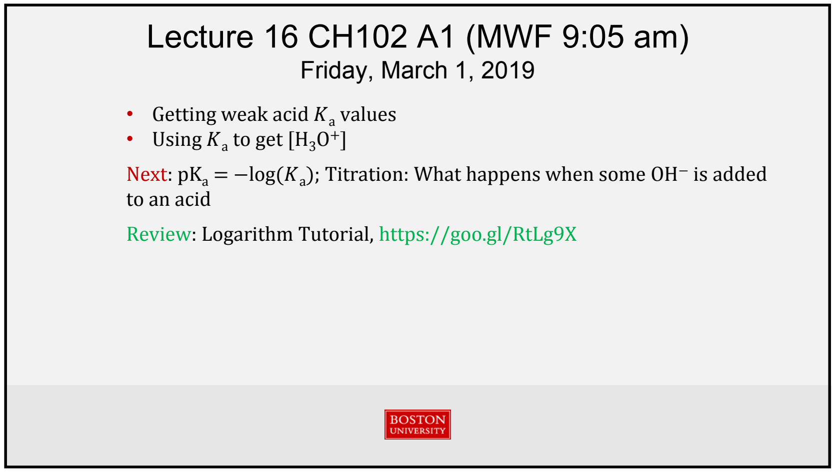


[TP] An acid has $K_a = 1.0 \times 10^{-7}$ at 25 °C.
In a $c_a = 0.40$ M solution of this acid solution, $[H_3O^+]$ = …

0%	1.	0.40
0%	2.	0.040
0%	3.	0.0010
0%	4.	0.0020
0%	5.	0.00020
0%	6.	0.00040
0%	7.	Something else

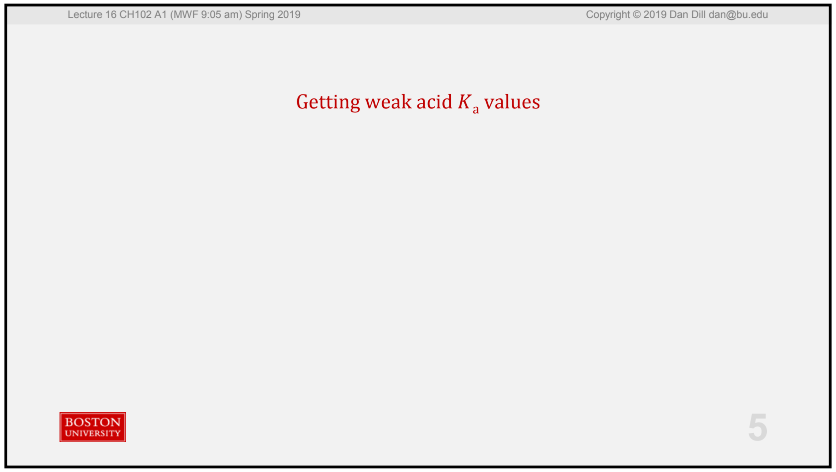

Lecture 16 CH102 A1 (MWF 9:05 am)

Friday, March 1, 2019

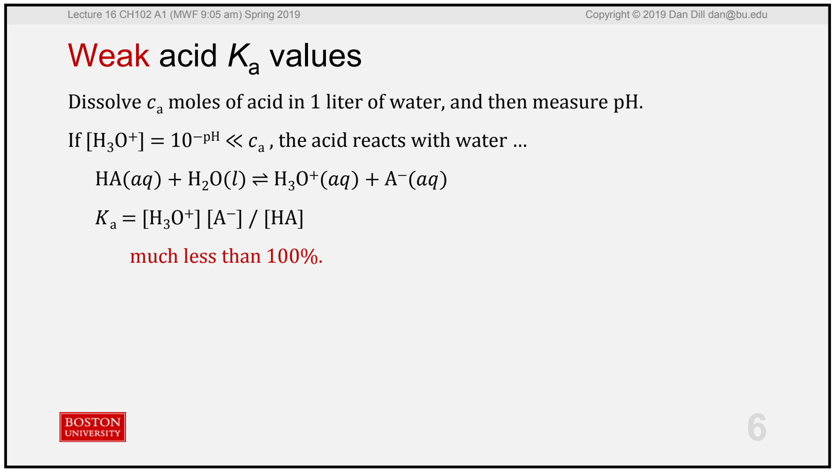
- Getting weak acid K_a values
- Using K_a to get $[H_3O^+]$

Next: $pK_a = -\log(K_a)$; Titration: What happens when some OH^- is added to an acid

