

Slide 1

**Acid/Base Properties of Salts**

Hiding in plain sight

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Slide 2

**Recognizing Bases**

- Sometimes it seems that all acids and bases are labeled with  $H^+$  or  $OH^-$
- Remember that a base is ANYTHING that can accept a proton
- The salt formed by the dissociation of an acid is the "conjugate base" of the acid. This must mean that the salt is a base, whether it has an  $OH^-$  or not.

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Slide 3

**Pick a salt, any salt**

- How about sodium acetate,  $NaOAc$ ? An excellent choice.
- Sodium acetate is an ionic solid.
- Ionic solids dissociate in aqueous solution
- Aqueous  $NaOAc$  will exist as anions and cations.

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Slide 4

**NaOAc in aqueous solution**

$\text{NaOAc}_{(aq)} \rightarrow \text{Na}^+_{(aq)} + \text{OAc}^-_{(aq)}$

So what can we say about  $\text{Na}^+$  and  $\text{OAc}^-$  in aqueous solution?

We need to think “backwards”. How did NaOAc get the  $\text{Na}^+$  in the first place? (Or, more accurately, what is one way it could have gotten it?)

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Slide 5

Salts are products of acid/base reactions

You might recall that the reaction of an acid and a base yields a salt and water:

$\text{NaOH} + \text{HOAc} \rightarrow \text{H}_2\text{O} + \text{NaOAc}$

Keep in mind, this is the “net reaction”, it doesn’t give any detailed information on mechanisms.

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Slide 6

**A more detailed reaction**

Think of a titration:

$\text{NaOH}_{(aq)} + \text{HOAc}_{(aq)} \leftrightarrow \text{H}_2\text{O}_{(l)} + \text{NaOAc}_{(aq)}$

But what are  $\text{NaOH}_{(aq)}$  and  $\text{HOAc}_{(aq)}$ ?

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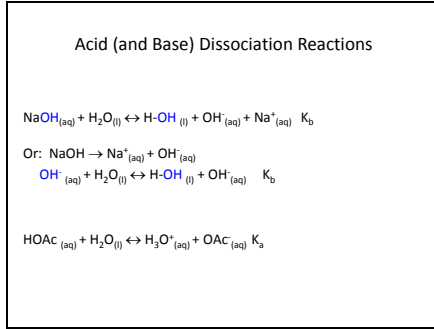
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Slide 7




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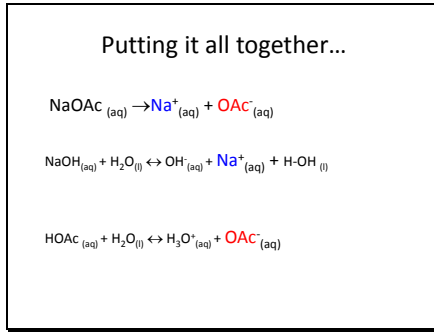
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Slide 8




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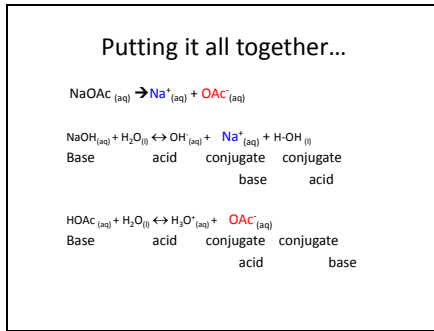
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Slide 10

In short...

We have the conjugate acid ( $\text{Na}^+$ ) of a base ( $\text{NaOH}$ ), and the conjugate base ( $\text{OAc}^-$ ) of an acid ( $\text{HOAc}$ ).

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Slide 11

You can always tell...

Take the anion and add an  $\text{H}^+$ , that'll tell you what acid the anion "came from".

Take the cation and either add an  $\text{OH}^-$  or take away an  $\text{H}^+$  and that will tell you what base the cation came from.

Ignore anything strong – it won't, it CAN'T go back!!!

