

**CHEM 2**  
**Problem Set Ch.16**

**Key Begins on page 3.**

1. A 0.0560 g quantity of acetic acid is dissolved in enough water to make 50.0 mL of solution. Calculate the concentrations of  $\text{H}^+$ ,  $\text{C}_2\text{H}_3\text{O}_2^-$ , and  $\text{HC}_2\text{H}_3\text{O}_2$  at equilibrium. ( $K_a$  for acetic acid =  $1.8 \times 10^{-5}$ .)
2. Use  $\text{NH}_3$  and its conjugate acid  $\text{NH}_4^+$  to derive the relationship between  $K_a$  and  $K_b$ .
3. Calculate the pH for a 0.050 M pyridine solution.
4. What is the original molarity of a solution of ammonia whose pH is 11.22?
5. Calculate the concentrations of  $\text{H}^+$ ,  $\text{HCO}_3^-$ , and  $\text{CO}_3^{2-}$  in a 0.025 M  $\text{H}_2\text{CO}_3$  solution.
6. Predict whether a water solution of each of the following salts will be acidic, basic, or neutral.

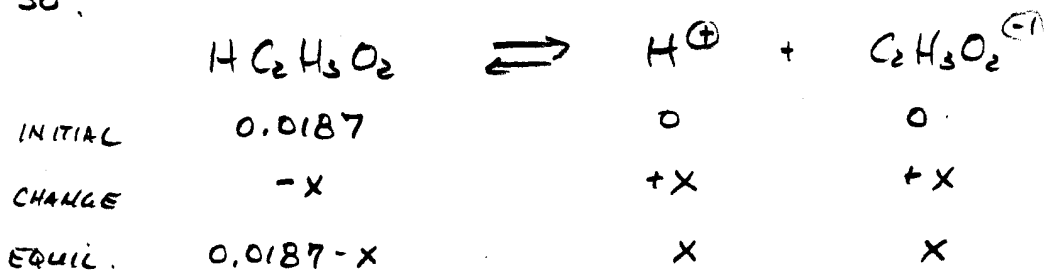
KF,	$\text{NaNO}_3$ ,
$\text{NH}_4\text{NO}_2$ ,	$\text{MgSO}_4$ ,
KCN,	$\text{NaC}_7\text{H}_5\text{O}_2$ ,
RbI,	$\text{Na}_2\text{CO}_3$ ,
$\text{CaCl}_2$ ,	$\text{KHCO}_2$

7. Calculate the pH of a 0.36 *M* NaC<sub>2</sub>H<sub>3</sub>O<sub>2</sub> solution.
8. Determine the hydrogen ion and acetate ion concentrations in a 0.100 *M* HC<sub>2</sub>H<sub>3</sub>O<sub>2</sub> solution and (b) the concentrations of the same ions in a solution that is 0.100 *M* in both HC<sub>2</sub>H<sub>3</sub>O<sub>2</sub> and HCl.
9. (a) Calculate the pH of the 0.20 *M* NH<sub>3</sub>/0.20 *M* NH<sub>4</sub>Cl buffer.
- (b) What is the pH of the buffer after the addition of 10.0 mL of 0.10 *M* HCl to 65.0 mL of the buffer.
10. If 25.0 mL of 0.100 *M* HC<sub>2</sub>H<sub>3</sub>O<sub>2</sub> is titrated with 0.100 *M* NaOH, what is the pH
- (a) after 2.00 mL of 0.100 *M* NaOH has been added?
- (b) after 25.00 mL of 0.100 *M* NaOH has been added?
- (c) after 40.00 mL of 0.100 *M* NaOH has been added?

