Slide 1		_	
		_	
		_	
	MORE ACIDS AND BASES		
		_	
	1		
		_	
		_	
Slide 2		1	
Shac 2	Let's try another little problem:	_	
	What is the pH of 0.123 M formic acid $(HCHO_2)$?		
	(Herro ₂).		
	$K_a(HCHO_2) = 1.8 \times 10^{-4}$		
		_	
		_	
	2		
		_	
		_	
		_	
Slide 3]	
		_	
	Why don't I write it as CH ₂ O ₂ ?	_	
	I could, same molecule, but by writing it		
	I could, same molecule, but by writing it HCHO ₂ I'm doing two things:		
	 I'm emphasizing it's an acid by putting the "H" out front. 	_	
	I'm indicating that only ONE "H" can come off the molecule.		
	come off the molecule.		
		_	
	3		
		_	
		_	
		_	

Not all H's are "acidic"

CH₄ - methane

It has 4 hydrogens...none of them are considered to be "acidic" because they don't easily come off.

Generally, acids have the "H" bonded to something more electronegative like "O" or a halogen.

.

Slide 5

H-O-H (acidic – H bonded to O)
H-CI (acidic – H bonded to halogen)
H-S-H (acidic – H bonded to S)
H-C... (not acidic – H bonded to C)

5

Slide 6

Let's try another little problem:

What is the pH of 0.123 M formic acid (HCHO $_{\! 2})?$

 $K_a(HCHO_2) = 1.8 \times 10^{-4}$

A. 2.03

B. 3.74

C. -1.41

D. 2.33

E. I have no clue

S		

The 1st thing we need is...

A BALANCED **EQUATION!**

Slide 8

HCHO₂

What does the formic acid react with?

How do you even know there's water? It's a solution! (M)

What happens in the reaction?

A proton moves from the acid (HCHO $_2$) to the base (H $_2$ O): HCHO $_2$ (aq) + H $_2$ O(I) \leftrightarrow CHO $_2$ -(aq) + H $_3$ O+(aq)

Slide 9

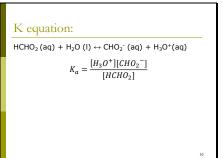
Once I have a balanced equation:

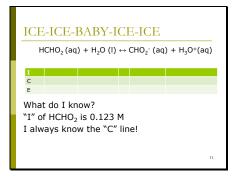
 $HCHO_2(aq) + H_2O(I) \leftrightarrow CHO_2^-(aq) + H_3O^+(aq)$

- 2 more parts:
- 2. K equation
- 3. Ice chart!

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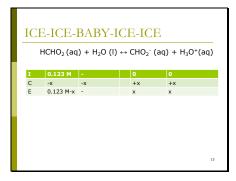
Slide	10
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Let's try another little problem:	
What is the pH of 0.123 M formic acid (HCHO $_2$)?	
$K_a(HCHO_2) = 1.8 \times 10^{-4}$	
	12

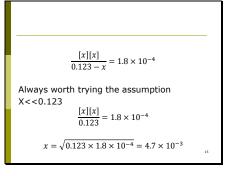
	-	-	



Slide 14

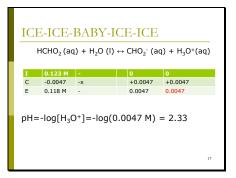
$$K_a = \frac{[H_3 0^+][CHO_2^-]}{[HCHO_2]}$$

$$K_a = \frac{[x][x]}{0.123-x} = 1.8\times 10^{-4}$$
 Always worth trying the assumption X<<0.123





$$x = \sqrt{0.123 \times 1.8 \times 10^{-4}} = 4.7 \times 10^{-3}$$
 Good assumption?
$$\frac{0.123}{20} = 6.15 \times 10^{-3}$$
 4.7x10⁻³<6.15x10⁻³ so it's a good assumption! (although it's close)



