WORKSHEET: SOLUTION EQUILIBRIUM (Weak acids and bases, buffers,Polyprotic acids, and Hydrolysis.)
SET A:

1) 40.00 ml of 0.350 M CH_3NH_2 is titrated with 0.280 M HCl until the end point is reached. Calculate the pH of the solution at the end point.(K_b for CH_3NH_2= 5.0×10^{-4})

Setup:

	CH_3NH_2	$+ HCl \rightarrow$	$CH_3NH_3^+ + HCl$
initial moles	$.0400 l \times .350 \frac{mole}{l}$ = .0140 mole	$.0500 l \times .280 \frac{mole}{l}$ = .0140 mole	0
change in moles	−.0140	−.0140	+.0140
final mole	0	0	.0140

$[CH_3NH_3^+]$ formed $= \frac{.0140 \text{ mole}}{.0900 l} = 0.156$ M

Hydrolysis problem

	$CH_3NH_3^+$	$+ H_2O \rightleftharpoons$	CH_3NH_2	$+ H_3O^+$
Initial conc.	0.156		0	0
Change in conc.	−x		+x	+x
Equi. conc	0.156−x		x	x

$$K_{a\,CH_3NH_3^+} = \frac{K_w}{K_{a\,CH_3NH_2}} = \frac{1.0 \times 10^{-14}}{5.0 \times 10^{-4}} = 2.0 \times 10^{-11}$$

$$K_{a\,CH_3NH_3^+} = \frac{[CH_3NH_2][H_3O^+]}{[CH_3NH_3^+]}$$

$$2.0 \times 10^{-11} = \frac{(x)(x)}{(0.156-x)}$$

$x = [H_3O^+] = 1.8 \times 10^{-6}$

pH = 5.74

Answer: 5.74

2) How many moles of HNO_2 must be added to a 1.00 liter of 0.370 M $NaNO_2$ to give a buffer of pH= 4.20? (Ignore any volume change due to the addition of HNO_2) (K_a for HNO_2 is 4.5×10^{-4}).

Setup:

$$HNO_2 + H_2O \rightleftharpoons H_3O^+ + NO_2^-$$

	HNO_2	H_3O^+	NO_2^-
Initial conc.	C moles in 1 liter	0	0.370
Change in conc.	-6.3×10^{-5}	$+6.3\times10^{-5}$	$+6.3\times10^{-5}$
Equi conc.	$C - 6.3\times10^{-5}$ negligible	6.3×10^{-5}	$.370 + 6.3\times10^{-5}$ negl.

$$K_a = \frac{[H_3O^+][NO_2^-]}{[HNO_2]}$$

$$4.5\times10^{-4} = \frac{(6.3\times10^{-5})(0.370)}{(C - \underbrace{6.3\times10^{-5}}_{negligible})} \; ; \; C = 0.052$$

Answer: 0.052 moles

3) a) Is $NaHCO_3$ (aq) acidic, basic, or neutral ?You must show your work to justify your answer. (K_{a1} for H_2CO_3 = 4.3 x 10-7, K_{a2} for $HCO_3^- = 4.8 \times 10^{-11}$)

Setup:

$$HCO_3^- + H_2O \rightleftharpoons H_3O^+ + CO_3^{2-} \qquad K_{a_2} = 4.8\times10^{-11}$$

$$HCO_3^- + H_2O \rightleftharpoons H_2CO_3 + OH^- \qquad K_b = \frac{K_w}{K_{a_1}} = \frac{1.0\times10^{-14}}{4.3\times10^{-7}} = 2.3\times10^{-8}$$

Answer: K_b for HCO_3^- is larger than K_{a2} for HCO_3^-, $NaHCO_3$ (aq) is basic.

b) Is $NaHCO_3$ (aq) a buffer? (You must show your work to prove that your answer is not a guess.)

