CHEM 206 section 01

LECTURE #20 Wed. March 19, 2008

LECTURE TOPICS:

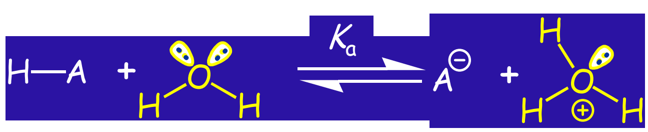
TODAY'S CLASS: continue Ch.17

NEXT CLASS: continue Ch.17

(1)

17.4 Equilibrium constants for acids & bases

For eqm involving reaction of an ACID with H_2O: "K_a"



$$K = \frac{[A^-][H_3O^+]}{[HA][H_2O]}$$

$[H_2O]$ constant since dilute solution ⇨ not included...
(in advanced treatment, value → 1 & disappears...)

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

K_a = "Acid Dissociation Constant"

Larger K_a for stronger acids

pK_a = - $\log(K_a)$

Smaller pK_a for stronger acids

Acids with K_a > 1 described as STRONG acids
Acids with K_a < 1 described as WEAK acids

(2)

K_a & pK_a: a way to quantify acid strength…

See K&T huge Table 17.3
Zumdahl's table ↓

$$HA + H_2O \overset{K_a}{\rightleftharpoons} A^- + H_3O^+$$

TABLE 14.2 Values of K_a for Some Common Monoprotic Acids

Formula	Name	Value of K_a*	pK_a
HSO_4^-	Hydrogen sulfate ion	1.2×10^{-2}	1.92
$HClO_2$	Chlorous acid	1.2×10^{-2}	1.92
$HC_2H_2ClO_2$	Monochloracetic acid	1.35×10^{-3}	2.87
HF	Hydrofluoric acid	7.2×10^{-4}	3.14
HNO_2	Nitrous acid	4.0×10^{-4}	3.40
$HC_2H_3O_2$	Acetic acid	1.8×10^{-5}	4.74
$[Al(H_2O)_6]^{3+}$	Hydrated aluminum(III) ion	1.4×10^{-5}	4.85
HOCl	Hypochlorous acid	3.5×10^{-8}	7.46
HCN	Hydrocyanic acid	6.2×10^{-10}	9.21
NH_4^+	Ammonium ion	5.6×10^{-10}	9.25
HOC_6H_5	Phenol	1.6×10^{-10}	9.80

↑ Increasing acid strength

NOTE: **K_a's of "strong" acids too large to measure in H_2O**
…because they ionize ~fully, we can't measure all [ ]'s!

17.7 Calculations with equilibrium constants

Some typical scenarios:

1.) Use solution pH to find K_a (or K_b).
Q: When a solution of weak acid HA (or base B) of known initial concentration is prepared, the pH of the solution is ____. Find K_a (or K_b).

2.) Determine the pH of a solution of a weak acid (or base).
Q: When a solution of known initial concentration of a certain weak base (known K_b) is prepared, what is the pH?

3.) Determine the pH of a solution after an acid/base rxn.
Q: When a known volume of solution of acid HA is mixed with a known volume of strong base, what is the pH of the resulting solution?

APPLYING OUR EQM CALCULATIONS: (17.7)
Finding the pH of a weak acid solution…

Q: What is the pH of a typical vinegar solution?

→ vinegar = 5% v/v acetic acid

→ acetic acid: MM = 60.05 g/mol; d = 1.049 g/mL

APPROACH:

- LOOK UP: K_a of CH_3COOH…
- USE EQM ATTACK PLAN:
  - balance chemical equation
  - write eq'm expression for K_a
  - set up an ICE table
  - calculate $[CH_3COOH]_o$ in molarity & put into ICE table
  - solve for $[H_3O^+]$
  - …& use pH = $-\log[H_3O^+]$

(5)

Q: What is the pH of a typical vinegar solution?

- vinegar = 5% v/v acetic acid → 5mL HA in approx. 100mL total
- acetic acid: $K_a = 1.82\times10^{-5}$; MM=60.05 g/mol; d=1.049 g/mL

→ $[HA]_o$=[(5mL*1.049g/mL)/60.05g/mol] / (0.100L) ≈ 0.873 M

$$CH_3COOH(aq) + H_2O(l) \rightleftharpoons CH_3COO^-(aq) + H_3O^+(aq)$$

	$CH_3COOH(aq)$	$H_2O(l)$	$CH_3COO^-(aq)$	$H_3O^+(aq)$
Initial	0.873 M	*constant…*	0	0
Change	-x		+ x	+ x
Eqm	0.873 - x		x	x

$$K_a = \frac{[CH_3COO^-][H_3O^+]}{[CH_3COOH]}$$

$$1.82\times10^{-5} = \frac{x^2}{0.873 - x} \approx \frac{x^2}{0.873}$$

$x^2 = (0.873)(1.82\times10^{-5})$

$x = 3.99\times10^{-3}$ M = $[H_3O^+]$

pH = $-\log[H_3O^+]$

= 2.4 *(1 SF)*

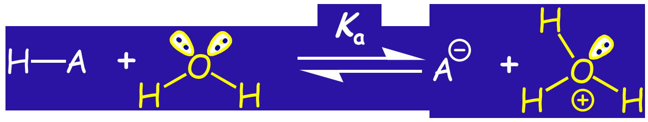
Check approximation:

$$\frac{x}{[HA]_{initial}} = \frac{0.00399}{0.873}$$

= 0.0047 <5% ∴ ok

Thus: % dissociation = ~0.5 %

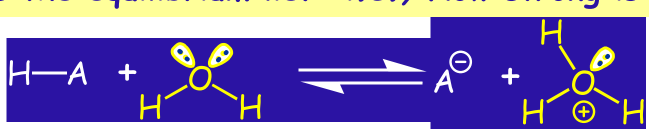
Summary of acid strengths



PROPERTY	STRONG acid	WEAK acid
K_a value	very large	small
pK_a value	very small	large
Equilibrium position	right	left
$[H^+]$ compared to $[HA]_0$	$[H^+] \approx [HA]_0$	$[H^+] \ll [HA]_0$
Strength of conjugate base A^- compared to H_2O	A^- is very WEAK	A^- is much STRONGER

