Weak Acids and Bases

Name: _____

AP Chemistry Lecture Outline

Video 1603 (10:25)

Weak Acids

-- most acids are weak

-- For a weak acid HX... $HX(aq) \rightleftharpoons H^+(aq) + X^-(aq)$

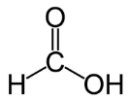
-- <u>acid-dissociation constant</u> $K_a =$

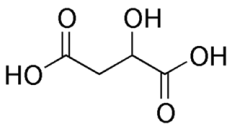
large K_a:

small K_a:

The % of a weak acid that is ionized is given by the equation:

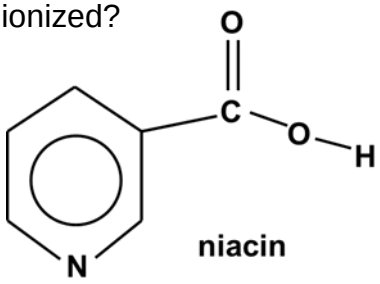
For organic acids (containing only C, H, and O), the "donated" H was connected to...





EX. A 0.020 M niacin solution has pH 3.26. (a) What % of the acid is ionized?

(b) What is K_a?



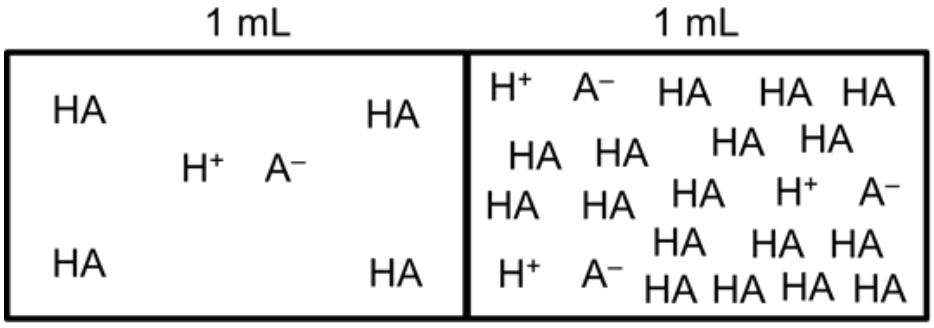
Video 1606 (6:50)

EX. If K_a for niacin is 1.6×10^{-5}, find the pH of a 0.010 M niacin solution.

Video 1609 (4:31)

The conc. of a weak acid affects its % ionization.

As [acid] conc. ↑ , % ion. ____; as [acid] conc. ↑ , % ion. ____.



-- more _____

-- ____ ionized = ____

(i.e., _____ % of H^+s popped off)

-- has _____ [H^+],

(i.e., _____ per _____)

and thus...

-- more _____

-- ____ ionized = ____

(i.e., _____ % of H^+s popped off)

-- has _____ [H^+],

(i.e., _____ per _____)

and thus...

Video 1612 (8:50)

EX. Calculate the % of HF molecules ionized in – and the pH of – a 0.10 M HF solution. ($K_a = 6.8 \times 10^{-4}$)

EX. Calculate the % of HF molecules ionized in – and the pH of – a 0.010 M HF solution. ($K_a = 6.8 \times 10^{-4}$)

Video 1615 (8:15)

Polyprotic acids – like sulfurous acid, H_2SO_3 – have more than one ionizable H.

$H_2SO_3(aq) \rightleftharpoons H^+(aq) + HSO_3^-(aq)$ $(K_{a1} = 1.7 \times 10^{-2})$

$HSO_3^-(aq) \rightleftharpoons H^+(aq) + SO_3^{2-}(aq)$ $(K_{a2} = 6.4 \times 10^{-8})$

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-- Usually, K_{a2} is at least 1000X smaller than K_{a1}. In such cases, one can calculate $[H^+]$ and pH based only on K_{a1} (i.e., ignore K_{a2} and pretend you have a monoprotic acid).

