1. $NaCl \rightarrow Na^+ + Cl^-$ neutral

$\uparrow$ conjugate base of HCl … NOT a base!

$NaNO_3 \rightarrow Na^+ + NO_3^-$ neutral

$\uparrow$ conjugate base of HNO_3 … NOT a base!

$KNO_2 \rightarrow K^+ + NO_2^-$

$\uparrow$ weak base = basic

$KH_2PO_4 \rightarrow K^+ + H_2PO_4^-$ → 2 possible reactions:

$H_2PO_4^- + H_2O \rightleftharpoons OH^- + H_3PO_4$ $pK_b = 11.84$

$H_2PO_4^- + H_2O \rightleftharpoons HPO_4^{2-} + H_3O^+$ $pK_a = 7.21$

$pK_a > pK_b$ … acidic

$Na(CH_3CO_2^-) \longrightarrow Na^+ + CH_3CO_2^-$

$\uparrow$ base = basic

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

$\uparrow$ acid = acidic

2. a. [HCl] vs HF   weak vs. strong

b. HNO_2 vs. [HNO_3]   weak vs. strong

c. [H_2SO_4] vs. HCl H_2SO_4 = diprotic (so more than 10mM H_3O^+ produced)

d. [H_3PO_4] vs. HF H_3PO_4 = polyprotic (1st pka is more acidic than HF)

e. [10 mM HNO_2] vs. 20 uM HNO_2 Higher concentration

f. 10 mM H_2SO_4 vs [0.2 M H_2SO_4]   Higher concentration

3\. a. $HClO$ $pK_a = 7.53$ $K_a = 10^{-7.53} = 2.95 \times 10^{-8}$

b. HF $pK_a = 3.2$ $K_a = 10^{-3.2} = 6.31 \times 10^{-4}$

4\. $HClO\,(aq) + H_2O \rightleftharpoons \boxed{ClO^-} + H_3O^+$ hypochlorite

$HF + H_2O \rightleftharpoons \boxed{F^-} + H_3O^+$

5\. $HClO$: $pK_b = 14 - 7.53 = 6.47$ $K_b = 10^{-6.47} = 3.39 \times 10^{-7}$

HF $pK_b = 14 - 3.2 = 10.8$ $K_b = 10^{-10.8} = 1.58 \times 10^{-11}$

6\. a. $pH = -\log 1.5 \times 10^{-6} = 5.82$

b. $[OH^-] = 1.5 \times 10^{-6}$ $pOH = 5.82$ $pH = 14 - 5.82 = 8.18$

c. $pOH = 5$ $pH = 14 - 5 = 9$

d. $pH = -\log 4.89 \times 10^{-3} = 2.31$

e. $[OH^-] = 18.6 \times 10^{-6}\,M$ $pOH = 4.73$ $pH = 14 - 4.73 = 9.27$

f. $pOH = 11$ $pH = 14 - 11 = 3$

7\. a. 650 μM HF $= 6.5 \times 10^{-4}\,M$

$pK_a = 3.20$

$K_a = 6.31 \times 10^{-4}$

	HF + H_2O	$\rightleftharpoons$ F^-	+ H_3O^+
I	6.5×10^{-4}	∅	∅
C	$-x$	$+x$	$+x$
E	$6.5 \times 10^{-4} - x$	x	x

$$6.31 \times 10^{-4} = \frac{x^2}{6.5 \times 10^{-4} - x}$$

$a = 1$

$b = 6.31 \times 10^{-4}$

$c = -4.1 \times 10^{-7}$

$x = 3.98 \times 10^{-4} = [H_3O^+]$ $pH = 3.4$

b. 175 μM $HClO = 1.75 \times 10^{-4}\,M$

$pK_a = 7.53$

$K_a = 2.95 \times 10^{-8}$

ICE Table as above

$a = 1$

$b = 2.95 \times 10^{-8}$

$c = -5.16 \times 10^{-12}$

$x = 2.26 \times 10^{-6} = [H_3O^+]$

$pH = 5.65$

c Strong acid

$650\ \mu M\ HCl \rightarrow 650\ \mu M\ H_3O^+ = 650 \times 10^{-6}\ M$

$-\log 6.5 \times 10^{-4} = 3.19$

d. Strong acid

$175\ \mu M\ HClO_4 \rightarrow 175\ \mu M\ H_3O^+ = 175 \times 10^{-6}\ M$

$-\log 1.75 \times 10^{-4} = 3.76$

e. strong base

$1\,mM\ Mg(OH)_2 \left| \frac{2\ mmol\ OH}{1\ mmol\ Mg(OH)_2} \right. = 2\,mM\ OH^- = 2 \times 10^{-3}\,M\ OH^-$

$pOH: -\log 2 \times 10^{-3} = 2.70 \qquad pH = 14 - 2.70 = 11.30$

f. strong base

$10\ \mu M\ Mg(OH)_2 \left| \frac{2\ \mu mol\ OH}{1\ \mu mol\ Mg(OH)_2} \right. = 20\,\mu M\ OH^- = 2 \times 10^{-5}\,M\ OH^-$