Sample Problem	
Calculate the pH of a 1x10 ⁻³ M solution of oxalic acid.	
	18

		9
lic		

Solution

As always, we 1st need a balanced equation. Or, in this case, 2 balanced equations! $\text{H}_2\text{C}_2\text{O}_4 \text{ (aq)} + \text{H}_2\text{O}_{\text{(j)}} \leftrightarrow \text{HC}_2\text{O}_4^+ \text{ (aq)} + \text{H}_3\text{O}^+ \text{ (aq)} \\ \text{K}_{a1} = 6.5\text{x}10^{-2} \\ \text{HC}_2\text{O}_4^- \text{ (aq)} + \text{H}_2\text{O}_{\text{(j)}} \leftrightarrow \text{C}_2\text{O}_4^{-2} \text{ (aq)} + \text{H}_3\text{O}^+ \text{ (aq)} \\ \text{K}_{a2} = 6.1\text{x}10^{-5}$

2 Equilbria = 2 ICE charts!

Slide 20

Polyprotic Acids (or bases)

- □ Some acids are capable of donating more than one proton
- $\hfill\Box$ Some bases are capable of accepting more than one proton

When this occurs, you will have more than one equilibrium to consider [YAY! We love equilibrium!]

Slide 21

How would you know it's a polyprotic acid?

- 2 ways:
- 1. Chemical formula
- 2. K_a (or K_b for bases):

Slide 22]		
	Some Polyprotic Acids			
	□ H ₂ SO ₄ – sulfuric acid			
	□ H ₂ SO ₃ - sulfurous acid	-	 	
	□ H_3PO_4 – phosphoric acid □ $H_2C_2O_4$ – oxalic acid			
	□ H ₂ S - hydrosulfuric acid	_	 	
	□ H ₂ CO ₃ – carbonic acid			
	22	-		
	п]		
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		_	 	
		-	 	
ci: I aa		ז		
Slide 23	IZ	-	 	
	K_{a}			
	If you look up the acid on the table of K _a values, it will have more than one K _a !	_	 	
	,			
		-	 	
		-	 	
	23			
		4	 	
		-	 	
		-	 	
Slide 24] _	 	
	Sample Problem			
	Calculate the pH of a 1x10 ⁻³ M solution of oxalic acid.			
	oxalic acid.	-	 	
		-	 	
		_	 	
	24			
ļ		J		
		-	 	
		-	 	

Solution

As always, we 1st need a balanced equation. Or, in this case, 2 balanced equations! $\text{H}_2\text{C}_2\text{O}_4 \text{ (aq)} + \text{H}_2\text{O}_{\text{(j)}} \leftrightarrow \text{HC}_2\text{O}_4^+ \text{ (aq)} + \text{H}_3\text{O}^+ \text{ (aq)} \\ \text{K}_{a1} = 6.5\text{x}10^{-2} \\ \text{HC}_2\text{O}_4^- \text{ (aq)} + \text{H}_2\text{O}_{\text{(j)}} \leftrightarrow \text{C}_2\text{O}_4^{-2} \text{ (aq)} + \text{H}_3\text{O}^+ \text{ (aq)} \\ \text{K}_{a2} = 6.1\text{x}10^{-5}$

2 Equilbria = 2 ICE charts!

Slide 26

Just take them 1 at a time...

```
{\rm H_{2}C_{2}O_{4\;(aq)}+\;H_{2}O_{\;(l)}\leftrightarrow HC_{2}O_{4}{}^{-}_{\;(aq)}+\;H_{3}O^{+}_{\;\;(aq)}}
I
С
                1x10<sup>-3</sup>
```

Slide 27

$$\mathsf{K}_{\mathsf{a1}} = 6.5 \mathsf{x} 10^{-2} = \frac{[H_3 O +][HC_2 O_4^{-}]}{[H_2 C_2 O_4^{-}]}$$
$$= \frac{(x)(x)}{(x)}$$