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Slide 12

$K_b$  becomes  $K_a$  as  $K_a$  becomes  $K_b$

$\text{NaOAc}_{(aq)} \rightarrow \text{Na}^+_{(aq)} + \text{OAc}^-_{(aq)}$

$\text{Na}^+_{(aq)} + 2 \text{H}_2\text{O}_{(l)} \leftrightarrow \text{NaOH}_{(aq)} + \text{H}_3\text{O}^+_{(aq)}$   
(or, if you prefer)

$\text{Na}^+_{(aq)} + \text{H}_2\text{O}_{(l)} \leftrightarrow \text{NaOH}_{(aq)} + \text{H}^+_{(aq)} \quad K_a = K_w / K_b$

$\text{OAc}^-_{(aq)} + \text{H}_2\text{O}_{(l)} \leftrightarrow \text{OH}^-_{(aq)} + \text{HOAc}_{(aq)} \quad K_b = K_w / K_a$

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Slide 13

But one is strong and the other weak.

$$\text{NaOH}_{(aq)} + \text{H}_2\text{O}_{(l)} \leftrightarrow \text{H-OH}_{(l)} + \text{OH}^-_{(aq)} + \text{Na}^+_{(aq)} \quad K_b = \infty$$
$$\text{Na}^+_{(aq)} + \text{H}_2\text{O}_{(l)} \leftrightarrow \text{NaOH}_{(aq)} + \text{H}^+_{(aq)} \quad K_a = K_w / K_b = 0$$
$$\text{HOAc}_{(aq)} + \text{H}_2\text{O}_{(l)} \leftrightarrow \text{H}_3\text{O}^+_{(aq)} + \text{OAc}^-_{(aq)} \quad K_a = 1.8 \times 10^{-5}$$
$$\text{OAc}^-_{(aq)} + \text{H}_2\text{O}_{(l)} \leftrightarrow \text{OH}^-_{(aq)} + \text{HOAc}_{(aq)} \quad K_b = K_w / K_a = 10^{-14} / 1.8 \times 10^{-5} = 5.56 \times 10^{-10}$$

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Slide 14

Net Result

NaOAc gives rise to a single equilibrium reaction that must be considered:

$$\text{OAc}^-_{(aq)} + \text{H}_2\text{O}_{(l)} \leftrightarrow \text{OH}^-_{(aq)} + \text{HOAc}_{(aq)}$$
$$K_b = 5.56 \times 10^{-10}$$

The salt is a base!!!!

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Slide 15

Sample problem

What is the pH of a 0.100 M solution of NaOAc?

What do we need?

Balanced equation

What is it?

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Slide 16

$\text{NaOAc (aq)} \rightarrow \text{Na}^+ \text{(aq)} + \text{OAc}^- \text{(aq)}$

Where does  $\text{Na}^+$  "come from"?

**NaOH**

Where does the  $\text{OAc}^- \text{(aq)}$  "come from"?

**HOAc**

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Slide 17

$\text{NaOAc (aq)} \rightarrow \text{Na}^+ \text{(aq)} + \text{OAc}^- \text{(aq)}$

~~NaOH~~  
Strong Base

**HOAc**  
Weak Acid

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$\text{OAc}^- \text{(aq)} + \text{H}_2\text{O (l)} \leftrightarrow \text{HOAc (aq)} + \text{OH}^- \text{(aq)}$

$\text{OAc}^- \text{(aq)} + \text{H}_2\text{O (l)} \leftrightarrow \text{HOAc (aq)} + \text{OH}^- \text{(aq)}$

I	0.100 M	-	0	0
C	-x	-	+x	+x
E	0.100-x	-	x	x

Now all we need is K!

$K_b(\text{OAc}^-) = K_w/K_a(\text{HOAc})$

$= 1 \times 10^{-14} / 1.8 \times 10^{-5} = 5.56 \times 10^{-10}$

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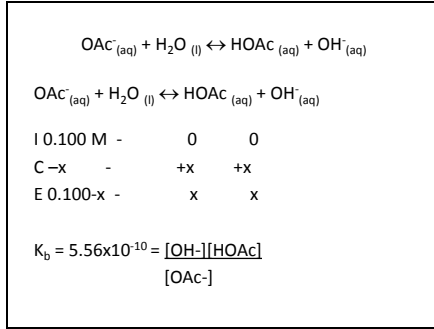
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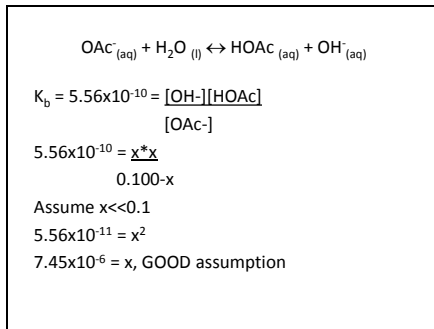
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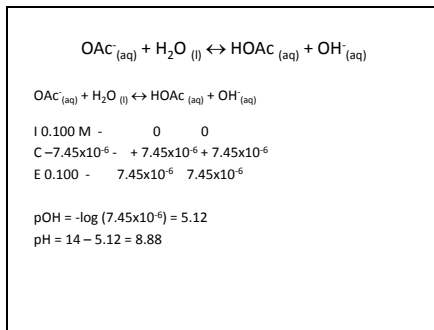
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Slide 21