1. THE INITIAL CONCENTRATION OF ACETIC ACID ( $\text{HC}_2\text{H}_3\text{O}_2$ )

$$\text{IS: } \frac{0.0560\text{g} \left( \frac{1\text{mol}}{60\text{g}} \right)}{0.050\text{L}} = 0.0187\text{M}$$

SO:



$$K_a = \frac{[\text{H}^+][\text{C}_2\text{H}_3\text{O}_2^-]}{[\text{HC}_2\text{H}_3\text{O}_2]}$$

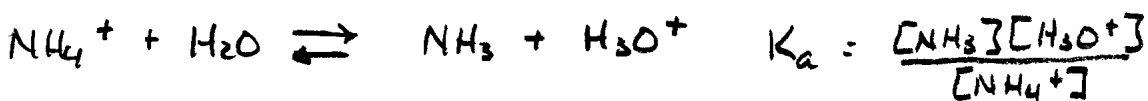
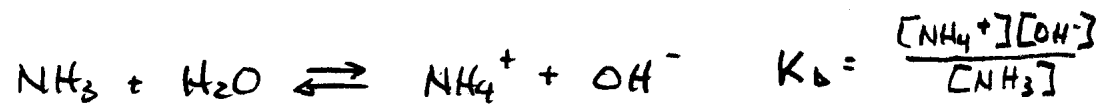
$$1.8 \times 10^{-5} = \frac{x^2}{(0.0187-x)} \quad x = 5.8 \times 10^{-4}\text{M}$$

IGNORE

$$[\text{H}^+] = [\text{C}_2\text{H}_3\text{O}_2^-] = 5.8 \times 10^{-4}\text{M}$$

$$[\text{HC}_2\text{H}_3\text{O}_2] = 0.0187 - 5.8 \times 10^{-4} = 1.81 \times 10^{-2}\text{M}$$

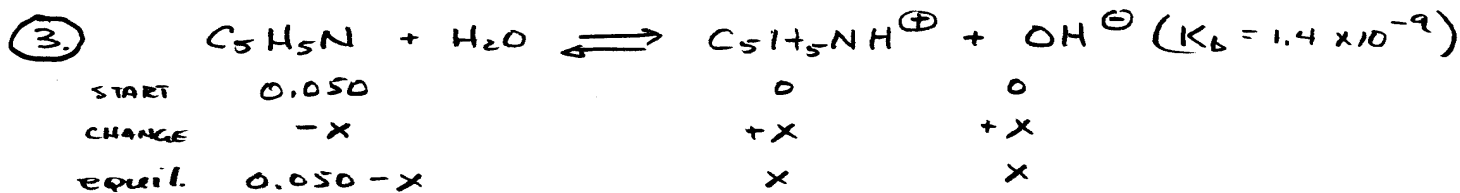
2.



$$K_a \times K_b = \frac{[\text{NH}_3][\text{H}_3\text{O}^+]}{[\text{NH}_4^+]} \times \frac{[\text{NH}_4^+][\text{OH}^-]}{[\text{NH}_3]} = [\text{H}_3\text{O}^+][\text{OH}^-] = K_w$$

SO

$$K_a \times K_b = K_w$$



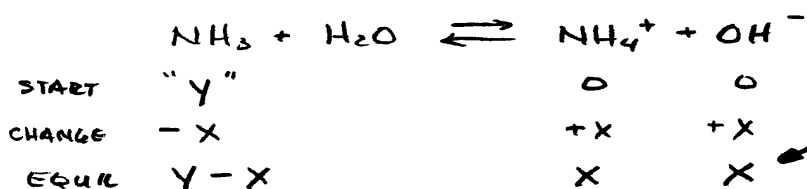
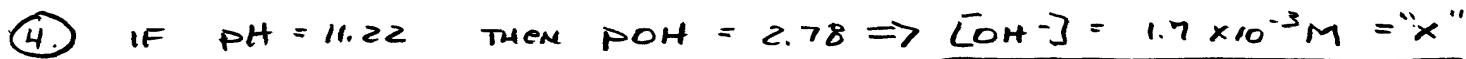
$$1.4 \times 10^{-9} = \frac{(x)(x)}{(0.050 - x)}$$

↑  
IGNORE

$$x = [OH^-] = 8.4 \times 10^{-6} M$$

$$pOH = 5.08$$

$pH = 8.92$



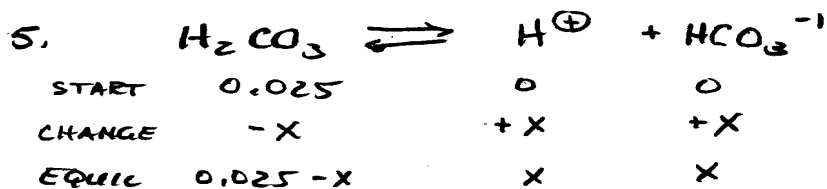
LET "y" = ORIGINAL  $NH_3$  CONC

$$1.8 \times 10^{-5} = \frac{(1.7 \times 10^{-3})(1.7 \times 10^{-3})}{(y - 1.73 \times 10^{-3})}$$