Try x<<1x10⁻³

$$6.5x10 - 2 = \frac{(x)(x)}{1 \times 10^{-3} - x} \approx \frac{x^2}{1 \times 10^{-3}}$$

 $6.5 \times 10^{-5} = x^2$

 $x=8.06x10^{-3}$ which is NOT much less than $1x10^{-3}$

We have to do it the Quadratic Way!

$$K_{a1} = 6.5 \times 10^{-2} = \frac{(x)(x)}{1 \times 10^{-3} - x}$$

$$6.5 \times 10^{-5} - 6.5 \times 10^{-2}x = x^{2}$$

$$0 = 6.5 \times 10^{-5} - = x^{2} + 6.5 \times 10^{-2}x - 6.5 \times 10^{-5}$$

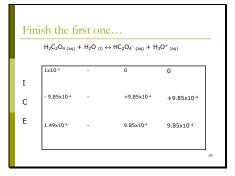
$$x = \frac{-b \pm \sqrt{b^{2} - 4ac}}{2a}$$

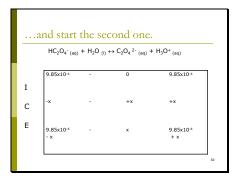
$$x = \frac{-6.5 \times 10^{-2} \pm \sqrt{(6.5 \times 10^{-2})^{2} - 4(1)(-6.5 \times 10^{-5})}}{2(1)}$$

$$x = \frac{-6.5 \times 10^{-2} \pm \sqrt{4.485 \times 10^{-3}}}{2} = \frac{-6.5 \times 10^{-2} \pm 6.697 \times 10^{-2}}{2}$$

$$x = 9.85 \times 10^{-4} \ OR - 0.066$$

Slide 29





$$K_{a2} = {}_{6.1}x10 - 5 = \frac{[H_30^{-4}][C_2O_4^{-2}]}{[HC_2O_4^{-1}]}$$

$$= \frac{(x)(9.85 \times 10^{-4} + x)}{9.85 \times 10^{-4} - x}$$
Let's try x<< 9.85x10⁻⁴

$$6.1x10 - 5 = \frac{(x)(9.85 \times 10^{-4} + x)}{9.85 \times 10^{-4} - x}$$

$$\approx \frac{x(9.85 \times 10^{-4})}{9.85 \times 10^{-4}}$$
6.1x10⁻⁵ = x
6.1x10⁻⁵ is NOT much less than 9.85x10⁻⁴
Dang it all!

Slide 32

$$K_{a2} = \frac{6.1 \times 10^{-5} = \frac{[H_3O +][C_2O_4^{-7}]}{[HC_2O_4^{-7}]}}{6.1\times10^{-5} = \frac{(x)(9.85\times10^{-4} + x)}{9.85\times10^{-4} + x}}$$

$$6.0085\times10^{-8} - 6.1\times10^{-5} \times = 9.85\times10^{-4} \times + x^2$$

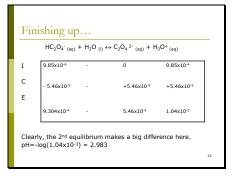
$$0 = x^2 + 1.046\times10^{-3} \times - 6.0085\times10^{-8}$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2}$$

$$x = \frac{-1.046 \times 10^{-3} \pm \sqrt{(1.046 \times 10^{-3})^2 - 4(1)(-6.0085 \times 10^{-8})}}{2}$$

$$x = \frac{-1.046 \times 10^{-3} \pm 0.155 \times 10^{-3}}{2}$$

$$x = 5.46 \times 10^{-5} OR - 1.1 \times 10^{-3}$$



Slide 34	Do I need to do this for all acids and bases? Most, but not all. There is a distinction between a "strong acid" and a "weak acid". (Or, a "strong base" and a "weak base".		
Slide 35	"strong" isn't STRONG, it's "complete"		
	Would you rather drink a strong acid or a weak acid?		
	Depends on the concentration.		
	"strong" = complete dissociation "weak" = partial dissociation		
	35		
Slide 36	Would you rather drink a strong acid]	
	or a weak acid?		
	A. Strong в. Weak c. Neither		
	D. It's a flawed question.		
	36		
			
			

$HA + H_2O = A^- + H_3O^+$

Strong = "→"

Weak = "↔"

$$K_\alpha = \frac{[H_3O^+][A^-]}{[HA]}$$

Complete dissociation means it all reacts so there is ZERO HA left. In other words, ${\rm K_a}$ is HUGE

Partial dissociation means there is some HA left. In other words, \mathbf{K}_{a} is a number.