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Slide 22

**More fun with salts...**

What can we say about:  
NaCl?  
NaCl = Na<sup>+</sup> + Cl<sup>-</sup>  
It came from...  
Cation + OH<sup>-</sup> = NaOH  
Anion + H<sup>+</sup> = HCl  
So....

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Slide 23

**If you can't find K<sub>a</sub> ...**

...maybe it's a strong acid.  
Or if you do find it, it is HUGE!

Strong acids:  
HCl K<sub>a</sub> ~10<sup>6</sup>  
HBr  
HI  
HNO<sub>3</sub>  
HClO<sub>4</sub>  
H<sub>2</sub>SO<sub>4</sub> (diprotic – more on this next week)

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Slide 24

**If you can't find a K<sub>b</sub>...**

...maybe it's a strong base. (Or K<sub>b</sub> is huge.)

List of strong bases:  
LiOH  
NaOH K<sub>b</sub> ~10<sup>8</sup>  
KOH  
Sr(OH)<sub>2</sub>  
Ca(OH)<sub>2</sub>  
Ba(OH)<sub>2</sub>

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Slide 25

What kind of acid/base is it?

NaOH?  
STRONG base

HCl?  
STRONG acid

The salt is...  
NEUTRAL we "ignore both"

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Slide 26

More fun with salts...

What can we say about:  
KCl

Came from:  
KOH and HCl

Also neutral!

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Slide 27

More fun with salts...

What can we say about:  
 $\text{Ca}(\text{OAc})_2$

It came from:  
 $\text{Ca}(\text{OH})_2$  and HOAc

Only the HOAc matters, it's weak.

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Slide 28

More fun with salts...

What can we say about:  
NH<sub>4</sub>Cl

It came from?  
NH<sub>3</sub> (or NH<sub>4</sub>OH) and HCl

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Slide 29

More fun with salts...

What can we say about:  
NH<sub>4</sub>OAc

It came from:  
NH<sub>3</sub> and HOAc

**BOTH WEAK!!!**

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Slide 30

If they are both weak...

Look at the K. Biggest K wins.

Although for NH<sub>4</sub>OAc..

$K_b(\text{NH}_3) = K_{\text{base}} = \frac{1.00 \times 10^{-14}}{1.76 \times 10^{-5}} = 5.68 \times 10^{-10}$   
 $K_b(\text{NH}_3) \ 1.76 \times 10^{-5}$

$K_b(\text{HOAc}) = K_{\text{base}} = \frac{1.00 \times 10^{-14}}{1.79 \times 10^{-5}} = 5.59 \times 10^{-10}$   
 $K_b(\text{HOAc}) \ 1.79 \times 10^{-5}$

NH<sub>4</sub>OAc ends up being neutral!

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Slide 31

**If they don't cancel...???**

We won't worry about the exact calculation (you'd need to do both simultaneous equilibria), but you can tell whether it is acidic or basic:

$\text{NH}_4\text{IO}_3$  (ammonium iodate)

It comes from:  
 $\text{NH}_3$  and  $\text{HIO}_3$

$K_b(\text{NH}_3) = 1.76 \times 10^{-5}$   
 $K_a(\text{HIO}_3) = 1.7 \times 10^{-1}$

$\text{HIO}_3$  is a better acid than  $\text{NH}_3$  is a base. Which means that  $\text{NH}_4^+$  is a better acid than  $\text{IO}_3^-$  is a base.

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Slide 32

**If they don't cancel...???**

$\text{NH}_4\text{IO}_3$  (ammonium iodate)

It comes from:  
 $\text{NH}_3$  and  $\text{HIO}_3$

$K_b(\text{NH}_3) = 1.76 \times 10^{-5}$   
 $K_a(\text{HIO}_3) = 1.7 \times 10^{-1}$

$\text{HIO}_3$  is a better acid than  $\text{NH}_3$  is a base. Which means that  $\text{NH}_4^+$  is a better acid than  $\text{IO}_3^-$  is a base.