Setup:

$$HCO_3^- + H^+_{added} \longrightarrow \underset{molecular}{H_2CO_3}$$

$$HCO_3^- + OH^-_{added} \longrightarrow CO_3^{2-} + H_2O_{molecular}$$

HCO_3^- ties up (reacts with) any H^+ or OH^- added.
A solution of HCO_3^- resists the change in pH when a small amount of H^+ or OH^- is added

Answer: Yes

4) How many moles of NaOH must be added to a 1.00 liter of 0.230 M benzoic acid, $HC_7H_5O_2$, to produce a solution of pH= 4.50? (Ka for $HC_7H_5O_2 = 6.3 \times 10^{-5}$)

Setup:

$$NaOH + HC_7H_5O_2 \rightarrow Na^+C_7H_5O_2^- + H_2O$$

	NaOH	$HC_7H_5O_2$	$Na^+C_7H_5O_2^-$
initial moles	C added - limiting	0.230	0
change in moles	-C	-C	+C
final moles	0	.230-C	C

Buffer problem: $HC_7H_5O_2 + H_2O \rightleftharpoons H_3O^+ + C_7H_5O_2^-$

	$HC_7H_5O_2$	H_3O^+	$C_7H_5O_2^-$
Initial conc.	0.230-C	0	C
change in conc.	-3.2×10^{-5}	$+3.2\times10^{-5}$	$+3.2\times10^{-5}$
Equi. conc.	$.230-C-3.2\times10^{-5}$	3.2×10^{-5}	$C+3.2\times10^{-5}$

negligible negligible

$$K_a = \frac{[H_3O^+][C_7H_5O_2^-]}{[HC_7H_5O_2]}$$

$$6.3\times10^{-5} = \frac{(3.2\times10^{-5})C}{(0.230-C)}$$

$C = 0.15$ mole

Answer: 0.15 mole

5) The $[S^{2-}]$ concentration of a 0.150 M H_2S is adjusted to a value of 4.18×10^{-8} moles/liter. What is the $[H^+]$ concentration?

(K_{a1} for $H_2S = 8.9 \times 10^{-8}$, K_{a2} for HS^- is 1.2×10^{-13})

Setup:

$$H_2S + 2H_2O \rightleftharpoons 2H_3O^+ + S^{2-}$$

$$K_{overall} = K_{a_1}K_{a_2} = \frac{[H_3O^+]^2[S^{2-}]}{[H_2S]}$$

$$(8.9\times10^{-8})(1.2\times10^{-13}) = \frac{[H_3O^+]^2(4.18\times10^{-8})}{0.150}$$

$[H_3O^+] = 1.9\times10^{-7}$ M

Answer: 1.9×10^{-7} M

6) What is the $[H^+]$ concentration of a solution made by adding 35.00 ml of 0.660 M $C_6H_5NH_2$ to 40.00 ml of 0.420 M HCl? (K_b for $C_6H_5NH_2$ is 4.6×10^{-7})

Setup:

	$C_6H_5NH_2$ +	HCl →	$C_6H_5NH_3^+$ +	Cl^-
initial moles	$0.350\,\ell \times .660\,\frac{mole}{\ell} = .0231$ mole	$.0400\,\ell \times .420\,\frac{mole}{\ell} = .0168$ mole	0	
change in moles	$-.0168$ mole	$-.016$ mole	$+.0168$ mole	
final moles	$.0231$ mole $- .0168$ mole $= .0063$ mole	0	$.0168$ mole	

Buffer problem:

	$C_6H_5NH_2$ +	H_2O ⇌	$C_6H_5NH_3^+$ +	OH^-
Initial conc	$\frac{.0063\text{ mole}}{.0750\,\ell} = .084$		$\frac{.0168\text{ mole}}{.0750\,\ell} = .224$	0
change in conc.	$-x$		$+x$	$+x$
Equilibrium conc	$.084 - x$		$.224 + x$	x

$$K_b = \frac{[C_6H_5NH_3^+][OH^-]}{[C_6H_5NH_2]}$$

$$4.6 \times 10^{-7} = \frac{(0.224 + x)(x)}{(0.084 - x)}$$

$$x = [OH^-] = 1.7 \times 10^{-7}\,M$$

$$[H^+] = \frac{1.0 \times 10^{-14}}{1.7 \times 10^{-7}} = 5.9 \times 10^{-8}\,M$$