↑  
 $K_b$  FOR  $NH_3$

↑  
IGNORE

$y = 0.153 M$



$$4.3 \times 10^{-7} = \frac{(x)(x)}{(0.025 - x)}$$

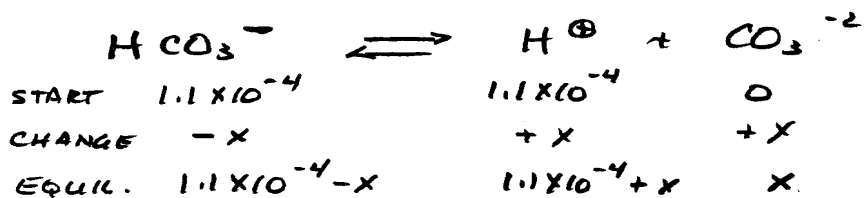
↑  
IGNORE

$$x = 1.1 \times 10^{-4}$$

SO

$$[H^+] = [HCO_3^-] = 1.1 \times 10^{-4} M$$

NOW FOR THE 2<sup>nd</sup> H<sup>+</sup>



$$4.8 \times 10^{-11} = \frac{(1.1 \times 10^{-4} + x)(x)}{(1.1 \times 10^{-4} - x)}$$

↑  
IGNORE

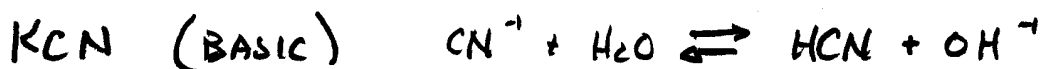
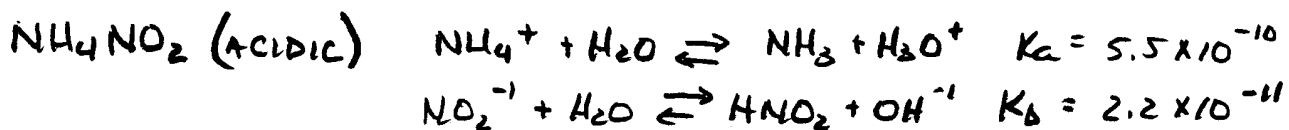
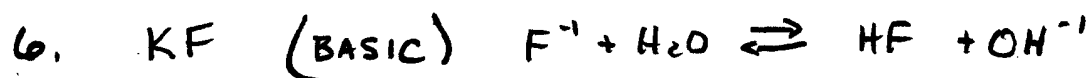
↑  
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$$x = 4.8 \times 10^{-11}$$

SO

$$[CO_3^{-2}] = 4.8 \times 10^{-11}$$

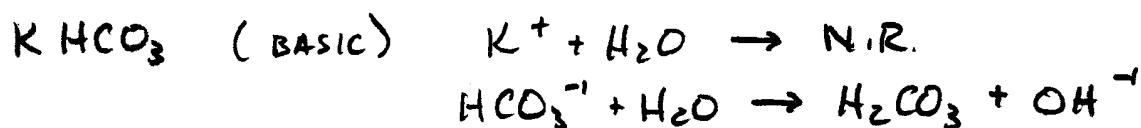
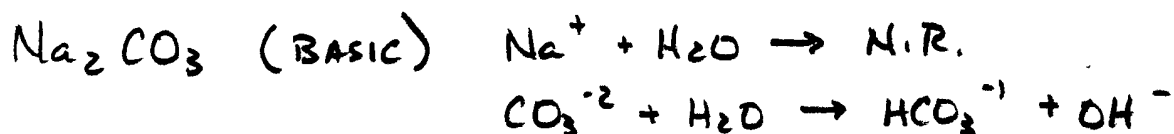
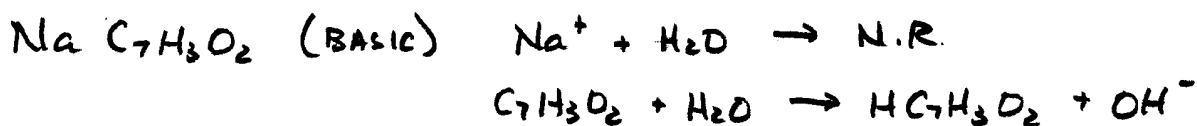
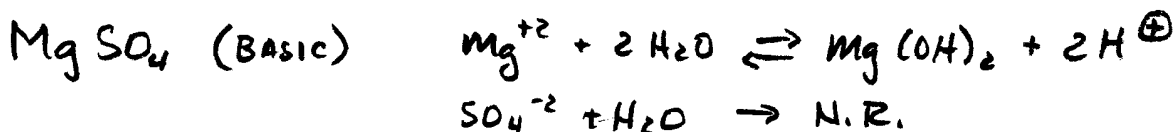
NOTE: FOR DIPROTIC ACIDS SUCH AS  $H_2A$ ,  
 $[A^{-2}]$  ALWAYS =  $K_{a2}$