A solution of  $\text{NH}_4\text{IO}_3$  would be acidic.

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Slide 33

**Another little problem**

What is the pH of a 0.250 M solution of  $\text{Ca}(\text{IO}_3)_2$ ?

Where do we start?

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Slide 34

**Split the salt into ions**

$\text{Ca}(\text{IO}_3)_2 \rightarrow \text{Ca}^{2+} + 2 \text{IO}_3^-$

Where did the ions come from?

$\text{Ca}(\text{OH})_2$  and  $\text{HIO}_3$

Which are...?

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Slide 35

$\text{Ca}(\text{OH})_2$  is strong

$\text{HIO}_3$  is weak.

Ignore the  $\text{Ca}^{2+}$

Now, we need to...

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Slide 36

**Write a balanced equation!**

$\text{IO}_3^-(\text{aq}) + \text{H}_2\text{O}(\text{l}) \leftrightarrow \text{HIO}_3(\text{aq}) + \text{OH}^-(\text{aq})$

Once I have a balanced equation:  
ICE chart  
K equation

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Slide 37

**ICE ICE BABY ICE ICE**

$\text{IO}_3^-(\text{aq}) + \text{H}_2\text{O}(\text{l}) \leftrightarrow \text{HIO}_3(\text{aq}) + \text{OH}^-(\text{aq})$

I		-		
C	-x	-	+x	+x
E		-		

What else?

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Slide 38

**Another little problem**

What is the pH of a 0.250 M solution of  $\text{Ca}(\text{IO}_3)_2$ ?

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Slide 39

**ICE ICE BABY ICE ICE**

$\text{IO}_3^-(\text{aq}) + \text{H}_2\text{O}(\text{l}) \leftrightarrow \text{HIO}_3(\text{aq}) + \text{OH}^-(\text{aq})$

I	0.500 M	-	0	0
C	-x	-	+x	+x
E	0.500-x	-	x	x

Now K

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Slide 40

$$K = \frac{[\text{HIO}_3][\text{OH}^-]}{[\text{IO}_3^-]}$$

This is the  $K_b$  of  $\text{IO}_3^-$

$$K_b(\text{IO}_3^-) = K_w/K_a$$
$$K_a(\text{HIO}_3) = 1.7 \times 10^{-1}$$
$$K_b = 1 \times 10^{-14} / 1.7 \times 10^{-1} = 5.88 \times 10^{-14}$$

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Slide 41

$$5.88 \times 10^{-14} = \frac{[\text{HIO}_3][\text{OH}^-]}{[\text{IO}_3^-]}$$
$$5.88 \times 10^{-14} = \frac{[x][x]}{[0.5-x]}$$

How do we solve this?

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Assume  $x \ll 0.5$

$$5.88 \times 10^{-14} = \frac{[x][x]}{[0.5-x]} \approx \frac{[x][x]}{0.5}$$
$$2.941 \times 10^{-14} = x^2$$
$$1.715 \times 10^{-7} = x$$

Good assumption?  
YES, MA'AM!

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Slide 43

**ICE ICE BABY ICE ICE**

$\text{IO}_3^-(\text{aq}) + \text{H}_2\text{O}(\text{l}) \leftrightarrow \text{HIO}_3(\text{aq}) + \text{OH}^-(\text{aq})$

I	0.500 M	-	0	0
C	$-1.715 \times 10^{-7}$	-	$+1.715 \times 10^{-7}$	$+1.715 \times 10^{-7}$
E	0.500	-	$1.715 \times 10^{-7}$	$1.715 \times 10^{-7}$

How do we finish?

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Slide 44

**Another little problem**

What is the pH of a 0.250 M solution of  $\text{Ca}(\text{IO}_3)_2$ ?

$[\text{OH}^-] = 1.715 \times 10^{-7}$   
 $\text{pOH} = -\log(1.715 \times 10^{-7}) = 6.77$   
 $\text{pH} = 14 - \text{pOH} = 14 - 6.77 = 7.23$

Make sense?  
You bet! Strongish acid ( $\text{HIO}_3$ ), very weak conjugate. Almost neutral.

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