Answer: 5.9×10^{-8} M

7) Predict whether the following solutions are acidic, basic, or neutral. Write the equilibrium equations, and all calculations if needed, to justify your answer. (K_b for NH_3 is 1.8×10^{-5}, K_a for HClO is 3.5×10^{-8})

a) NH_4ClO

Setup:

$$NH_4^+ + H_2O \rightleftharpoons NH_3 + H_3O^+ \ldots K_a(NH_4^+) = \frac{K_w}{K_b(NH_3)} = \frac{1.0 \times 10^{-14}}{1.8 \times 10^{-5}}$$

$$ClO^- + H_2O \rightleftharpoons HClO + OH^- \ldots K_b(ClO^-) = \frac{K_w}{K_a(HClO)} = \frac{1.0 \times 10^{-14}}{3.5 \times 10^{-8}} = 2.9 \times 10^{-7}$$

Answer: K_b for ClO^- > Ka for NH_4^+ . Basic

b) $NaNO_2$

Setup:

$$NO_2^- + H_2O \rightleftharpoons HNO_2 + OH^-$$

Answer: Basic

c) $Ni(NO_3)_3$

Setup:

$$Ni(H_2O)_6^{3+} + H_2O \rightleftharpoons Ni(H_2O)_5OH^{2+} + H_3O^+$$

Answer: Acidic

SET B:

1) How many moles of $HCHO_2$ must be added to a 1.00 liter of 0.400 M $NaCHO_2$ to give a buffer of pH= 3.60? Ignore any volume change due to the addition of $HCHO_2$. (Ka for $HCHO_2$=1.8×10^{-4})

Setup:

	$HCHO_2 + H_2O$	$\rightleftharpoons H_3O^+$	$+ CHO_2^-$
Initial	$C_{added/to\ 1.0\ liter}$	0	0.400 mol/l
change	-2.5×10^{-4}	$+2.5 \times 10^{-4}$	$+2.5 \times 10^{-4}$
Equilibrium	$C - 2.5 \times 10^{-4}$	2.5×10^{-4}	$0.400 + 2.5 \times 10^{-4}$

$$K_a = \frac{[H_3O^+][CHO_2^-]}{[HCHO_2]}$$

$$1.8 \times 10^{-4} = \frac{(2.5 \times 10^{-4})(0.400 + 2.5 \times 10^{-4})}{C - 2.5 \times 10^{-4}}$$

$$1.8 \times 10^{-4} = \frac{(2.5 \times 10^{-4})(.400)}{C}$$

$$C = 0.55 \text{ mole/l}$$

Answer: 0.55 mole

2) a) Is Na_2HPO_4 (aq) a buffer? You must show your work to prove that your answer is not a guess.

Setup: Na_2HPO_4 is a buffer.

$$HPO_4^{2-} + H^+_{added} \rightleftharpoons H_2PO_4^-$$

$$HPO_4^{2-} + OH^-_{added} \rightleftharpoons PO_4^{3-} + H_2O$$

Answer: Yes

b) Is Na_2HPO_4 acidic, basic, or neutral? You must show your work to justify your answer.

K_{a3} for HPO_4^{2-} is 1.00×10^{-12}, K_{a2} for $H_2PO_4^-$ is 6.2×10^{-8}

Setup:

$$HPO_4^{2-} + H_2O \rightleftharpoons PO_4^{3-} + H_3O^+ \quad K_{a_3} = 1.0 \times 10^{-12}$$

$$HPO_4^{2-} + H_2O \rightleftharpoons H_2PO_4^- + OH^- \quad K_b \text{ for } HPO_4^{2-} = \frac{K_w}{K_{a_2}} = \frac{1.0 \times 10^{-14}}{6.2 \times 10^{-8}} = 1.6 \times 10^{-7}$$

Answer: K_b (for HPO_4^{2-}) > K_{a3} (for HPO_4^{2-}), Basic

3) What is the $[H^+]$ concentration of a solution made by titrating 30.00 ml of 0.7200 M $C_6H_5NH_2$ with 0.2500 M HCl until the equivalence point is reached? K_b for $C_6H_5NH_2$ is 4.6×10^{-7}.