Review: Logarithm Tutorial, https://goo.gl/RtLg9X



Getting weak acid K_a values



Weak acid K_a values

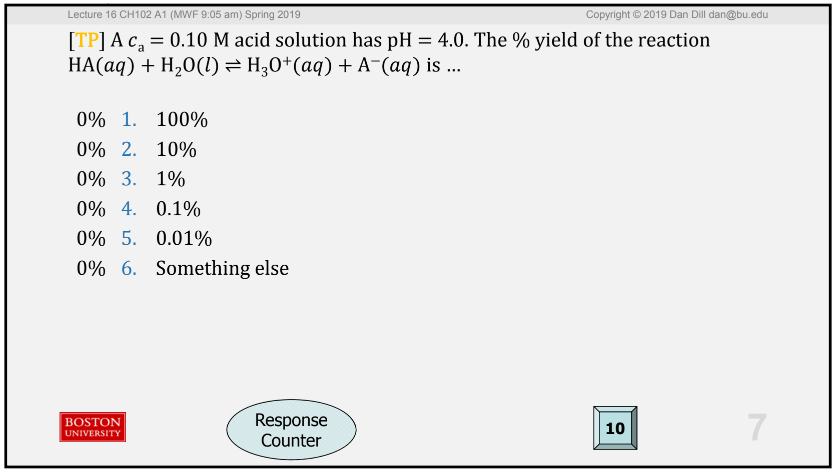
Dissolve c_a moles of acid in 1 liter of water, and then measure pH.

If $[H_3O^+] = 10^{-pH} \ll c_a$, the acid reacts with water …

$HA(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + A^-(aq)$

$K_a = [H_3O^+]\,[A^-] / [HA]$

much less than 100%.

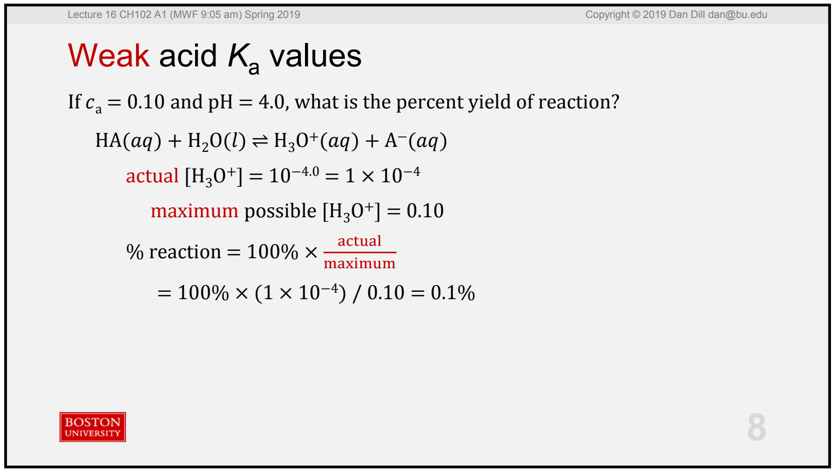


[TP] A $c_a = 0.10$ M acid solution has pH = 4.0. The % yield of the reaction $HA(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + A^-(aq)$ is ...

0% 1. 100%
0% 2. 10%
0% 3. 1%
0% 4. 0.1%
0% 5. 0.01%
0% 6. Something else

Response Counter

10



Weak acid K_a values

If $c_a = 0.10$ and pH = 4.0, what is the percent yield of reaction?

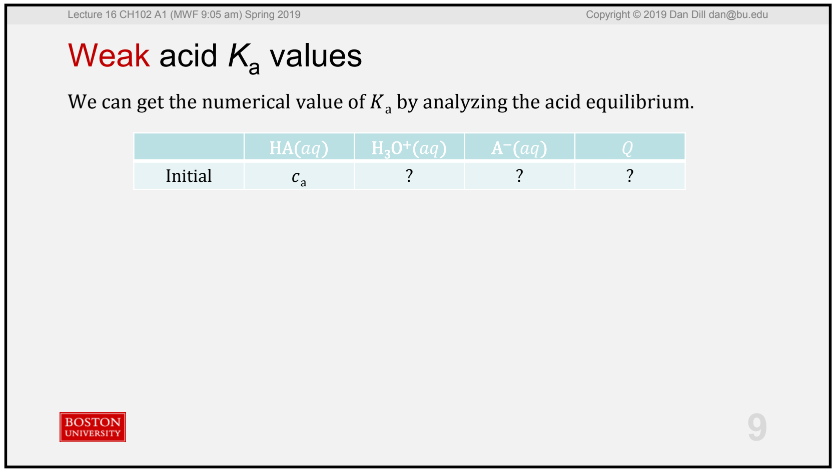
$HA(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + A^-(aq)$