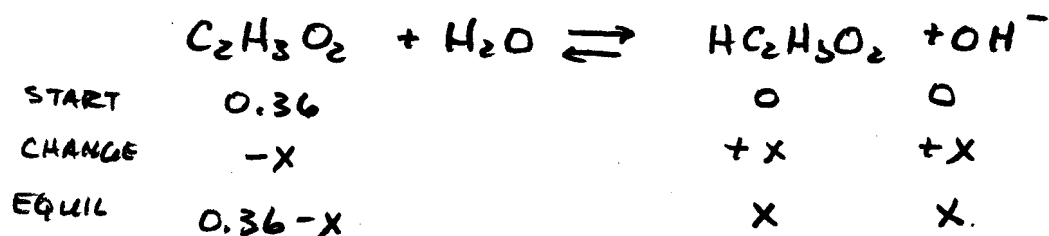
RbI (NEUTRAL) BOTH ARE CONJUGATES OF STRONG ELECTROLYTES

$CaCl_2$  (NEUTRAL) Ebbing & I DISAGREE ON WHETHER  $Ca(OH)_2$  IS STRONG ... HE SAYS YES SO THIS SALT WOULD BE NEUTRAL.

$NaNO_3$  (NEUTRAL) BOTH IONS ARE CONJUGATES OF STRONG ELECTROLYTES



7.  $K_b \text{ FOR } C_2H_3O_2 = \frac{K_w}{K_a \text{ HC}_2H_3O_2} = \frac{1 \times 10^{-14}}{1.7 \times 10^{-5}} = 5.9 \times 10^{-10}$



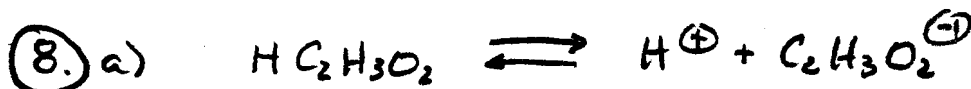
$$5.9 \times 10^{-10} = \frac{(x)(x)}{(0.36-x)}$$

↑ IGNORE

$$x = [OH^-] = 1.5 \times 10^{-5} \text{ M}$$

$$pOH = 4.84$$

$$pH = 9.16$$



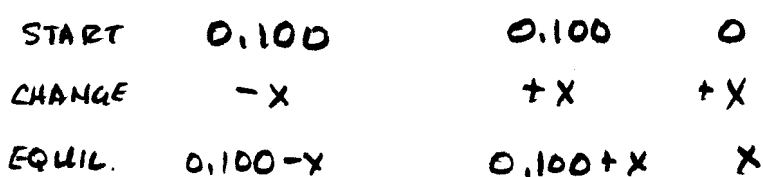
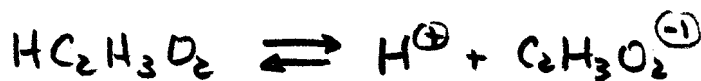
$$1.7 \times 10^{-5} = \frac{(x)(x)}{(0.100-x)}$$