Slide 38

Appendix II (your BEST friend)

If you look at the Table of $\rm K_a$ in Appendix II you'll see numbers from $10^{\text{-}1}$ down to $10^{\text{-}13}.$ All are "weak acids".

If you look on page 665, you'll see a short list of "strong acids". These actually have $\rm K_a$ of $\rm 10^6$ or higher. They are soooo big, they are usually considered infinite.

38

Slide 39

Strong Acids

H₂SO₄ HNO₃

HCI

HCIO₄

HBr HI

H with a big electronegative group.

•			
,	 		
,	 		
,	 		
,	 		



Strong Bases (p. 682)

LiOH NaOH

KOH Sr(OH)₂

Ca(OH)₂ Ba(OH)₂

Alkali metals (hey! Where'd the name come from! $\ensuremath{\circledcirc}$) with hydroxide ions.

40

Slide 41

Question

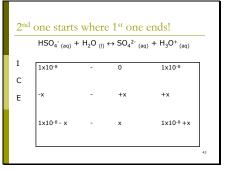
What is the pH of $1x10^{-8}$ M H_2SO_4 ? K_{a1} = infinite K_{a2} = $1.0x10^{-2}$

41

Slide 42

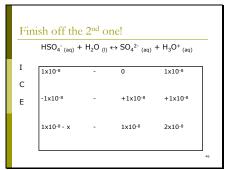
Just take them 1 at a time...

•				
•				
•		 		



Slide 44

```
K_{32} = 1.0x10^{-2} = \underbrace{[H_{2}0^{+}][SO_{c}^{+}]}_{[HSO_{c}^{+}]}
1.0x10^{-2} = \underbrace{(1x10^{+}x)(x)}_{[HSO_{c}^{+}]}
1.0x10^{-10} - 1.0x10^{-2} x = 1.0x10^{-6} x + x2
0 = x^{2} + 1.000001x10^{-2} x - 1.0x10^{-10}
x = -b + f - SQRT(b^{2} - 4ac)
x = -1.000001x10^{-2} + f - SQRT((1.000001x10^{-2})^{2} - 4(1)(-1.0x10^{-10}))
x = -1.000001x10^{-2} + f - SQRT(1.000006x10^{-4})
x = -1.000001x10^{-2} + f - 1.000003x10^{-2}
x = -1.000001x10^{-2} + f - 1.000003x10^{-2}
x = -1.9999998x10^{-9} = 1x10^{-8}
```

Slide 47

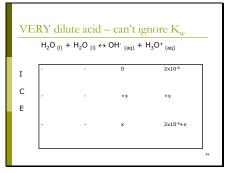
pH=-log(2x10-8)
pH=7.699

How do you feel about that?

A. Happy
B. Sad
C. Confused
D. Mad
E. what the hell kind of question is that?

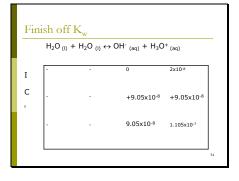
Slide 48

AND START THE 3RD ONE!!!!!!!