actual $[H_3O^+] = 10^{-4.0} = 1 \times 10^{-4}$

maximum possible $[H_3O^+] = 0.10$

$$\% \text{ reaction} = 100\% \times \frac{\text{actual}}{\text{maximum}}$$

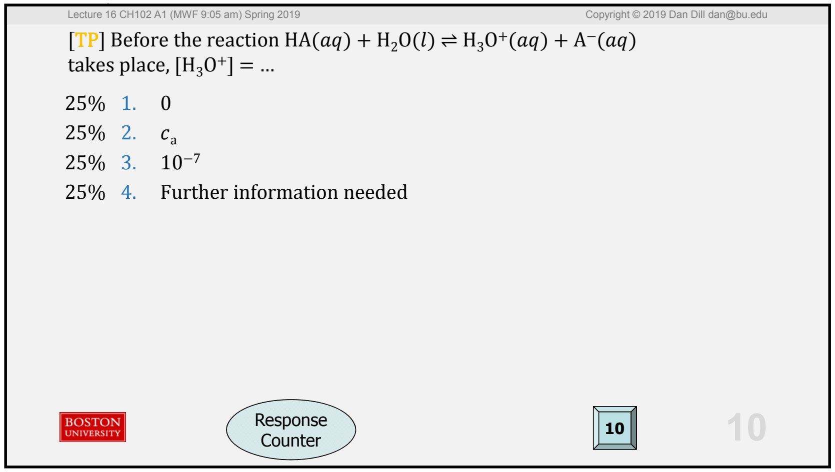
$$= 100\% \times (1 \times 10^{-4}) / 0.10 = 0.1\%$$



Weak acid K_a values

We can get the numerical value of K_a by analyzing the acid equilibrium.

	$HA(aq)$	$H_3O^+(aq)$	$A^-(aq)$	Q
Initial	c_a	?	?	?



[TP] Before the reaction $HA(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + A^-(aq)$ takes place, $[H_3O^+]$ = ...

25% 1. 0
25% 2. c_a
25% 3. 10^{-7}
25% 4. Further information needed

Response Counter

10

[TP] Before the reaction $HA(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + A^-(aq)$ takes place, at 25 °C, $[H_3O^+]$ = ...

25% 1. 0
25% 2. c_a
25% 3. 10^{-7}
25% 4. Further information needed

Response Counter

10

[TP] Before the reaction $HA(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + A^-(aq)$ takes place, $[A^-]$ = ...

25% 1. 0
25% 2. c_a
25% 3. 10^{-7}
25% 4. Further information needed

Response Counter

10

Weak acid K_a values

We can get the numerical value of K_a by analyzing the acid equilibrium.

	$HA(aq)$	$H_3O^+(aq)$	$A^-(aq)$	Q
Initial	c_a	10^{-7}	0	0

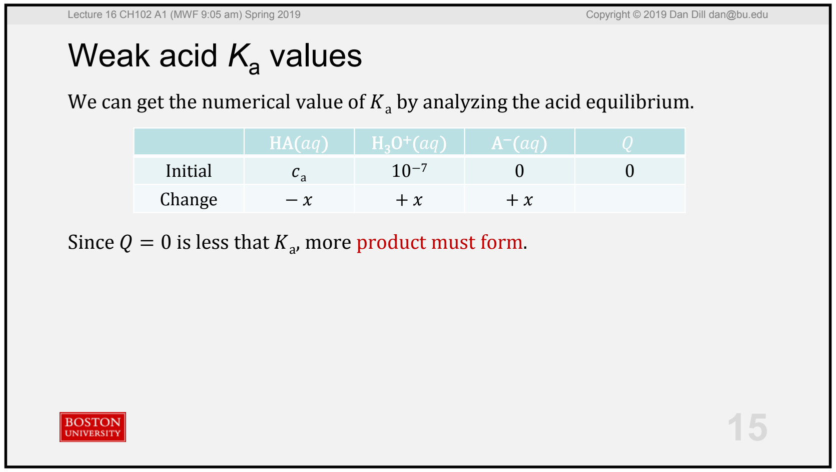
If we assume 25 °C.

Weak acid K_a values

We can get the numerical value of K_a by analyzing the acid equilibrium.

	$HA(aq)$	$H_3O^+(aq)$	$A^-(aq)$	Q
Initial	c_a	10^{-7}	0	0
Change	?	?	?	

What change is needed to achieve equilibrium?