↑ IGNORE

$$x = 1.3 \times 10^{-3} \text{ M}$$

$$[H^+] = [C_2H_3O_2^-] = 1.3 \times 10^{-3} \text{ M}$$

b)



$$1.7 \times 10^{-5} = \frac{(0.1+x)(x)}{(0.1-x)}$$

↑ IGNORE

$$x = 1.7 \times 10^{-5}$$

$$[H^+] = 0.100 + 1.7 \times 10^{-5} \approx 0.100 \text{ M}$$

$$[C_2H_3O_2^-] = 1.7 \times 10^{-5} \text{ M}$$

9. a)

$$pH = pK_a + \log \frac{[NH_3]}{[NH_4^+]}$$

$$pH = -\log(5.6 \times 10^{-10}) + \log \left( \frac{0.20}{0.20} \right)$$

$$pH = 9.26$$

NOTE:  $K_a$  FOR  $NH_4^+$

$$K_a = \frac{K_w}{K_b \text{ FOR } NH_3}$$

$$K_a = \frac{1 \times 10^{-14}}{1.8 \times 10^{-5}}$$

$$K_a = 5.6 \times 10^{-10}$$

b) ADDITION OF HCl WILL CONVERT  $NH_3$  TO  $NH_4^+$

$$(10.0 \text{ mL})(0.10 \text{ M}) = 1 \text{ mmol HCl}$$

$$(65.0 \text{ mL})(0.20 \text{ M}) = 13.0 \text{ mmol } NH_3$$

$$(65.0 \text{ mL})(0.20 \text{ M}) = 13.0 \text{ mmol } NH_4^+$$



START 13 mmol 1 mmol

13 mmol

END 12 mmol 0

14 mmol 1 mmol

SO, NEW CONC.

$$[NH_3] = \frac{13 \text{ mmol}}{75 \text{ mL}}$$

$$= 0.160 \text{ M}$$

$$[NH_4^+] = \frac{14 \text{ mmol}}{75 \text{ mL}}$$

$$= 0.187 \text{ M}$$

NOW

$$pH = pK_a + \log \frac{[NH_3]}{[NH_4^+]}$$

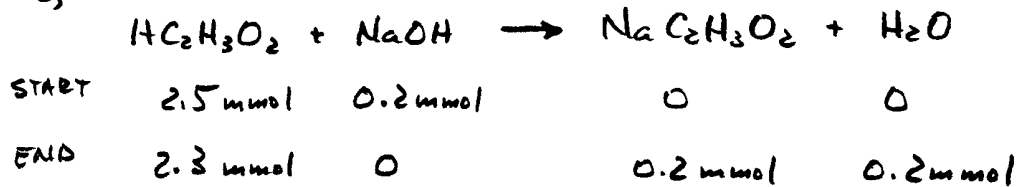
$$pH = 9.26 + \log \left( \frac{0.160}{0.187} \right)$$

$$pH = 9.19$$

10. a)  $(25.0 \text{ mL})(0.1 \text{ M}) = 2.5 \text{ mmol HC}_2\text{H}_3\text{O}_2$  INITIALLY.

ADDITION OF  $(2.0 \text{ mL})(0.100 \text{ M NaOH}) = 0.20 \text{ mmol OH}^-$

SO,



SO, NEW INITIAL CONCENTRATIONS:

$$[\text{HC}_2\text{H}_3\text{O}_2] = \frac{2.3 \text{ mmol}}{27 \text{ mL}} = 0.085 \text{ M HC}_2\text{H}_3\text{O}_2$$

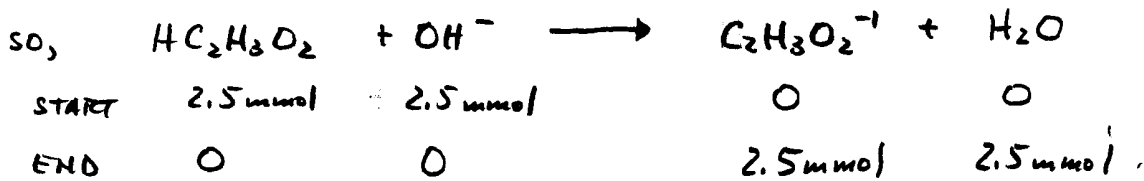
$$[\text{C}_2\text{H}_3\text{O}_2^-] = \frac{0.2 \text{ mmol}}{27 \text{ mL}} = 0.0074 \text{ M C}_2\text{H}_3\text{O}_2^-$$

$$\text{pH} = \text{pK}_a + \log \frac{[\text{C}_2\text{H}_3\text{O}_2^-]}{[\text{HC}_2\text{H}_3\text{O}_2]}$$