$pOH: -\log 2 \times 10^{-5} = 4.70 \qquad pH = 14 - 4.70 = 9.30$

g $650\,mM\ MgF_2 \left| \frac{2\ mmol\ F^-}{1\ mmol\ MgF_2} \right. = 1300\ mM\ F^- = 1.3\ M\ F^-$

	F^- + H_2O	$\rightleftharpoons$ HF	+ OH^-
I	1.3M	∅	∅
C	$-x$	$+x$	$+x$
E	$1.3-x$	x	x

$K_b = 1.58 \times 10^{-11} = \frac{x^2}{1.3 - x}$

assume: $x << 1.3$

$1.58 \times 10^{-11} = \frac{x^2}{1.3} \qquad x^2 = 2.054 \times 10^{-11}$

$x = 4.5 \times 10^{-6} = [OH^-]$

$pOH = -\log 4.5 \times 10^{-6} = 5.34$

$pH = 14 - 5.34 = 8.66$

h. 175 mM $Ca(ClO)_2$ | $\frac{2 \text{ mmol } ClO^-}{1 \text{ mmol } Ca(ClO)_2}$ = 350 mM ClO^- = 0.35 M ClO^-

$ClO^- + H_2O \rightleftharpoons HClO + OH^-$

	ClO^-	$HClO$	OH^-
I	0.35	∅	∅
C	$-x$	$+x$	$+x$
E	$0.35-x$	x	x

$K_b = 3.39\times10^{-7} = \frac{x^2}{1.3-x}$

assume: $x << 0.35$

$3.39\times10^{-7} = \frac{x^2}{0.35}$

$x^2 = 1.17\times10^{-7}$

$x = 3.4\times10^{-4}$ M = $[OH^-]$

pOH = $-\log 3.4\times10^{-4}$ = 3.47

pH = 14 − 3.47 = 10.53

8. a. 650 mM NaF = 650 mM F^- = 0.65 M F^-

$F^- + H_2O \rightleftharpoons HF + OH^-$

	F^-	HF	OH^-
I	0.65	∅	∅
C	$-x$	$+x$	$+x$
E	$0.65-x$ ≈ 0.65	x	x

$1.58\times10^{-11} = \frac{x^2}{0.65}$

$x^2 = 1.03\times10^{-11}$

$x = [OH^-] = 3.2\times10^{-6}$

pOH = $-\log$ ↗ = 5.49

4

b. 175 mM NaClO = 0.175 M ClO^-

$ClO^- + H_2O \rightleftharpoons HClO + OH^-$

	ClO^-	$HClO$	OH^-
I	0.175	0	0
C	$-x$	$+x$	$+x$
E	$0.175-x$ ≈ 0.175	x	x

$3.39\times10^{-7} = \frac{x^2}{0.175}$

$x^2 = 5.9\times10^{-8}$

$x = [OH^-] = 2.4\times10^{-4}$

9. a. HCl $pH = 5.5$

strong acid, so $[H_3O^+] = [HCl] = 10^{-5.5} = 3.16 \times 10^{-6}$ M $= 3.16\ \mu M$

b. HNO_3 Same as HCl! $3.16\ \mu M$

c. $NH_4Cl \rightarrow NH_4^+ + Cl$

$pK_a = 9.25$ $K_a = 10^{-9.25}$

NH_4^+	$+ H_2O \rightleftharpoons$	H_3O^+	$+ NH_3$
I		$\emptyset$	$\emptyset$
$-x$		$+x$	$+x$
$I-x$		x	x

$x = [H_3O^+] = 3.16 \times 10^{-6}$ M (because $pH = 5.5$)

$$10^{-9.25} = \frac{(3.16 \times 10^{-6})^2}{I - 3.16 \times 10^{-6}}$$

$$10^{-9.25} I - 1.77 \times 10^{-15} = 9.99 \times 10^{-12}$$

$$10^{-9.25} I = 9.987 \times 10^{-12}$$

$$I = 0.0178\ M$$

$$I = 17{,}800\ \mu M$$

d.

HX	$+ H_2O \rightleftharpoons$	X^-	$+ H_3O^+$
I		$\emptyset$	$\emptyset$
$-x$		$+x$	$+x$
$I-x$		x	x

