WEAK ACID, WEAK BASE AND SALT PROBLEMS KEY

1. a) Calculate the equilibrium concentrations of H_3O^+, ClO^- and HClO in a 0.50 M solution of hypochlorous acid, HClO(aq). b) What is the pH of this solution? HClO is WA!

WA hydrolysis: $HClO(aq) + H_2O(l) \leftrightarrows H_3O^+(aq) + ClO^-(aq)$ $K_a = 3.5\times10^{-8}$

	HClO(aq) +	H₂O(l) ⇆	H₃O⁺(aq) +	ClO⁻(aq)
I	0.50		0	0
C	-x		+x	+x
E	0.50 - x		x	x

$K_a = \frac{[H_3O^+][ClO^-]}{[HClO]}$ $3.5\times10^{-8} = \frac{x^2}{0.50-x}$

Assume x is much smaller than the initial [HClO] ⇒ 0.50 - x = 0.50

$\frac{x^2}{0.50} = 3.5\times10^{-8}$ $x^2 = 0.50(3.5\times10^{-8}) = 1.75\times10^{-8}$ $x = \sqrt{1.75\times10^{-8}} = 1.32\times10^{-4}$

- **check assumption**: $\frac{x}{[HA]_{initial}}\times100 = \frac{1.3\times10^{-4}}{0.50}\times100 = 0.026\,\%$ is less than 5% ✓

a) Eq [ ]'s: $[H_3O^+] = [ClO^-] =$ **1.3×10^{-4} M**; $[HClO] = 0.50 - 1.3\times10^{-4} =$ **0.50 M**

b) $pH = -\log[H_3O^+]$ $pH = -\log 1.3\times10^{-4}$ **pH= 3.89**

2. a) Find the K_a of a 1.25 M solution of nitrous acid, $HNO_2(aq)$. The pH of this solution is measured to be 1.62. HNO_2 is WA.

WA Hydrolysis: $HNO_2 + H_2O \leftrightarrows H_3O^+ + NO_2^-$

	HNO₂ +	H₂O ⇆	H₃O⁺ +	NO₂⁻
I	1.25		0	0
C	-x		+x	+x
E	1.25 - x		x	x

pH = 1.62 $[H_3O^+] = 10^{-pH}$ $[H_3O^+] = 10^{-1.62} = 2.4\times10^{-2}$ M; thus, $x = 2.4\times10^{-2}$

Eq [ ]'s: $[HNO_2] = 1.25 - 2.4\times10^{-2} =$ **1.23 M**; $[H_3O^+] = [NO_2^-] =$ **2.4×10^{-2} M**

$K_a = \frac{[H_3O^+][NO_2^-]}{[HNO_2]}$ $K_a = \frac{x^2}{1.25-x} = \frac{(2.4x10^{-2})^2}{1.23} =$ **$4.7x10^{-4}$**

- **Note: don't ignore –x since we know x ($x = 10^{-pH}$); we only assume x is small to avoid solving a quadratic (or polynomical) formula!**

b) What is the %dissociation for this $HNO_{2(aq)}$ solution?

$\%dissociation = \frac{[H_3O^+]}{[HA]_{initial}}\times100$ $\%dissociation = \frac{2.4x10^{-2}}{1.25}\times100 =$ **1.9%**

3. A 0.200 M solution of a weak acid is 9.4% dissociated. Use this information to calculate $[H_3O^+]$, $[A^-]$, [HA] and K_a.

$HA(aq) + H_2O(l) \leftrightarrows H_3O^+(aq) + A^-(aq)$

	$HA(aq) + H_2O(l) \leftrightharpoons H_3O^+(aq) + A^-(aq)$			
I	0.200		0	0
C	-x		+x	+x
E	0.200 - x		x	x

$\%\text{ionization} = \frac{x}{[HA]_{in}} \times 100$ $\quad 9.4\% = \frac{x}{0.200} \times 100$

$x = \frac{0.200(9.4)}{100} = 0.0188$ $\quad x = 0.019$

Eq [ ]'s: $[HA] = 0.200 - 0.019 =$ **0.181 M**; $[H_3O^+] = [A^-] =$ **1.9×10^{-2} M**

$K_a = \frac{[H_3O^+][A^-]}{[HA]} = \frac{x^2}{0.200 - x} = \frac{(0.019)^2}{0.181} =$ **2.0×10^{-3}**

4. Calculate the pH of a 0.50 M dimethylamine $(CH_3)_2NH$ solution. $K_b = 5.4\times10^{-4}$

   $(CH_3)_2NH$ is WB

WB hydrolysis: $(CH_3)_2NH_2 + H_2O \leftrightharpoons (CH_3)_2NH_3^+ + OH^-$

	$(CH_3)_2NH_2 + H_2O \leftrightharpoons (CH_3)_2NH_3^+ + OH^-$			
I	0.50		0	0
C	-x		+x	+x
E	0.50 - x		x	x

$K_b = \frac{[(CH_3)_2NH_3^+][OH^-]}{[(CH_3)_2NH_2]}$ **assume x is small**! $5.4\times10^{-4} = \frac{x^2}{0.50}$

