ch 16.8 relate K_a & K_b

review : K_a : K_c of a weak acid react with H_2O

eg $CH_3COOH + H_2O \rightleftharpoons H_3O^+ + CH_3COO^-$

K_b : K_c of a weak base react with H_2O

eg $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$

background : conjugate pair
- in equilibrium with each other
- differ by H
- one is a base & other is an acid

eg 1 $CH_3COOH + H_2O \rightleftharpoons H_3O^+ + CH_3COO^-$

acid — base — conjugate acid — conjugate base

ex 2 $NH_3 + H_2O \rightleftharpoons OH^- + NH_4^+$

base — acid — conjugate base — conjugate acid

relate K_a & K_b

$$K_a \cdot K_b = K_w$$

conjugate pair

"pseudo-proof"

ex 1 $CH_3COOH + H_2O \rightleftharpoons H_3O^+ + CH_3COO^-$

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

$CH_3COO^- + H_2O \rightleftharpoons CH_3COOH + OH^-$

$$K_b = \frac{[CH_3COOH][OH^-]}{[CH_3COO^-]}$$

note: $K_a(CH_3COOH) \cdot K_b(CH_3COO^-) = K_w$?

$$\frac{[H_3O^+][\cancel{CH_3COO^-}]}{[\cancel{CH_3COOH}]} \cdot \frac{[\cancel{CH_3COOH}][OH^-]}{[\cancel{CH_3COO^-}]}$$

$[H_3O^+][OH^-] = K_w$ ✓

ex 2 $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$

$$K_b(NH_3) = \frac{[NH_4^+][OH^-]}{[NH_3]}$$

$NH_4^+ + H_2O \rightleftharpoons H_3O^+ + NH_3$

$$K_a(NH_4^+) = \frac{[H_3O^+][NH_3]}{[NH_4^+]}$$

note: $K_b(NH_3) \cdot K_a(NH_4^+) = K_w$?

$$\frac{[\cancel{NH_4^+}][OH^-]}{[\cancel{NH_3}]} \cdot \frac{[H_3O^+][\cancel{NH_3}]}{[\cancel{NH_4^+}]}$$

$[OH^-][H_3O^+] = K_w$ ✓

(1) 1 g NH_4Cl pH acidic salt

$NH_4Cl \rightarrow NH_4^+ + Cl^-$
- ionic cpd
- product of acid-base Rx
- cation from base anion from acid

ex 1 $HCl + NaOH \rightarrow NaCl + H_2O$

strong acid, strong base, neutral salt

ex 2 $HCl + NH_3 \rightarrow NH_4Cl$

strong acid, weak base, acidic salt

why is it an acidic salt?

$NH_4Cl \rightarrow NH_4^+ + Cl^-$

$NH_4^+ + H_2O \rightleftharpoons H_3O^+ + NH_3$

(H_3O^+ ↑ acid)

ex $CH_3COOH + NaOH \rightarrow NaCH_3COO + H_2O$

weak acid, strong base, basic salt

why basic salt?

$NaCH_3COO \rightarrow Na^+ + CH_3COO^-$

$CH_3COO^- + H_2O \rightarrow OH^- + CH_3COOH$

i) $NH_4^+ + H_2O \rightleftharpoons H_3O^+ + NH_3$

	NH_4^+		H_3O^+	NH_3
I	1m M		0	0
C	$-x$		$+x$	$+x$
E	$1mM - x$		x	x

$$K_a(NH_4^+) = \frac{[H_3O^+][NH_3]}{[NH_4^+]} = \frac{x^2}{0.001 - x}$$

$$\approx \frac{x^2}{0.001} \quad (1)$$

ii) $K_a(NH_4^+) \cdot K_b(NH_3) = K_w$

$K_a(NH_4^+)$ $1.8 \cdot 10^{-5} = 10^{-14}$

$$K_a(NH_4^+) \simeq 5.56 \cdot 10^{-10} \quad (2)$$

iii) Subst (2) into (1)

$$5.56 \cdot 10^{-10} = \frac{x^2}{0.001}$$

$$x = \sqrt{5.56 \cdot 10^{-13}} \simeq 7.45 \cdot 10^{-7} M$$

iv) $pH = -\log[H^+] = -\log(7.45 \cdot 10^{-7})$

$\simeq 6.13$

(2) 1m M $NaCH_3COO$, basic salt

$NaCH_3COO \longrightarrow Na^+ + CH_3COO^-$

i) $CH_3COO^- + H_2O \rightleftharpoons OH^- + CH_3COOH$

I	1m M	0	0
C	$-x$	$+x$	$+x$
E	$1m M - x$	x	x

$$K_b(CH_3COO^-) = \frac{[OH^-]\,[CH_3COOH]}{[CH_3COO^-]}$$

$$= \frac{x^2}{0.001 - x} \simeq \frac{x^2}{0.001} \quad (1)$$

ii) $K_b(CH_3COO^-) \cdot K_a(CH_3COOH) = K_w$

$K_b(CH_3COO^-)\ 1.8 \cdot 10^{-5} = 10^{-14}$

$K_b(CH_3COO^-) \simeq 5.56 \cdot 10^{-10}$ (2)

iii) sub (2) into (1)

$5.56 \cdot 10^{-10} = \frac{x^2}{0.001}$

$x = \sqrt{5.56 \cdot 10^{-13}} = 7.45 \cdot 10^{-7}\ M$

iv) $[OH^-] \longrightarrow pOH \longrightarrow pH$

$[OH^-] \longrightarrow [H^+] \longrightarrow pH$

$[OH^-]\,[H^+] = 10^{-14}$

$(7.45 \cdot 10^{-7})\,[H^+] = 10^{-14}$

$[H^+] = 1.34 \cdot 10^{-8}\ M$

v) $pH = -\log [H^+] = -\log (1.34 \cdot 10^{-8})$

$= 7.87$