Setup:

$$C_6H_5NH_2 + HCl \longrightarrow C_6H_5NH_3^+ + Cl^-$$

① moles $C_6H_5NH_2$ = $M_{C_6H_5NH_2} V_{C_6H_5NH_2} = .7200 \text{ mole/l} \times .03000 \text{ l} = .02160$ mole $C_6H_5NH_2$

② $.0216 \text{ mole } C_6H_5NH_2 \left(\frac{1 \text{ mole HCl}}{1 \text{ mole } C_6H_5NH_2}\right) = .0216$ mole HCl

③ $V_{HCl} = \frac{.02160 \text{ mole HCl}}{.2500 \text{ mole/liter}} = .08640 \text{ Liter}_{HCl} = 86.40$ ml

④ Total volume of solution = 30.00 ml + 86.40 ml = 116.40 ml solution

⑤ At the end point, all $C_6H_5NH_2$ has reacted completely.

0.02160 mole $C_6H_5NH_3^+$ is formed.

$$[C_6H_5NH_3^+] = \frac{.02160 \text{ mole}}{.1164 \text{ liter}} = 0.1856 \text{ M}$$

Hydrolysis problem:

	$C_6H_5NH_3^+$	$+ H_2O \rightleftharpoons$	$C_6H_5NH_2$	$+ H_3O^+$
Initial conc.	.1856		0	0
change in conc	$-x$		$+x$	$+x$
Equil. conc	$.1856-x$		x	x

Answer: 6.4×10^{-5}

$$K_a \text{ for } C_6H_5NH_3^+ = \frac{K_w}{K_b \text{ for } C_6H_5NH_2} = \frac{[H_3O^+][C_6H_5NH_2]}{[C_6H_5NH_3^+]} = \frac{(x)(x)}{(.1856-x)}$$

$[H_3O^+] = 6.4 \times 10^{-5}$ M

4) Predict whether each of the following solutions is acidic, basic, or neutral. Write the equilibrium equations, and ~~all~~ calculations if needed, to justify your answer. K_b for NH_3= 1.8×10^{-5}, K_a for $HCHO_2$ is 1.8×10^{-4}.

a) NH_4CHO_2 $NH_4^+ + H_2O \rightleftharpoons NH_3 + H_3O^+ \ldots K_{a\,NH_4^+} = \frac{K_w}{K_{b\,NH_3}} = \frac{1.0\times10^{-14}}{1.8\times10^{-5}} = 5.5\times10^{-10}$

Setup:

$CHO_2^- + H_2O \rightleftharpoons HCHO_2 + OH^- \ldots K_{b\,CHO_2^-} = \frac{K_w}{K_{a\,HCHO_2}} = \frac{1.0\times10^{-14}}{1.8\times10^{-4}} = 5.5\times10^{-11}$

Answer: K_a (for NH_4^+) > Kb (for CHO_2^-) , Acidic

b) Na_2S

Setup:

$S^{2-} + H_2O \rightleftharpoons HS^- + OH^-$

Answer: Basic

c) $Cr(NO_3)_3$

Setup:

$Cr(H_2O)_6^{3+} + H_2O \rightleftharpoons Cr(H_2O)_5OH^{2+} + H_3O^+$

Answer: Acidic

5) The $C_6H_6O_6^{2-}$, ascorbate ion, concentration of a 0.270 M ascorbic acid, is adjusted to a value of 8.5×10^{-8} mole/liter. What is the [H^+] concentration? K_{a1} for $H_2C_6H_6O_6$ is 7.9×10^{-5} and K_{a2} for $HC_6H_6O_6^-$ is 1.6×10^{-12}.