$x = \sqrt{(5.4x10^{-4})(0.50)} = \sqrt{2.7x10^{-4}} = 1.64\times10^{-2}$ $\quad x = [OH^-] = 1.64\times10^{-2}$ M

check assumption: $\frac{x}{[B]_{initial}} \times 100 = \frac{1.64\times10^{-2}}{0.50} \times 100 = 3.28\,\%$ **is less than 5%** ✓

$pOH = -\log[OH^-] = -\log 1.64\times10^{-2} = 1.79$ $\quad pH = 14 - pOH = 14 - 1.79 =$ **12.21**

5. A 0.065 M solution of methylamine, CH_3NH_2, has a pH of 11.70. What is K_b for CH_3NH_2?

WB hydrolysis: $CH_3NH_2 + H_2O \rightleftharpoons CH_3NH_3^+ + OH^-$ $\quad pH = 11.70$

	$CH_3NH_2 + H_2O \rightleftharpoons CH_3NH_3^+ + OH^-$			
I	0.065		0	0
C	-x		+x	+x
E	0.065 - x		x	x

$pOH = 14 - pH$ $\quad pOH = 14 - 11.70 = 2.30$

$[OH^-] = 10^{-2.30} = 5.0 \times 10^{-3}$ M; thus $x = 5.0\times10^{-3}$ M

Eq [ ]'s: $[CH_3NH_2] = 0.065 - 0.0050 =$ **0.060 M**; $[OH^-] = [CH_3NH_3^+] =$ **5.0×10^{-3} M**

$K_b = \frac{[CH_3NH_3^+][OH^-]}{[CH_3NH_2]}$ $\quad K_b = \frac{(5.0\times10^{-3})^2}{0.060} =$ **4.2×10^{-4}**

- **Note we don't ignore –x since we find x from the pOH; we only assume x is small to avoid solving a quadratic (or polynomical) formula!**

6. Is KF an acidic, basic or neutral salt? Write the hydrolysis reaction and calculate the pH of a 0.10 M KF solution. K_a (HF) = 3.5×10^{-4}

$KF(aq) \rightarrow \underset{\textbf{N}}{K^+} + \underset{\textbf{B}}{F^-}$ F^- will react with water:

WB hydrolysis: $F^- + H_2O(l) \leftrightarrows HF + OH^-$

	F^- +	$H_2O(l) \leftrightarrows$	HF +	OH^-
I	0.10		0	0
C	-x		+x	+x
E	0.10 - x		x	x

1:1 ratio so $[F^-] = [KF] = 0.10$ M K_a for HF = 3.5×10^{-4}

$K_a \times K_b = 1\times10^{-14}$ K_b for $F^- = \dfrac{1\times10^{-14}}{3.5\times10^{-4}} = 2.86\times10^{-11}$

$K_b = \dfrac{[HF][OH^-]}{[F^-]}$ **Assume x is small!** $2.86\times10^{-11} = \dfrac{x^2}{0.10}$

$x^2 = (2.86\times10^{-11})(0.10)$ $x = \sqrt{(2.86\times10^{-11})(0.10)} = 1.69\times10^{-6}$ $x = [OH^-] = \underline{1.69\times10^{-6}\ M}$

$pOH = -\log [OH^-] = -\log [1.69\times10^{-6}] = 5.77$ $pH = 14 - 5.77 =$ **8.23 basic✓**

***Note: You must use K_b instead of K_a because F^- acts as a weak base in water; for WB problems remember that x = $[OH^-]$, so –log x gives us pOH not pH!**

7. Is NH_4Cl an acidic, basic, or neutral salt? Write the hydrolysis reaction and calculate the pH of a 0.10 M NH_4Cl solution. K_b (NH_3) = 1.8×10^{-5}

$NH_4Cl \rightarrow \underset{\textbf{A}}{NH_4^+} + \underset{\textbf{N}}{Cl^-}$ NH_4^+ will react with water:

WA hydrolysis: $NH_4^+ + H_2O(l) \leftrightarrows NH_3 + H_3O^+$

	NH_4^+ +	$H_2O(l) \leftrightarrows$	NH_3 +	H_3O^+
I	0.10		0	0
C	-x		+x	+x
E	0.10 - x		x	x

1:1 ratio so $[NH_4^+] = [NH_4Cl] = 0.10$ M K_b for $NH_3 = 1.8\times10^{-5}$

$K_a = \dfrac{1\times10^{-14}}{K_b}$ K_a for $NH_4^+ = \dfrac{1\times10^{-14}}{1.8\times10^{-5}} = 5.56\times10^{-10}$

$K_a = \dfrac{[NH_3][H_3O^+]}{[NH_4^+]}$ **Assume x is small!** $5.56\times10^{-10} = \dfrac{x^2}{0.10}$

$x^2 = (5.56\times10^{-10})(0.10)$ $x = \sqrt{5.56\times10^{-11}} = 7.46\times10^{-6}$ $x = [H_3O^+] = \underline{7.46\times10^{-6}\ M}$

$pH = -\log [H_3O^+]$ $pH = -\log \underline{7.46\times10^{-6}}$ **pH= 5.13 acidic✓**

***Note: You must use K_a instead of K_b because NH_4^+ acts as a weak acid in water; for WA problems remember that x = $[H_3O^+]$, so –log x gives us pH!**