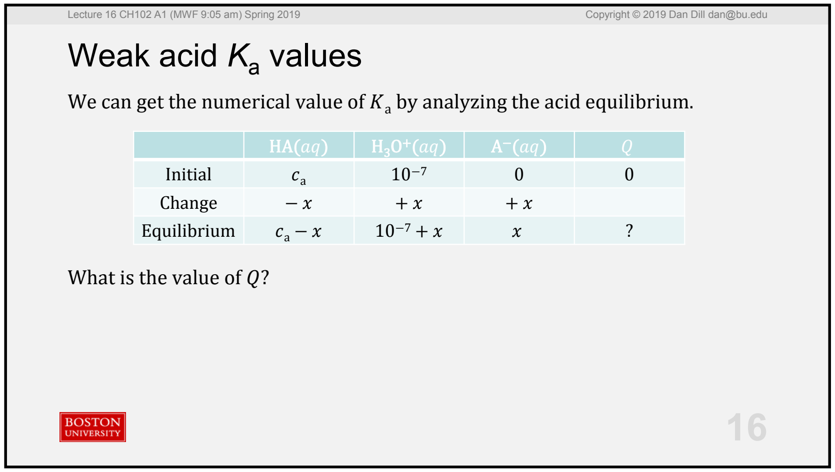


Weak acid K_a values

We can get the numerical value of K_a by analyzing the acid equilibrium.

	$HA(aq)$	$H_3O^+(aq)$	$A^-(aq)$	Q
Initial	c_a	10^{-7}	0	0
Change	$-x$	$+x$	$+x$	

Since $Q = 0$ is less that K_a, more product must form.

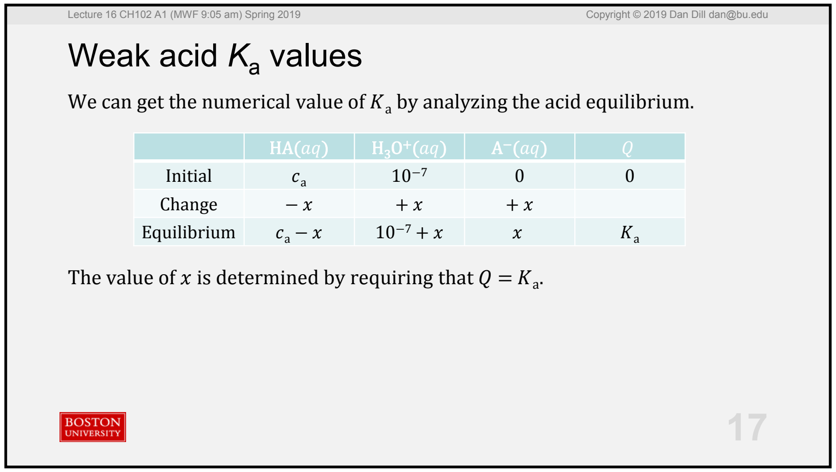


Weak acid K_a values

We can get the numerical value of K_a by analyzing the acid equilibrium.

	$HA(aq)$	$H_3O^+(aq)$	$A^-(aq)$	Q
Initial	c_a	10^{-7}	0	0
Change	$-x$	$+x$	$+x$	
Equilibrium	$c_a - x$	$10^{-7} + x$	x	?

What is the value of Q?

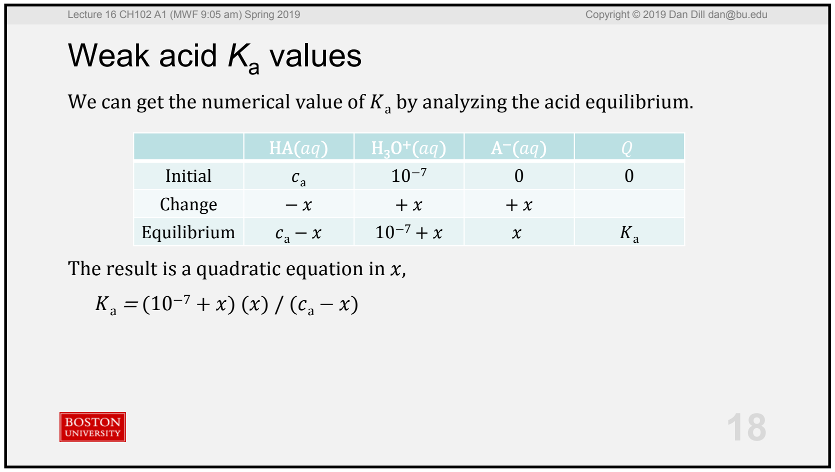


Weak acid K_a values

We can get the numerical value of K_a by analyzing the acid equilibrium.

	$HA(aq)$	$H_3O^+(aq)$	$A^-(aq)$	Q
Initial	c_a	10^{-7}	0	0
Change	$-x$	$+x$	$+x$	
Equilibrium	$c_a - x$	$10^{-7} + x$	x	K_a

The value of x is determined by requiring that $Q = K_a$.