Setup:

$H_2C_6H_6O_6 + 2H_2O \rightleftharpoons 2H_3O^+ + C_6H_6O_6^{2-}$

0.270 ? 8.5×10^{-8}

$$K_{overall} = K_{a_1} K_{a_2} = \frac{[H_3O^+]^2 [C_6H_6O_6^{2-}]}{[H_2C_6H_6O_6]}$$

$$(7.9\times10^{-5})(1.6\times10^{-12}) = \frac{[H_3O^+]^2 (8.5\times10^{-8})}{0.270}$$

$$[H_3O^+] = 2.0\times10^{-5}\ M$$

Answer: 2.0×10^{-5} M

6) How many moles of NaOH should be added to a 1.00 liter of 0.190 M HNO_2 to produce a solution of pH= 4.80? Assume there is no change in volume upon the addition of NaOH. Ka for HNO_2 is 4.5×10^{-4}.

Setup:

$NaOH + HNO_2 \rightarrow NaNO_2 + H_2O$

	NaOH	HNO_2	$NaNO_2$
Initial moles	C limiting	0.190	0
change in moles	−C	−C	+C
final moles	0	.190−C	C

Buffer problem:-

$HNO_2 + H_2O \rightleftharpoons H_3O^+ + NO_2^-$

	HNO_2	H_3O^+	NO_2^-
Initial conc	.190−C	0	C
change in conc	-1.6×10^{-5}	$+1.6\times10^{-5}$	$+1.6\times10^{-5}$
Equi. conc	$.190-C-1.6\times10^{-5}$ negligible	1.6×10^{-5}	$C+1.6\times10^{-5}$ negligible

$$Ka = \frac{[H_3O^+][NO_2^-]}{[HNO_2]}$$

$$4.5\times10^{-4} = \frac{(1.6\times10^{-5})(C+1.6\times10^{-5})}{(0.190-C-1.6\times10^{-5})}$$

$$4.5\times10^{-4} = \frac{(1.6\times10^{-5})\,C}{(0.196-C)}$$

C = 0.18 mole NaOH to be added to a 1.0 liter

Answer: 0.18 mole

7) What is the pH of a solution made by mixing 25.00 ml of 0.440 M CH_3NH_3Cl and 37.00 ml of 0.200 M NaOH? K_b for CH_3NH_2 is 5.0×10^{-4}.

Setup:

$$CH_3NH_3^+ + OH^- \rightarrow CH_3NH_2 + H_2O$$

① # moles $CH_3NH_3^+$ available $= M_{CH_3NH_3^+} V_{CH_3NH_3^+}$

$= .440 \frac{mole}{\ell} \times .02500 \ell$

$= .0110$ mole $CH_3NH_3^+$

② # moles OH^- added $= M_{NaOH} V_{NaOH}$

$= .03700 \ell \times .200 \frac{mole}{\ell}$

$= 7.40 \times 10^{-3}$ mole NaOH

	$CH_3NH_3^+$ +	OH^- →	CH_3NH_2 +	H_2O
initial moles	0.0110 mole	7.40×10^{-3} mole	0	
change in moles	-7.40×10^{-3}	-7.40×10^{-3}	$+7.4 \times 10^{-3}$	
final moles	$.0110 - 7.40 \times 10^{-3}$	0	7.4×10^{-3}	

Buffer problem:

	CH_3NH_2 + H_2O ⇌	$CH_3NH_3^+$ +	OH^-
initial conc	$\frac{7.40 \times 10^{-3} \text{ mole}}{.0620 \ell} = .119$	$\frac{3.60 \times 10^{-3} \text{ mole}}{.0620 \ell} = .0581$	0
change in conc	$-x$	$+x$	$+x$
Equi. conc	$0.119 - x$	$.0581 + x$	x

$$K_b = \frac{[CH_3NH_3^+][OH^-]}{[CH_3NH_2]}$$

$$5.0 \times 10^{-4} = \frac{(.0581 + x)(x)}{(0.119 - x)}$$

$x = [OH^-] = 1.0 \times 10^{-3}$ M

pOH = 3.00

pH = 11.00

Answer: pH= 11.00

SET C:

1) The oxalate ion concentration, $C_2O_4^{2-}$, of 0.20 M $H_2C_2O_4$ is adjusted to a value of 3.00×10^{-3} M. What is the $[H^+]$ ion concentration in the solution? K_{a1} for $H_2C_2O_4$ is 5.6×10^{-2} and K_{a2} for $HC_2O_4^-$ is 5.1×10^{-5}.