$x = [H_3O^+] = 3.16 \times 10^{-6}$ M (because $pH = 5.5$)

$$10^{-2.87} = \frac{(3.16 \times 10^{-6})^2}{I - 3.16 \times 10^{-6}}$$

$$10^{-2.87} I - 4.26 \times 10^{-9} = 9.99 \times 10^{-12}$$

$$10^{-2.87} I = 4.27 \times 10^{-9}$$

$$I = 3.165 \times 10^{-6}\ M$$

$$I = 3.17\ \mu M$$

10. a. hypochlorous acid $pK_a = 7.40$ buffer range: $6.4 \rightarrow 8.4$

b. boric acid $pK_a = 9.27$ buffer range $8.27 \rightarrow 10.27$

c. formic acid $pK_a = 3.75$ buffer range $2.75 \rightarrow 4.75$

11. $pK_a = 5.75$ $pH = 4.5$ $pH = pK_a + \log A^-/HA$

$4.5 = 5.75 + \log A^-/HA$ $-1.25 = \log A^-/HA$ $A^-/HA = 0.056$

more HA

b. $pK_a = 3.75$ $pH = 4.5$ more A^- $pH > pK_a$

c. $pH = pK_a$ $[HA] = [A^-]$

d. $pK_a = 7.1$ $pH = 7.2$ more A^- $pH > pK_a$

12. $[HA] = 0.15M$ $[A^-] = 0.25M$ $pK_a = 4.74$

$$pH = 4.74 + \log \frac{0.25}{0.15} = 4.96$$

b. $[HA] = 1.38\ M$ $pK_a = 3.2$ $pH = 3.2 + \log \frac{1.25}{1.38} = 3.16$

$[A^-] = 1.25\ M$

13. a. $7.0 = 7.4 + \log \frac{x}{100\ mM}$

$-0.4 = \log \frac{x}{100}$

$10^{-0.4} = \frac{x}{100}$

$x = [ClO^-] = 39.81\ mM$

$$\frac{250\ mL}{} \left| \frac{L}{1mL} \right| \frac{39.81\ mmol}{L} \left| \frac{10^{3} mol}{1\ mmol} \right| \frac{90.55\ g}{mol}$$

0.901 g KClO

b. $3.8 = 3.25 + \log \frac{x}{75}$

$0.55 = \log \frac{x}{75}$

$10^{0.55} = \frac{x}{75}$

$x = 266\,mM = 0.266\,M$

$\frac{0.5\,L \mid 0.266\,mol \mid 69.02\,g}{ \mid L \mid mol} = 9.18\,g\ NaNO_2$

14. a. ① Stoichiometry step: 0.005 mol HCl added to the buffer

HCl: $10\,mL \rightarrow \frac{0.01\,L \mid 0.5\,mol\ HCl}{ \mid L} = 0.005\,mol\ HCl$

(HCl is L.R.)

A^-: $\frac{1.8\,L \mid 14.23\,mmol}{ \mid L} = 25.614\,mmol \rightarrow 0.025614\,mol\ A^-$

HA: $\frac{1.8\,L \mid 35.77\,mmol}{ \mid L} = 64.39\,mmol \rightarrow 0.06439\,mol$

	A^- +	HCl →	HA	+ Cl^-
I_{mol}	0.025614	0.005 mol	0.06439	
C_{mol}	−0.005	−0.005	+0.005	
F_{mol}	0.020614	∅	0.06939	

② Equilibrium Step (Henderson-Hasselbach)

$$pH = 7.4 + \log \frac{0.020614}{0.06939}$$

$pH = 6.873$

b. ① Stoichiometry step: 0.005 mol HCl added to the buffer

HCl: $10\,mL \rightarrow \frac{0.01\,L \mid 0.5\,mol\ HCl}{ \mid L} = 0.005\,mol\ HCl$

(HCl is L.R.)

A^-: $\frac{3.6\,L \mid 156.04\,mmol}{ \mid L} = 561.74\,mmol \rightarrow 0.56174\,mol\ A^-$

HA: $\frac{3.6\,L \mid 43.96\,mmol}{ \mid L} = 158.26\,mmol \rightarrow 0.15826\,mol$

	A^- +	HCl	→ HA	+ Cl^-
I_{mol}	0.56174	0.005 mol	0.15820	
C_{mol}	−0.005	−0.005	+0.005	
F_{mol}	0.55674	∅	0.16326	

② Equilibrium Step (Henderson-Hasselbach)

$$pH = 3.25 + \log \frac{0.55674}{0.16326}$$

$pH = 3.78$

15. a. 1.00 M HA $pK_a = 4.74$ $pH = 5.3$

$$5.3 = 4.74 + \log \frac{[A^-]}{1.00\,M} \qquad 0.56 = \log \frac{[A^-]}{1.00\,M} \qquad [A^-] = 3.63\,M$$

need 3.63 M acetate → moles?

sodium acetate
$NaCH_3CO_2$
MW = 82.04 g/mol

$$\frac{0.5\,L \mid 3.63\,mol}{\mid L} = 1.81\,mol \,\Big|\, \frac{82.04\,g}{mol} = 148.49\,g$$

b. $$5.3 = 4.74 + \log \frac{[A^-]}{0.385\,M} \qquad \frac{[A^-]}{0.385\,M} = 3.63 \qquad [A^-] = 1.398\,M$$

$$\frac{0.5\,L \mid 1.389\,mol \mid 82.04\,g}{\mid L \mid mol} = 57.34\,g$$