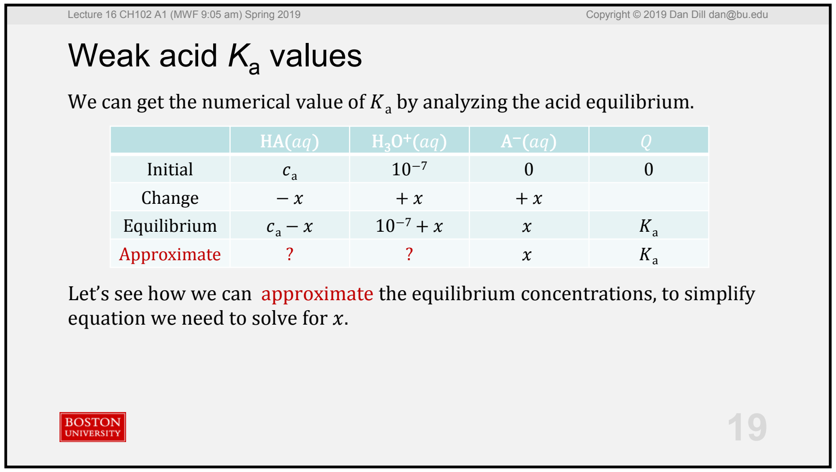
Weak acid K_a values

We can get the numerical value of K_a by analyzing the acid equilibrium.

	$HA(aq)$	$H_3O^+(aq)$	$A^-(aq)$	Q
Initial	c_a	10^{-7}	0	0
Change	$-x$	$+x$	$+x$	
Equilibrium	$c_a - x$	$10^{-7} + x$	x	K_a

The result is a quadratic equation in x,

$$K_a = (10^{-7} + x)\,(x)\,/\,(c_a - x)$$



Weak acid K_a values

We can get the numerical value of K_a by analyzing the acid equilibrium.

	$HA(aq)$	$H_3O^+(aq)$	$A^-(aq)$	Q
Initial	c_a	10^{-7}	0	0
Change	$-x$	$+x$	$+x$	
Equilibrium	$c_a - x$	$10^{-7} + x$	x	K_a
Approximate	?	?	x	K_a

Let's see how we can approximate the equilibrium concentrations, to simplify equation we need to solve for x.

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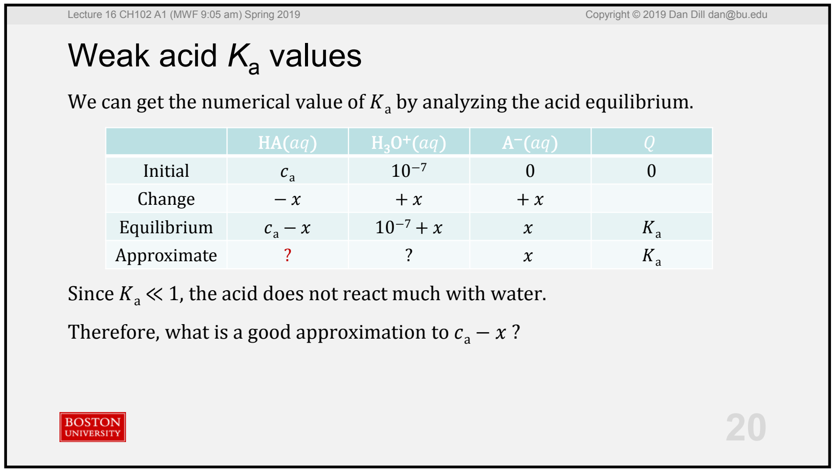

Weak acid K_a values

We can get the numerical value of K_a by analyzing the acid equilibrium.

	$HA(aq)$	$H_3O^+(aq)$	$A^-(aq)$	Q
Initial	c_a	10^{-7}	0	0
Change	$-x$	$+x$	$+x$	
Equilibrium	$c_a - x$	$10^{-7} + x$	x	K_a
Approximate	?	?	x	K_a

Since $K_a \ll 1$, the acid does not react much with water.

Therefore, what is a good approximation to $c_a - x$?

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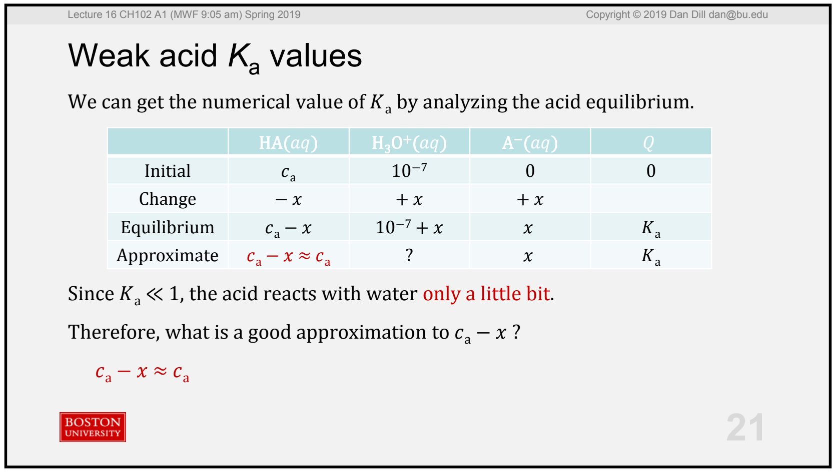

Weak acid K_a values

We can get the numerical value of K_a by analyzing the acid equilibrium.