Setup:

$$H_2C_2O_4 + 2H_2O \rightleftharpoons 2H_3O^+ + C_2O_4^{2-}$$

$$K_{overall} = K_{a_1} K_{a_2} = \frac{[H_3O^+]^2 [C_2O_4^{2-}]}{[H_2C_2O_4]}$$

$$(5.6 \times 10^{-2})(5.1 \times 10^{-5}) = \frac{[H_3O^+]^2 (3.00 \times 10^{-3})}{(0.20)}$$

$$[H_3O^+] = 1.4 \times 10^{-2}$$

Answer: 1.4×10^{-2} M

2) Predict whether each of the following solutions is acidic, basic, or neutral. Write the equilibrium equations, and all calculations if needed, to justify your answer. Kb for NH_3 is 1.8×10^{-5}, K_a for HClO is 3.5×10^{-8}.

a) NH_4ClO

Setup:

$$NH_4^+ + H_2O \rightleftharpoons H_3O^+ + NH_3 \qquad K_{a\,NH_4^+} = \frac{K_w}{K_{b\,NH_3}} = \frac{1.0 \times 10^{-14}}{1.8 \times 10^{-5}} = 5.5 \times 10^{-10}$$

$$ClO^- + H_2O \rightleftharpoons HClO + OH^- \qquad K_{b\,ClO^-} = \frac{K_w}{K_a\,HClO} = \frac{1.0 \times 10^{-14}}{3.5 \times 10^{-8}} = 2.9 \times 10^{-7}$$

K_b for ClO^- > K_a for NH_4^+

Answer: K_b for ClO^- > K_a for NH_4^+. Basic

b) KCNO

Setup:

$$CNO^- + H_2O \rightleftharpoons HCNO + OH^-$$

Answer: Basic

c) $Ni(ClO_4)_3$

Setup:

$$Ni(H_2O)_6^{3+} + H_2O \rightleftharpoons Ni(H_2O)_5OH^{2+} + H_3O^+$$

Answer: Acidic

3) What is the pH at the equivalence point when 27.0 ml of 0.200 M CH_3NH_2 are titrated with 0.350 M HCl? K_b for CH_3NH_2 is 4.4×10^{-4}.

Setup:

① $CH_3NH_2 + HCl \rightarrow CH_3NH_3^+ + Cl^-$

$.200 \frac{mole}{l} \times .0270\,l$ $= 5.40 \times 10^{-3}$ mole (react)	5.40×10^{-3} mole (react)	5.40×10^{-3} mole (formed)

② Find vol of HCl added:

$$0.200 \frac{mole}{l} CH_3NH_2 \times 0.0270\, l_{CH_3NH_2} \left(\frac{1 \text{ mole HCl}}{1 \text{ mole } CH_3NH_2}\right)\left(\frac{1\, l_{HCl}}{0.350 \text{ mole HCl}}\right)$$

$$= 0.0154\, l_{HCl} = 15.4\, ml_{HCl}$$

③ Find total volume after end point is reached:

$$27.0\, ml_{CH_3NH_2} + 15.4\, ml_{HCl} = 42.4\, ml = .0424\, l$$

④ Hydrolysis problem:

$$CH_3NH_3^+ + H_2O \rightleftharpoons CH_3NH_2 + H_3O^+$$

	$CH_3NH_3^+$	CH_3NH_2	H_3O^+
Initial conc.	$\frac{5.40 \times 10^{-3} \text{ mole}}{.0424\, l} = 0.127M$	0	0
change in conc	$-x$	$+x$	$+x$
Equi. conc.	$(.127 - x)$	x	x