Slide 50

```
\begin{split} K_w &= 1.0x10^{-14} = [H_3O^+][OH^-] = (2.0x10^{-8} + x)(x) \\ -1.0x10^{-14} &= 2.0x10^{-8} x + x^2 \\ 0 &= x^2 + 2.0x10^{-8} x - 1.0x10^{-14} \\ x &= -b + t - SQRT(b^2 - 4ac) \\ 2a \\ x &= -2.0x10^{-8} + t - SQRT((2.0x10^{-8})^2 - 4(1)(-1.0x10^{-14})) \\ 2(1) \\ x &= -2.0x10^{-8} + t - SQRT(4.04x10^{-14}) \\ 2 \\ x &= -2.0x10^{-8} + t - 2.00998x10^{-7} \\ x &= \frac{1.809975x10^{-7}}{2} \\ x &= 9.04988x10^{-8} = 9.05x10^{-8} \end{split}
```







Strong acids, completely dissociate

So 0.100 M HCl yields 0.100 M H_3O^+ . pH = $-log[H_3O^+]$ = -log(0.100) = 1.0

(I don't even need the ICE chart ⊗)

55

Slide 56

What is the pH of $1x10^{-7}$ M HCl?

HCl is still a strong acid, so it completely dissociates.

 $1x10^{-7}\,\text{M}$ HCl gives you $1x10^{-7}\,\text{M}$ H_3O^+ pH = - log (1x10^-7) = 7

Is that it, are we done? A really dilute acid is neutral. Seems reasonable.

56

Slide 57

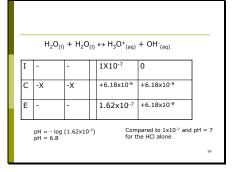
There is another equilibrium!

$$\begin{split} &H_2O_{(I)} \,+\, H_2O_{(I)} \leftrightarrow H_3O^+_{(aq)} \,+\, OH^-_{(aq)} \\ &K_w \,=\, 1.0 \,\, x10^{-14} \end{split}$$

And H₃O⁺ is part of it!

Slide 58

	H ₂ O ₍₁₎	+ H ₂ O _(I)	$\leftrightarrow H_3O^+_{(aq)}$	+ OH ⁻ (aq)			
I	-	-	1X10 ⁻⁷	0			
С	-X	-X	+X	+X			
Е	-	-	1.0x10 ⁻⁷ +x	х			



Slide 60

When do I need to consider K_w ?

- 1. The acid is very dilute 2. The acid is very weak (K_a less than 10^{-12})
- 3. Both 1 and 2



A very weak acid problem

What is the pH of a 1 x 10^{-7} M solution of HOAc?

 $K_{a,HOAc} = 1.8 \times 10^{-5}$

61

Slide 62

ICE ICE Baby ICE ICE

Slide 63

K,

$$K_a = 1.8 \times 10^{-5} = \frac{[OAc^-][H_3O^+]}{[HOAc]}$$
$$= \frac{(x)(x)}{1 \times 10^{-7} - x} = \frac{x^2}{1 \times 10^{-7} - x}$$

I will not assume x is small since $1x10^{-7}$ is pretty small itself (you could try it)

$$1.8x10^{-12} - 1.8x10^{-5} x = x^2$$
$$0 = x^2 + 1.8x10^{-5} x - 1.8x10^{-12}$$

•			
•			
•			
•			

Solving for x

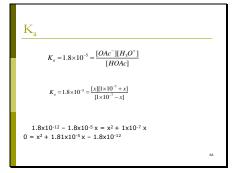
 $0 = x^2 + 1.8x10^{-5}x - 1.8x10^{-12}$

- $\begin{array}{l} x = -b \ +/- \ SQRT(b^2-4ac) \\ 2a \\ x = -1.8x10^5 \ +/- \ SQRT((1.8x10^{-5})^2-4(1)(-1.8x10^{-12})) \\ 2(1) \\ x = -1.8x10^5 \ +/- \ SQRT(3.24x10^{-10}+7.2x10^{-12}) \\ x = -1.8x10^5 \ +/- \ SQRT(3.312x10^{-10}) \\ x = -1.8x10^5 \ +/- \ SQRT(3.312x10^{-10}) \\ x = -1.8x10^5 \ +/- \ 1.8199x10^5 \\ x = 9.95 \ x10^{-8} \ M \end{array}$