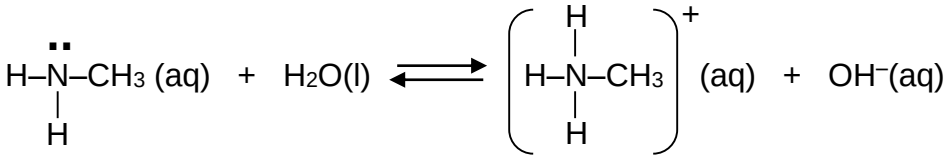
EX. Find the pH of a 0.0037 M carbonic acid solution. ($K_{a1} = 4.3 \times 10^{-7}$, $K_{a2} = 5.6 \times 10^{-11}$)

Video 1618 (7:56)

Weak Bases

weak base + $H_2O \rightleftharpoons$ conjugate acid + OH^- $K_b =$

Weak bases are often nitrogen-containing molecules ("amines") or anions.

Example: 

EX. What is the equilibrium concentration of ammonia in a solution of pH 9.35? Ammonia's $K_b = 1.8 \times 10^{-5}$.

Video 1621 (10:04)

The K_a / K_b Relationship for Conjugates

(1) NH_3

(2) NH_4^+

K_a = K_b =

Then K_a x K_b =

For an acid and its conj. base:

Because they are easily calculated from K_a values, reference tables are often "short" on K_b values. Just like pH = –log $[H^+]$,

EX. For hydrofluoric acid, $K_a = 6.8 \times 10^{-4}$.

a. Write the formula of the conjugate base.

b. Write the equation for which K_b applies.

c. Write the equation for which K_a applies.

d. Find pK_a, pK_b, and K_b.

Video 1624 (6:30)

Ions related to weak acids or bases can themselves exhibit acidic or basic properties.

One such ion is...	which is related to ____, which is a 'weak'.	The ion would tend to _____ H^+...	...and would thus exhibit _____ properties.
CO_3^{2-}			
HCO_3^-			
ClO^-			
ClO_2^-			
NH_4^+			
CH_3COO^-			

** NOTE: The ions we are dealing with here MUST be related to weaks, NOT strongs. Thus, ions such as Cl^- or NO_3^- or K^+ or Sr^{2+} do NOT exhibit acidic or basic properties.

Because weak-related ions transfer H^+s (as mentioned above, strong-related ions DO NOT), solutions of salts containing 'weak' ions can be acidic or basic.

For example, consider adding a spoonful of the salt sodium hypochlorite to water. The salt immediately does this...

The strong-related ion has no effect on H^+ transfer, but the weak-related ion DOES, in this way...

We expect a solution of sodium hypochlorite to have a pH...

Video 1627 (6:24)

EX. What mass of solid potassium fluoride is required to make 5.0 L of a pH 8.35 solution?

Video 1630 (6:30)

To predict the pH of a salt solution, look at the formula of the salt.

For salts with ions related to a...

(1) ...strong base and a weak acid, e.g.,

we predict a pH...

(2) ...weak base and a strong acid, e.g.,

we predict a pH...

(3) ...strong base and a strong acid, e.g.,

we predict a pH...

(4) ...weak base and a weak acid

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e.g.,

Video 1633 (4:02)

EX. Would we predict an NH_4CN soln to be acidic or basic?

What related info is found in the ref. tables?

But we have _____, not ____, and _____ would _____ a proton, so we need its ___.

And we have _____, not ____, and _____ would _____ a proton, so we need its ___.

Video 1636 (5:34)

Anions that still have ionizable protons (e.g., HSO_3^-) are <u>amphoteric</u>.

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Equation for K_a:

Equation for K_b:

EX. Does $KHSO_3$ form an acidic or a basic solution in water?

From a reference table, we find... (a) $H_2SO_3 \rightleftharpoons H^+ + HSO_3^-$

(b) $HSO_3^- \rightleftharpoons H^+ + SO_3^{2-}$

Video 1639 (7:13)

<u>General Factors Affecting Acid Strength</u>

1. To transfer H^+, acid must have the polarity...

-- ionic hydrides don't

-- C–H bonds don't

As polarity increases, acid strength *generally* increases. BUT...