	$HA(aq)$	$H_3O^+(aq)$	$A^-(aq)$	Q
Initial	c_a	10^{-7}	0	0
Change	$-x$	$+x$	$+x$	
Equilibrium	$c_a - x$	$10^{-7} + x$	x	K_a
Approximate	$c_a - x \approx c_a$	?	x	K_a

Since $K_a \ll 1$, the acid reacts with water only a little bit.

Therefore, what is a good approximation to $c_a - x$?

$c_a - x \approx c_a$

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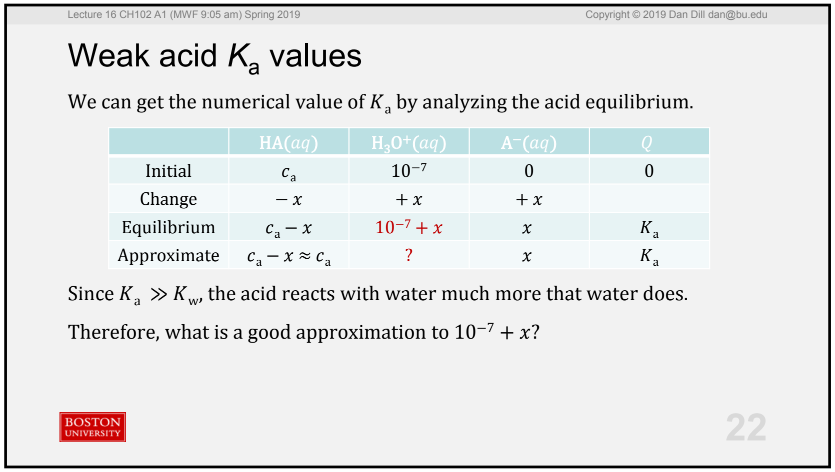

Weak acid K_a values

We can get the numerical value of K_a by analyzing the acid equilibrium.

	$HA(aq)$	$H_3O^+(aq)$	$A^-(aq)$	Q
Initial	c_a	10^{-7}	0	0
Change	$-x$	$+x$	$+x$	
Equilibrium	$c_a - x$	$10^{-7} + x$	x	K_a
Approximate	$c_a - x \approx c_a$	?	x	K_a

Since $K_a \gg K_w$, the acid reacts with water much more that water does.

Therefore, what is a good approximation to $10^{-7} + x$?

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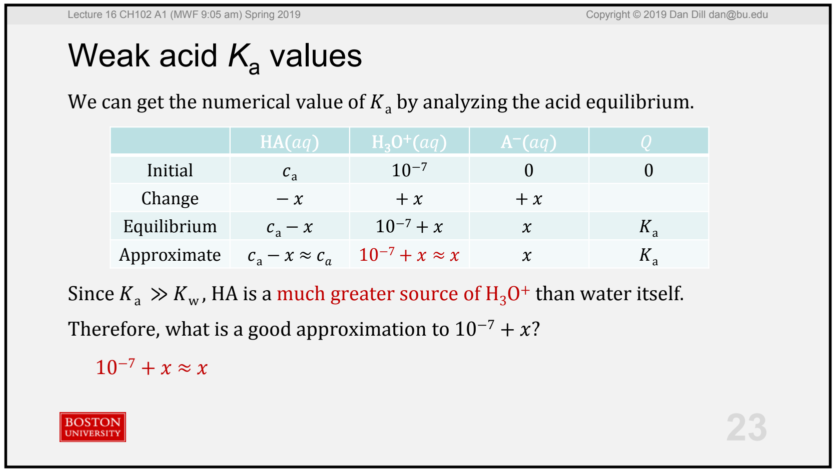


Weak acid K_a values

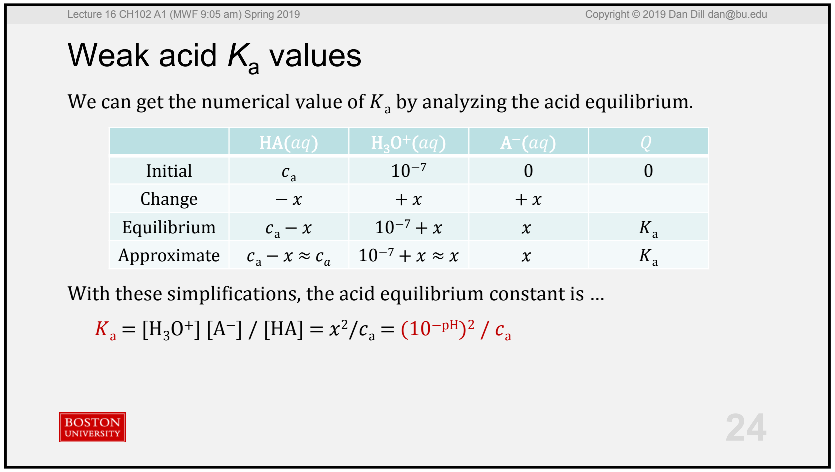
We can get the numerical value of K_a by analyzing the acid equilibrium.