$$K_{a\,CH_3NH_3^+} = \frac{K_w}{K_{b\,CH_3NH_2}} = \frac{1.00 \times 10^{-14}}{4.4 \times 10^{-4}} = 2.3 \times 10^{-11}$$

$$K_a = \frac{[CH_3NH_2][H_3O^+]}{CH_3NH_3^+}$$

$$2.3 \times 10^{-11} = \frac{(x)(x)}{(.127 - x)} \quad ; \quad x = [H^+] = 1.7 \times 10^{-6}$$

$$pH = 5.76$$

Answer: 5.76

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4) How many ml of 0.250 M HF (aq) must be added to 500.0 ml of 0.300 M NaF to give a buffer of pH= 3.50? K_a for HF is 6.8×10^{-4}.

Setup:

	HF + H_2O	$\rightleftharpoons$ H_3O^+	+ F^-
Initial conc.	$\frac{C_{moles}}{V_{Total}}$	0	$\frac{.500\,l \times .300\,mole/l}{V_{Total}} = \frac{.15}{V_{Total}}$
change in con	-3.2×10^{-4}	$+3.2\times10^{-4}$	$+3.2\times10^{-4}$
Equi. conc	$\frac{C_{moles}}{V_{Total}} - 3.2\times10^{-4}$	3.2×10^{-4}	$\frac{.15}{V_{Total}} + 3.2\times10^{-4}$

$$K_a = \frac{[H_3O^+][F^-]}{[HF]}$$

negligible

$$6.8\times10^{-4} = \frac{(3.2\times10^{-4})\left(\frac{0.15}{V_{Total}} + 3.2\times10^{-4}\right)}{\left(\frac{C}{V_{Total}} - 3.2\times10^{-4}\right)}$$

negligible

$$6.8\times10^{-4} = \frac{(3.2\times10^{-4})\left(\frac{0.15}{V_{Total}}\right)}{\frac{C}{V_{Total}}}$$

$$6.8\times10^{-4} = \frac{(3.2\times10^{-4})(0.15)}{C}$$

$$C_{moles} = 0.0706 \text{ moles}$$

$$V_{HF} = .0706\,mole\left(\frac{1\,liter}{0.250\,mole}\right) = .282\,l = 282\,ml$$

Answer: 282 ml

5) Find the pH of a solution made by mixing 25.0 ml of 0.0650 M benzylamine, $C_7H_7NH_2$, and 13.9 ml of 0.0500 M HCl. K_b for $C_7H_7NH_2$ is 4.7×10^{-10}.

Setup:

	$C_7H_5NH_2$	$+ HCl \longrightarrow$	$C_7H_5NH_3^+$
Initial moles	$.0250\,l \times .0650\,\frac{mole}{l}$ $= 1.63 \times 10^{-3}$ mole	$.0139\,l \times .0500\,\frac{mole}{l}$ $= 6.95 \times 10^{-4}$ mole	0
change in moles	-6.95×10^{-4} mole	-6.95×10^{-4} mole	$+6.95 \times 10^{-4}$ mole
final moles	$1.63 \times 10^{-3} - 6.95 \times 10^{-4}$ $= .94 \times 10^{-3}$ mole	0	6.95×10^{-4} mole

Buffer problem

	$C_7H_5NH_2$	$+ H_2O \rightleftharpoons$	$C_7H_5NH_3^+$	$+ OH^-$
initial conc	$\frac{0.94 \times 10^{-3}\text{ mole}}{.0389\,l}$ $= 2.39 \times 10^{-2}$		$\frac{6.95 \times 10^{-4}\text{ mole}}{.0389\,l}$ $= 1.79 \times 10^{-2}$	0
change in conc	$-x$		$+x$	$+x$
Equi conc	$2.4 \times 10^{-2} - x$		$1.79 \times 10^{-2} + x$	x

$$K_b = \frac{[C_7H_5NH_3^+][OH^-]}{[C_7H_5NH_2]}$$

$$4.7 \times 10^{-10} = \frac{\left(\frac{6.95 \times 10^{-4}}{.0389} + x\right)(x)}{\left(\frac{0.94 \times 10^{-3}}{.0389} - x\right)}$$

$x = [OH^-] = 6.3 \times 10^{-10}$ M

$pOH = 9.20$

$pH = 4.80$

Answer: 4.80

6) A chemist wants to prepare a buffer of pH = 4.35. How many milliliters of 0.455 M acetic acid must be added to 465 ml of 0.0941 M NaOH solution to obtain such a buffer? Ka for $HC_2H_3O_2$ is 1.7×10^{-5}.