Slide 65

Suppose I already have $1 \times 10^{-7} \,\mathrm{M} \,[\mathrm{H}_3\mathrm{O}^+]$ from the K_w ?

```
\mathsf{HOAc}_{\ (\mathsf{aq})} + \ \mathsf{H}_2\mathsf{O}_{\ (\mathsf{I})} \leftrightarrow \mathsf{H}_3\mathsf{O^+}_{\ (\mathsf{aq})} + \ \mathsf{OAc^-}_{\ (\mathsf{aq})}
I
С
Е
                      1x10<sup>-7</sup>-x
                                                                                               1×10<sup>-7</sup> + x x
```



Solving for x

 $0 = x^2 + 1.81x10^{-5}x - 1.8x10^{-12}$

- $x = 9.88 \times 10^{-8} M$

Slide 68

But I already have $1 \times 10^{-7} \, \mathrm{M} \, [\mathrm{H}_3\mathrm{O}^+]$ from the K_w before I even add the HOAc

```
HOAc _{(aq)} + H_2O _{(I)} \leftrightarrow H_3O^+ _{(aq)} + OAc^- _{(aq)}
I
С
            - 9.88 x10<sup>-5</sup>M
                                                 +9.88 x10-4M
                                                                  +9.88 ×10-8 M
Е
                                                 1.98×10-8 M
                                                                     9.88 x10-8 M
```

Slide 69

Comparing the 2 numbers

- - $[H_3O^+] = 9.95 \times 10^{-8} M$
- ${\color{red}\square}$ Considering K_w and $K_a,$ I calculate:
 - $[H_3O^+] = 1.988 \times 10^{-7} M$

A significant difference!!

lid	7	

Polyprotic acids have multiple equilibria

Phosphoric acid, H₃PO₄, is **tri**protic, so there are three equilibria to consider:

70

Slide 71

Polyprotic acids have multiple equilibria

Phosphoric acid, H_3PO_4 , is **tri**protic, so there are three equilibria to consider: H_3PO_4 _(aq) + H_2O _(I) \leftrightarrow H_2PO_4 ⁻_(aq) + H_3O ⁺_(aq)

 ${\rm H_{2}PO_{4^{^{-}}(aq)} \, + \, H_{2}O_{\ (I)} \leftrightarrow {\rm HPO_{4}^{2^{-}}}_{(aq)} \, + \, {\rm H_{3}O^{+}}_{(aq)}}$

 $\mathsf{HPO_4^{2^-}}_{(\mathsf{aq})} + \, \mathsf{H_2O}_{\,\,(I)} \leftrightarrow \mathsf{PO_4^{3^-}}_{(\mathsf{aq})} + \, \mathsf{H_3O^+}_{(\mathsf{aq})}$

Each of which has a separate K_a

71

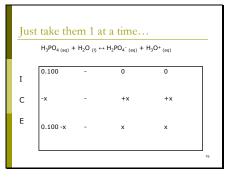
Slide 72

Polyprotic acids have multiple equilibria

Phosphoric acid, H₃PO₄, is **tri**protic, so there are three equilibria to consider: $H_3PO_{4\,(aq)} + H_2O_{(1)} \leftrightarrow H_2PO_{4}^-\,(aq) + H_3O^+\,(aq) \\ K_{a1} = 7.5 \times 10^{-3} \\ H_2PO_{4}^-\,(aq) + H_2O_{(1)} \leftrightarrow HPO_{4}^{2^-}\,(aq) + H_3O^+\,(aq) \\ K_{a2} = 6.2 \times 10^{-8} \\ HPO_{4}^{2^-}\,(aq) + H_2O_{(1)} \leftrightarrow PO_{4}^{3^-}\,(aq) + H_3O^+\,(aq) \\ K_{a3} = 5.8 \times 10^{-13}$