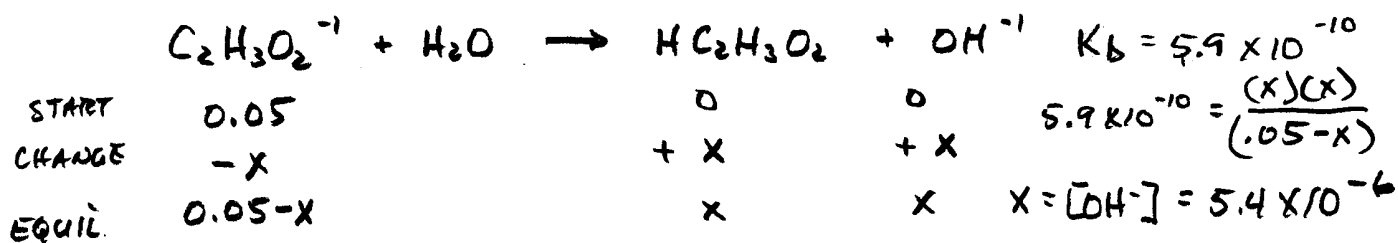
$$\text{pH} = -\log(1.7 \times 10^{-5}) + \log \left( \frac{0.0074}{0.085} \right)$$

$$\text{pH} = 3.71$$

b) 25 mL of 0.1 M NaOH = 2.5 mmol  $\text{OH}^-$

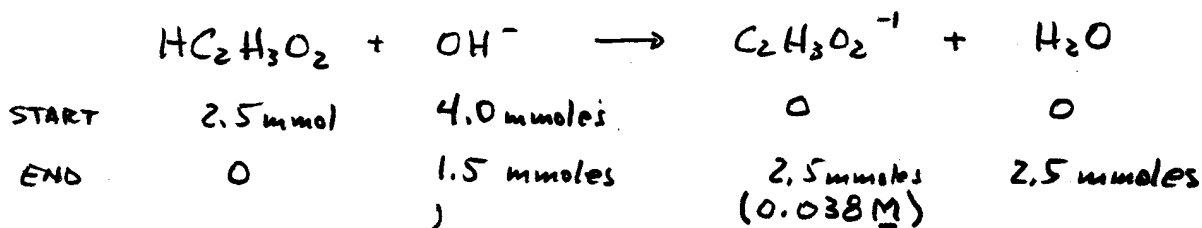


SO ALL THAT'S LEFT HERE AT EQ. PT IS  $[\text{C}_2\text{H}_3\text{O}_2^-] = \frac{2.5 \text{ mmol}}{50 \text{ mL}} = 0.05 \text{ M}$



$$\text{pOH} = 5.27 \quad \text{pH} = 8.73$$

c) ONCE 40.0 mL OF NaOH IS ADDED, YOU'RE PAST THE EQUIV. POINT AND HAVE ONLY EXCESS NaOH AND  $C_2H_3O_2^-$ .



$$[OH^-] = \frac{1.5 \text{ mmols}}{65 \text{ mL}} = 0.023 \text{ M } OH^-$$

$$pOH = 1.04$$

$$pH = 12.36$$

WHAT ABOUT ANY EXTRA  $OH^-$  PRODUCED BY THE HYDROLYSIS OF  $C_2H_3O_2^-$ ? LET'S CHECK.



START:	0.038 M	0	0.023
CHANGE	-X	+X	+X
EQUIL.	0.038 - X	X	0.023 + X

$$5.9 \times 10^{-10} = \frac{(X)(0.023 + X)}{(0.038 - X)} \approx \frac{(X)(0.023)}{(0.038)}$$

$\swarrow$  IGNORE
 $\nwarrow$  IGNORE

$$X = 9.7 \times 10^{-10} \quad (\text{CONTRIBUTION TO } OH^- \text{ FROM HYDROLYSIS OF } C_2H_3O_2^-)$$

SO  $[OH^-] = 0.023 + 9.7 \times 10^{-10} \approx 0.023 \text{ M}$  SAME AS ABOVE

$$pH = 12.36$$