Setup:

	$HC_2H_3O_2$ +	NaOH $\rightarrow$	$Na^+C_2H_3O_2^-$ + H_2O
Initial moles	C	$.465\,l \times .0941\,\frac{mole}{l}$ $= 0.0438$ mole limiting	0
change in # moles	$-.0438$	-0.0438	$+0.0438$
final moles	$C - .0438$	0	$.0438$

	$HC_2H_3O_2 + H_2O$ $\rightleftharpoons$	H_3O^+ +	$C_2H_3O_2^-$
Initial conc	$\frac{C - .0438}{V_{total}}$	0	$\frac{.0438\text{ mole}}{V_{total}}$
Change in conc	-4.5×10^{-5}	$+4.5 \times 10^{-5}$	$+4.5 \times 10^{-5}$
Equi. conc	$\frac{C - .0438}{V_{total}} - 4.5 \times 10^{-5}$	4.5×10^{-5}	$\frac{.0438}{V_{total}} + 4.5 \times 10^{-5}$

negligible negligible

$$K_a = \frac{[H_3O^+][C_2H_3O_2^-]}{[HC_2H_3O_2]}$$

$$1.7 \times 10^{-5} = \frac{(4.5 \times 10^{-5})\left(\frac{.0438}{V_{total}}\right)}{\left(\frac{C - .0438}{V_{total}}\right)}$$

$$1.7 \times 10^{-5} = \frac{(4.5 \times 10^{-5})(.0438)}{(C - .0438)}$$

$C = 0.160$ mole $HC_2H_3O_2$; $V_{HC_2H_3O_2} = \frac{.160\text{ mole}}{4.55\text{ mole}/l} = 0.351\,l$

Answer: 351 ml

7) a) Is $NaHC_2O_4$ (aq) a buffer? You must show your work to prove that your answer is not a guess.
Setup:

$$HC_2O_4^- + H^+_{added} \longrightarrow \underset{\text{molecular}}{H_2C_2O_4}$$

$$HC_2O_4^- + OH^-_{added} \longrightarrow \underset{\text{molecular}}{H_2O} + C_2O_4^{2-}$$

$HC_2O_4^-$ ties up any H^+ or OH^- added to form molecular species. $HC_2O_4^-$ (aq) resists the change in pH.

Answer: Yes

b) Is $NaHC_2O_4$ (aq) acidic, basic, or neutral? K_{a1} for $H_2C_2O_4$ is 5.6×10^{-2}, K_{a2} for $HC_2O_4^-$ is 5.1×10^{-5}. You must show your work to justify your answer.
Setup:

① $$HC_2O_4^- + H_2O \rightleftharpoons H_2C_2O_4 + \underset{\text{basic}}{OH^-}$$

$$\underset{\text{for } HC_2O_4^-}{K_b} = \frac{K_w}{K_a \text{ for } H_2C_2O_4} = \frac{1.0 \times 10^{-14}}{5.6 \times 10^{-2}} = 1.8 \times 10^{-13}$$

② $$HC_2O_4^- + H_2O \rightleftharpoons \underset{\text{acidic}}{H_3O^+} + C_2O_4^{2-}$$

$$K_{a_2} \text{ for } HC_2O_4^- = 5.1 \times 10^{-5}$$

K_{a_2} for $HC_2O_4^-$ is larger than K_b for $HC_2O_4^-$.
Solution is acidic.

Answer: K_{a2} for $HC_2O_4^-$ > K_b for $HC_2O_4^-$, Acidic