2. ...if H–X bond is too strong.. (e.g.,)

3. Stable (i.e., weak) conjugate bases (e.g.,) indicate a...

For binary acids:

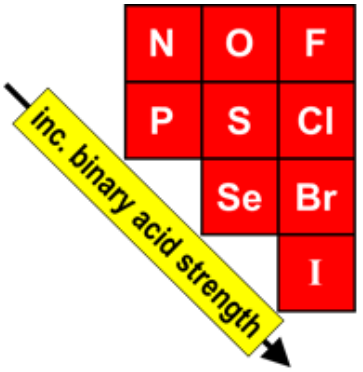
(1) In a group, bond strength is the determining factor.

As we go down a group... H_2S

...charge separation ___,

so bond strength ___

and acid strength ___. H_2Se



(2) In a period, bond polarity governs.

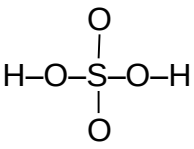
As we go L to R across a period... H_2O HF

...bond polarity ___ and acid strength ___.

Video 1642 (8:24)

oxyacids:

Consider H_2SO_4 (an acid) and $Ca(OH)_2$ (a base).



H–O–Ca–O–H

The ΔEN between S and O is _____ than that between O and H. This means that...

The ΔEN between Ca and O is _____ than that between O and H. This means that...

When comparing related oxyacids, remember this...

Anything that draws e^- density AWAY from the "donate-able" H makes for a stronger acid.

Related-Oxyacids Comparison #1:

For oxyacids with the same # of O atoms, acid strength increases with increasing electronegativity of the central atom.

e.g., HClO
HBrO
HIO

H_2SeO_3
H_2SO_3

Related-Oxyacids Comparison #2:

For oxyacids with the same central atom, acid strength increases as the # of oxygens attached to the central atom increases.

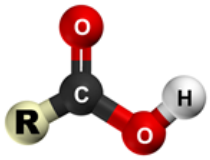
e.g., HBrO
$HBrO_2$

HIO_3
HIO_2

Related-Oxyacids Comparison #3:

This comparison deals with carboxylic acids, which contain the _____.

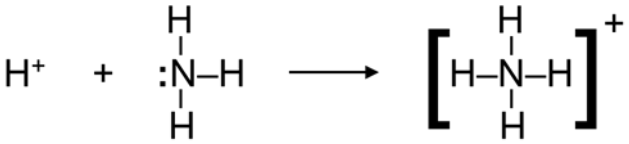
-- these are the largest category of organic acids
-- acid strength increases from adding add'l high-EN atoms



e.g., CH_3COOH
CHF_2COOH
CF_3COOH

Video 1645 (7:42)

Lewis Acids and Lewis Bases



The Lewis definitions greatly broaden the range of acids because many species other than H-containing ones can accept an e^- pair.

Another example:

The simple term “acid” suggests that we are referring to an Arrhenius or a Bronsted-Lowry acid, i.e., an H-containing substance in an aqueous solution. If you are referring to a Lewis acid, then use the term “Lewis acid.”

Substances with an incomplete octet (e.g., BF_3) or ones having vacant orbitals (e.g., Fe^{3+}) can function as Lewis acids.

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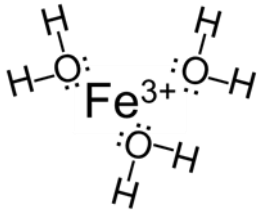
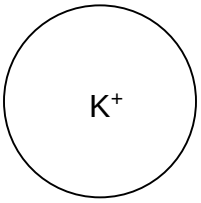
-- The (+) charge attracts (i.e., accepts) the lone pairs of e^- on the O of a water molecule. This process is hydration: the “glomming” of H_2O m’cules onto metal ions.



Cation size and cation charge determine the extent to which the pH is affected.



-- short distance

-- strong interaction

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-- larger distance

-- weaker interaction

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