	HA(*aq*)	H_3O^+(*aq*)	A^-(*aq*)	*Q*
Initial	c_a	10^{-7}	0	0
Change	$-x$	$+x$	$+x$	
Equilibrium	$c_a - x$	$10^{-7} + x$	x	K_a
Approximate	$c_a - x \approx c_a$	$10^{-7} + x \approx x$	x	K_a

Since $K_a \gg K_w$, HA is a much greater source of H_3O^+ than water itself.

Therefore, what is a good approximation to $10^{-7} + x$?

$10^{-7} + x \approx x$



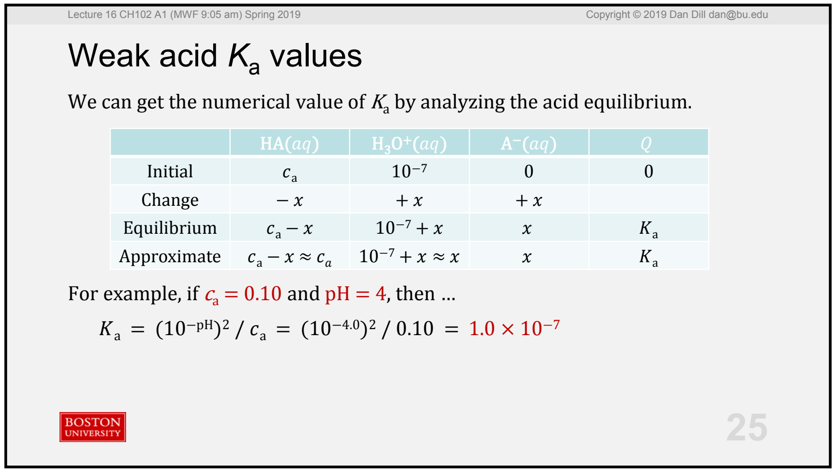
Weak acid K_a values

We can get the numerical value of K_a by analyzing the acid equilibrium.

	HA(*aq*)	H_3O^+(*aq*)	A^-(*aq*)	*Q*
Initial	c_a	10^{-7}	0	0
Change	$-x$	$+x$	$+x$	
Equilibrium	$c_a - x$	$10^{-7} + x$	x	K_a
Approximate	$c_a - x \approx c_a$	$10^{-7} + x \approx x$	x	K_a

With these simplifications, the acid equilibrium constant is ...

$K_a = [H_3O^+]\,[A^-] / [HA] = x^2/c_a = (10^{-pH})^2 / c_a$



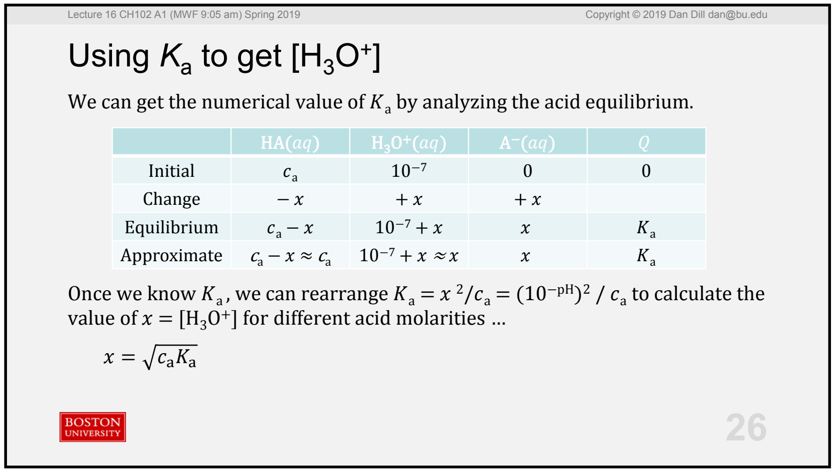
Weak acid K_a values

We can get the numerical value of K_a by analyzing the acid equilibrium.

	HA(*aq*)	H_3O^+(*aq*)	A^-(*aq*)	*Q*
Initial	c_a	10^{-7}	0	0
Change	$-x$	$+x$	$+x$	
Equilibrium	$c_a - x$	$10^{-7} + x$	x	K_a
Approximate	$c_a - x \approx c_a$	$10^{-7} + x \approx x$	x	K_a

For example, if $c_a = 0.10$ and pH = 4, then ...