Each of which has a separate ${\rm K_a}$

Slide 73		_	
	When calculating the pH of Polyprotic acids, all equilibria must be consideredeven if you consider them just to dismiss them!	_	
	п	_	
		_	
		_	
Slide 74	C 1 D 11	_	
	Sample Problem Calculate the pH of a 0.100 M solution of phosphoric acid.	_	
		_	
		_	
	24	_	
		_	
		_	
Slide 75	Solution	_	
	As always, we 1st need a balanced equation. Or, in		
	H ₃ PO ₄ (aq) + H ₂ O ₀ (\rightarrow H ₂ PO ₄ (aq) + H ₃ O+ (aq) $K_{a1} = 7.5 \times 10^{3}$ (aq) + H ₃ O+ (aq) H ₂ PO ₄ (aq) + H ₂ O ₁ (\rightarrow HPO ₄ ² (aq) + H ₃ O+ (aq) $K_{a2} = 6.2 \times 10^{-8}$ HPO ₄ ^{2*} (aq) + H ₂ O ₀ (\rightarrow PO ₄ ^{3*} (aq) + H ₃ O+ (aq) $K_{a3} = 5.8 \times 10^{-13}$ (aq) + H ₃ O+ (aq)		
	3 Equilbria = 3 ICE charts!	_	
		l —	



Slide 77

$$K_{a1} = 7.5 \times 10^{-3} = \frac{[H_3 O^+][H_2 P O_4^-]}{[H_3 P O_4]} = \frac{(x)(x)}{(0.100-x)}$$
 Can we assume x<<0.100?? Never hurts to try.
$$7.5 \times 10^{-3} = \frac{(x)(x)}{(0.100-x)} \approx \frac{x^2}{0.100}$$
 7.5x10⁻⁴ = x^2 x=0.0274 which is NOT much less than 0.100 We have to do it the Quadratic Way!

$$K_{a1} = 7.5 \times 10^{-3} = \frac{[H_3 0^+][H_2 P 0_4^-]}{[H_3 P 0_4]} = \frac{(x)(x)}{(0.100 - x)}$$

$$7.5x10^-4 - 7.5x10^-3 x = x^2$$

$$0 = x^2 + 7.5x10^-3 x - 7.5x10^-4$$

$$x = -b + - \frac{5QRT(b^2 - 4ac)}{2a}$$

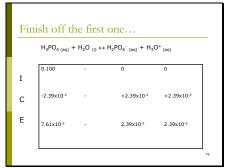
$$x = -7.5x10^{-3} + - \frac{5QRT((7.5x10^{-3})^2 - 4(1)(-7.5x10^{-4}))}{2(1)}$$

$$x = -7.5x10^{-3} + -\frac{7}{5} - \frac{5QRT(3.0563x10^{-3})}{2}$$

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$$x = -7.5x10^{-3} + -\frac{7}{5} - \frac{5QRT(3.0563x10^{-3})}{2}$$

$$x = -7.5x10^{-3} + -\frac{7}{5} - \frac{7}{5} - \frac{7}{5}$$



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```
K_{a2} = 6.2 \times 10^{-8} = \frac{[H_3 0^+][HPO_4^{2^-}]}{[H_2 PO_4^{-1}]} = \frac{(x)(0.0239 + x)}{(0.0239 - x)}
Let's try x<<0.0239
6.2 \times 10^{-8} = \frac{(x)(0.0239 + x)}{(0.0239 - x)}
\approx \frac{x(0.0239)}{0.0239}
6.2 \times 10^{-8} = x
x = 6.2 \times 10^{-8} \text{ which is much less than 0.0239}
YIPEE!
```


2	2.39x10 ⁻²	-	0	2.39x10 ⁻²	1
-	6.2x10 ⁻⁸		+6.2x10 ⁻⁸	+6.2x10 ⁻⁸	
2	2.39x10 ⁻²	-	6.2x10 ⁻⁸	2.39x10 ⁻²	