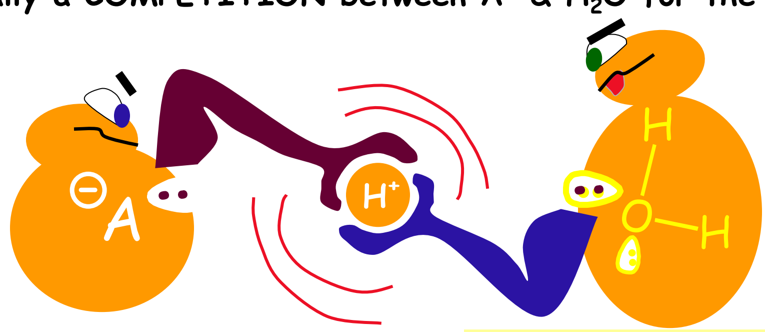
(7)

Where does the equilibrium lie? *i.e.,* How strong is HA?



IT'S ALL ABOUT THE BASE...

Really a COMPETITION between A^- & H_2O for the H^+:



The stronger base wins!

Many molecules...distribution of energies...fwd & reverse rxn...
At EQM: more molecules of the stronger base are bonded to H^+!

RELATING STRENGTHS OF ACIDS & THEIR CONJUGATE BASES

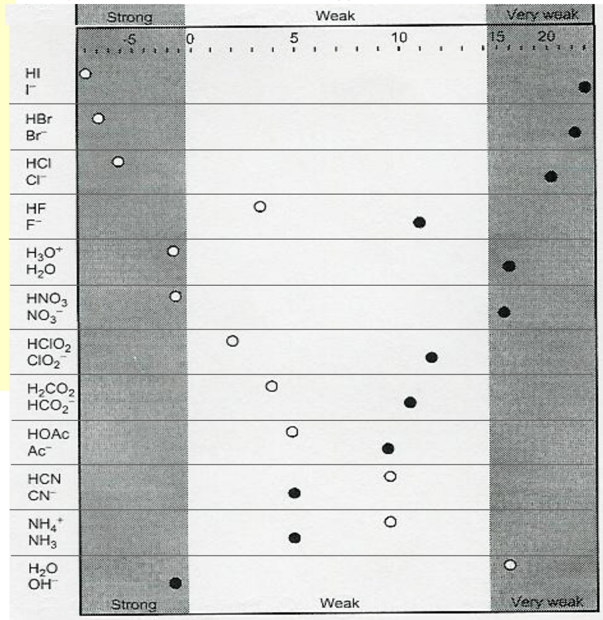
The numerical values shown refer to:
p*K*$_a$ values of conj. acids (○) &
p*K*$_b$ values of conj. bases (●).

The labels
strong*, *weak* & *very weak
refer to the
acid (○) *OR* base (●)
that appears
in that region of the figure.

JChemEd.chem.wisc.edu
Journal of Chemical Education
Vol. 78 No. 11 November 2001
1495

STRONG acids & bases react 100% with H_2O.
p$K_{a/b}$< 0, not in most tables.

Very weak conj. bases & acids don't react noticeably with H_2O.
p$K_{a/b}$ > 14, not in most tables.



Weak acids have weak conj. bases.
<u>Both</u> react noticeably with H_2O.

ASSIGNED READINGS:

BEFORE NEXT CLASS:

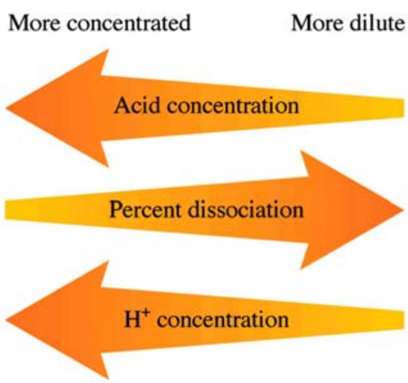
Read: Ch.16 (all),
Ch.17 up to section 17.4 (to 6th Ed. p.809),
& 17.7 (to 6th Ed. p.824)

+ WORK ON Problems from Ch.16, Ch.17
including finding the pH of weak acid solutions
***e.g.,* section 17.7 problems, #47-50**

Zumdahl's Figure 14.10

Extra information:

% DISSOCIATION: extent of ionization depends on [initial]



$$\text{\% diss'n} = \frac{[A^-]}{[HA]_o} \times 100\%$$

For 5% acetic acid example:

$$\text{\% diss'n} = \frac{[3.99\times10^{-3}\ M]}{[0.873\ M]} \times 100\%$$

= 0.457 %

= 0.5 % (1SF in data)

PROVE IT TO YOURSELF: On your own, use calculations to show that a **lower %** of the acetic acid molecules are ionized in 2.5 M CH_3COOH than in a 2.5×10^{-3} M solution, even though the more concentrated acid solution indeed has a lower pH.