Acids and Bases …Weak…

A Weak Acid Equilibrium Problem

What is the pH of a 0.50 M solution of acetic acid, $HC_2H_3O_2$, $K_a = 1.8 \times 10^{-5}$?

Step #1: Write the dissociation equation

$$HC_2H_3O_2 \leftrightarrows C_2H_3O_2^- + H^+$$

A Weak Acid Equilibrium Problem

What is the pH of a 0.50 M solution of acetic acid, $HC_2H_3O_2$, $K_a = 1.8 \times 10^{-5}$?

Step #2: ICE it!

	$HC_2H_3O_2 \leftrightarrows$	$C_2H_3O_2^-$	+ H^+
I	0.50	0	0
C	- x	+x	+x
E	0.50 - x	x	x

A Weak Acid Equilibrium Problem

What is the pH of a 0.50 M solution of acetic acid, $HC_2H_3O_2$, $K_a = 1.8 \times 10^{-5}$?

Step #3: Set up the law of mass action

	$HC_2H_3O_2$	$\leftrightarrows$	$C_2H_3O_2^-$	+	H^+
E	0.50 - x		x		x

$$1.8\,x10^{-5} = \frac{(x)(x)}{(0.50-x)} \cong \frac{x^2}{(0.50)}$$

A Weak Acid Equilibrium Problem

What is the pH of a 0.50 M solution of acetic acid, $HC_2H_3O_2$, $K_a = 1.8 \times 10^{-5}$?

Step #4: Solve for x, which is also $[H^+]$

$$HC_2H_3O_2 \leftrightarrows C_2H_3O_2^- + H^+$$

E	0.50 - x	x	x

$$1.8x10^{-5} = \frac{x^2}{(0.50)}$$

$[H^+] = 3.0 \times 10^{-3}$ M

A Weak Acid Equilibrium Problem

What is the pH of a 0.50 M solution of acetic acid, $HC_2H_3O_2$, $K_a = 1.8 \times 10^{-5}$?

Step #5: Convert $[H^+]$ to pH

	$HC_2H_3O_2$	⇆	$C_2H_3O_2^-$	+	H^+
E	0.50 - x		x		x

$$pH = -\log(3.0\,x10^{-3}) = 4.52$$

Reaction of Weak Bases with Water

The base reacts with water, producing its conjugate acid and hydroxide ion:

$CH_3NH_2 + H_2O \leftrightarrows CH_3NH_3^+ + OH^-$ $\quad K_b = 4.38 \times 10^{-4}$

$$K_b = 4.38 x 10^{-4} = \frac{[CH_3NH_3^+][OH^-]}{[CH_3NH_2]}$$

K_b for Some Common Weak Bases

Many students struggle with identifying weak bases and their conjugate acids. What patterns do you see that may help you?

Base	Formula	Conjugate Acid	K_b
Ammonia	NH_3	NH_4^+	1.8×10^{-5}
Methylamine	CH_3NH_2	$CH_3NH_3^+$	4.38×10^{-4}
Ethylamine	$C_2H_5NH_2$	$C_2H_5NH_3^+$	5.6×10^{-4}
Diethylamine	$(C_2H_5)_2NH$	$(C_2H_5)_2NH_2^+$	1.3×10^{-3}
Triethylamine	$(C_2H_5)_3N$	$(C_2H_5)_3NH^+$	4.0×10^{-4}
Hydroxylamine	$HONH_2$	$HONH_3^+$	1.1×10^{-8}
Hydrazine	H_2NNH_2	$H_2NNH_3^+$	3.0×10^{-6}
Aniline	$C_6H_5NH_2$	$C_6H_5NH_3^+$	3.8×10^{-10}
Pyridine	C_5H_5N	$C_5H_5NH^+$	1.7×10^{-9}

Reaction of Weak Bases with Water

The generic reaction for a base reacting with water, producing its conjugate acid and hydroxide ion:

$$B + H_2O \leftrightarrows BH^+ + OH^-$$

$$K_b = \frac{[BH^+][OH^-]}{[B]}$$

(Yes, all weak bases do this – DO NOT endeavor to make this complicated!)

A Weak Base Equilibrium Problem

What is the pH of a 0.50 M solution of ammonia, NH_3, $K_b = 1.8 \times 10^{-5}$?

Step #1: Write the equation for the reaction

$$NH_3 + H_2O \leftrightarrows NH_4^+ + OH^-$$

A Weak Base Equilibrium Problem

What is the pH of a 0.50 M solution of ammonia, NH_3, $K_b = 1.8 \times 10^{-5}$?

Step #2: ICE it!

$$NH_3 + H_2O \leftrightarrows NH_4^+ + OH^-$$

I	0.50	0	0
C	- x	+x	+x
E	0.50 - x	x	x

A Weak Base Equilibrium Problem

What is the pH of a 0.50 M solution of ammonia, NH_3, $K_b = 1.8 \times 10^{-5}$?

Step #3: Set up the law of mass action

$$NH_3 + H_2O \leftrightarrows NH_4^+ + OH^-$$

E	0.50 - x	x	x

$$1.8\,x10^{-5} = \frac{(x)(x)}{(0.50-x)} \cong \frac{x^2}{(0.50)}$$

A Weak Base Equilibrium Problem

What is the pH of a 0.50 M solution of ammonia, NH_3, $K_b = 1.8 \times 10^{-5}$?

Step #4: Solve for x, which is also $[OH^-]$

$$NH_3 + H_2O \leftrightarrows NH_4^+ + OH^-$$

E	0.50 - x	x	x

$$1.8x10^{-5} = \frac{x^2}{(0.50)}$$

$$[OH^-] = 3.0 \times 10^{-3}\ M$$

A Weak Base Equilibrium Problem

What is the pH of a 0.50 M solution of ammonia, NH_3, $K_b = 1.8 \times 10^{-5}$?

Step #5: Convert $[OH^-]$ to pH

$$NH_3 + H_2O \leftrightarrows NH_4^+ + OH^-$$

E	0.50 - x	x	x

$$pOH = -\log(3.0\,x\,10^{-3}) = 4.52$$

$$pH = 14.00 - pOH = 9.48$$