$K_a = (10^{-pH})^2 / c_a = (10^{-4.0})^2 / 0.10 = 1.0 \times 10^{-7}$



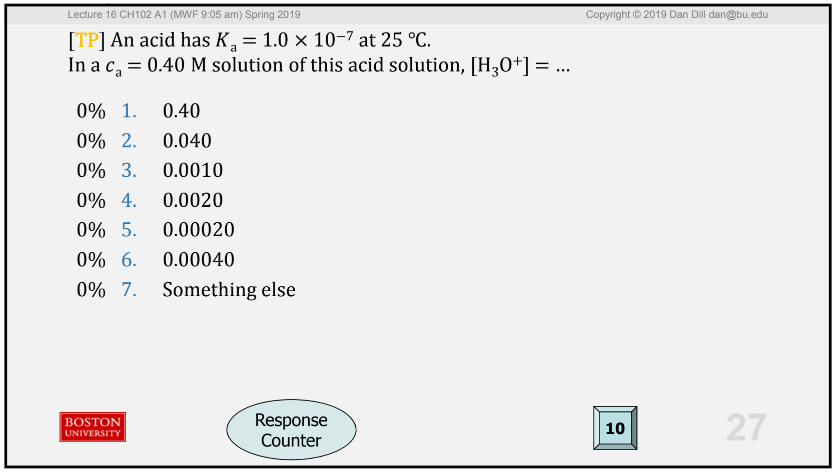
Using K_a to get $[H_3O^+]$

We can get the numerical value of K_a by analyzing the acid equilibrium.

	HA(*aq*)	H_3O^+(*aq*)	A^-(*aq*)	*Q*
Initial	c_a	10^{-7}	0	0
Change	$-x$	$+x$	$+x$	
Equilibrium	$c_a - x$	$10^{-7} + x$	x	K_a
Approximate	$c_a - x \approx c_a$	$10^{-7} + x \approx x$	x	K_a

Once we know K_a, we can rearrange $K_a = x^2/c_a = (10^{-pH})^2 / c_a$ to calculate the value of $x = [H_3O^+]$ for different acid molarities ...

$x = \sqrt{c_a K_a}$

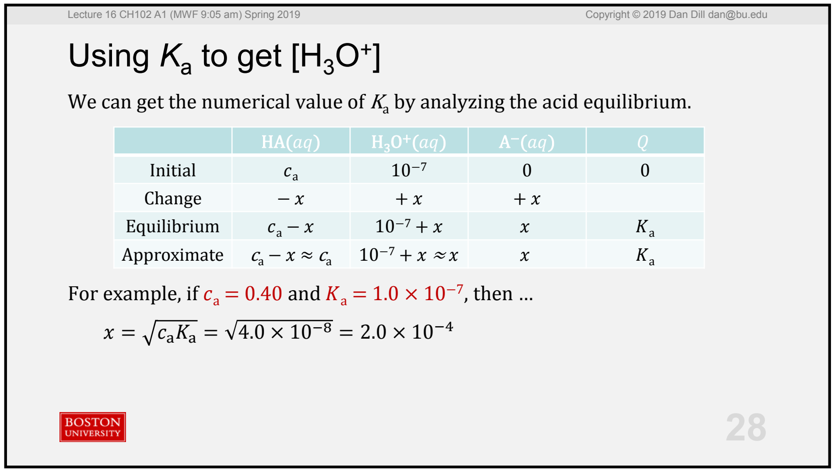


[TP] An acid has $K_a = 1.0 \times 10^{-7}$ at 25 °C.
In a $c_a = 0.40$ M solution of this acid solution, $[H_3O^+]$ = …

0% 1. 0.40
0% 2. 0.040
0% 3. 0.0010
0% 4. 0.0020
0% 5. 0.00020
0% 6. 0.00040
0% 7. Something else

Response Counter

10



Using K_a to get $[H_3O^+]$

We can get the numerical value of K_a by analyzing the acid equilibrium.

	$HA(aq)$	$H_3O^+(aq)$	$A^-(aq)$	Q
Initial	c_a	10^{-7}	0	0
Change	$-x$	$+x$	$+x$	
Equilibrium	$c_a - x$	$10^{-7} + x$	x	K_a
Approximate	$c_a - x \approx c_a$	$10^{-7} + x \approx x$	x	K_a

For example, if $c_a = 0.40$ and $K_a = 1.0 \times 10^{-7}$, then …

$$x = \sqrt{c_a K_a} = \sqrt{4.0 \times 10^{-8}} = 2.0 \times 10^{-4}$$