CHM 51-Dang **Homework – Chapter 14-part 2** **Name** Key

Due Thursday 4/30/20 at 6PM

*For each problem, show all necessary chemical reaction (hydrolysis in water and neutralization)

1. Calculate the pH of a buffer solution prepared by dissolving 0.10 moles of cyanic acid, HCNO, and 0.50 moles of sodium cyanate, NaCNO, in enough water to make 0.500 liter of solution. For HCNO, $K_a = 2.0 \times 10^{-4}$ at 25°C. *Set-up a chemical equation and an ICE table. Do no use Henderson-Hasselbalch.*

$HCNO + H_2O(l) \rightleftharpoons H_3O^+(aq) + CNO^-(aq)$

	$HCNO$	H_3O^+	CNO^-
I	$\frac{0.10\,mol}{0.500\,L}$	0	$\frac{0.50\,mol}{0.500\,L}$
C	$-x$	$+x$	$+x$
E	$0.20-x$	x	$1.00+x$

$K_a = 2.0\times10^{-4} = \frac{(x)(1.00 \cancel{+x})}{0.200 \cancel{-x}}$

$x = 4.0\times10^{-5}$ (check < 5%)

$pH = -\log(4.0\times10^{-5})$

$= \underline{4.40}$

a. Find the pH after 10.0 mL of 1.00 M KOH is added to the buffer from part (a). *You can use Henderson-Hasselbalch after completing neutralization table.*

mmol $HCNO$ = 0.10 mol = 100 mmol

mmol CNO^- = 0.50 mol = 500 mmol

mmol OH^- = 10.0 mL × 1.00 M = 10.0 mmol

Neutralization

$HCNO + OH^-(aq) \rightarrow H_2O + CNO^-$

	$HCNO$	OH^-	CNO^-
I	100 mmol	10.0 mmol	500 mmol
C	−10.0	−10.0	+10.0
E	90 mmol	0	510 mmol

Hydrolysis HCNO

$HCNO + H_2O \rightleftharpoons H_3O^+ + CNO^-$

	$HCNO$	H_3O^+	CNO^-
I	$\frac{90\,mmol}{510\,mL}$	0	$\frac{510\,mmol}{510\,mmol}$
C	$-x$	$+x$	$+x$
E	0.18 M	0	1.0 M + x

$K_a = 2.0\times10^{-4} = \frac{(x)(1.0 \cancel{+x})}{0.18 \cancel{-x}}$

$x = 3.6\times10^{-5}$

$pH = -\log(3.6\times10^{-5})$

$= 4.44 > 4.40$

more basic

6. For the titration of 25.00 mL of 0.150 M HBr with 0.250 M NaOH:

SA SB

a. Calculate the initial pH.

$[H_3O^+] = 0.150\,M$

$pH = -\log(0.150) = 0.824$

b. How much NaOH is required to reach the equivalence point?

$V_b = \frac{(0.150\,\cancel{M})(25.00\,mL)}{0.250\,\cancel{M}} = 15.0\,mL$

c. What is the pH at the equivalent point?

$pH = 7.00$

above equivalence

d. What is the pH after 20.50 mL of titrant has been added?

mmol $H_3O^+ = 25.00\,mL \times 0.150\,M = 3.75\,mmol$

mmol $^-OH = 20.50\,mL \times 0.250\,M = 5.13\,mmol$

Neutralization

	$H_3O^+_{(aq)}$ +	$^-OH_{(aq)}$ →	$2H_2O$
I	3.75	5.13	
C	−3.75	−3.75	
E	0	1.38	

new $[^-OH] = \frac{1.38\,mmol}{45.5\,mL} = 0.0303$

$pH = -\log\left(\frac{1.0\times10^{-14}}{0.0303}\right) = 12.48$

1. 40.0 mL of propionic acid (HPr) 0.100 M, Ka = 1.3 x 10^{-5}, is titrated with 0.125 M NaOH. Answer the following questions:

a) What is the initial pH?

	HPr + H_2O ⇌	$H_3O^+_{(aq)}$ +	Pr^-
I	0.100 M	0	0
C	− x	+ x	+ x
E	0.100 − x	x	x

$K_a = 1.3\times10^{-5} = \frac{(x)(x)}{0.100 \cancel{- x}}$

$x = 1.1\times10^{-3}$

check < 5%.

$pH = -\log(1.1\times10^{-3})$

$= 2.96$

b) How many mL of NaOH are required to reach the equivalence point of this reaction?

$V_b = \frac{(40.0\,mL)(0.100\,M)}{0.125\,M} = 32.0\,mL$

c) What is the pH after adding 15.0mL of NaOH?

mmol HPr = 40.0 ml × 0.100M = 4.00mmol

mmol ^-OH = 15.0ml × 0.125M = 1.88mmol

Neutralization

	HPr +	^-OH →	H_2O +	Pr^-
I	4.00	1.88		0
C	-1.88	-1.88		+1.88
E	2.12	0		1.88

Hydrolysis HPr

	HPr +	H_2O ⇌	H_3O^+ +	Pr^-
I	$\frac{2.12}{55.0}$		0	$\frac{1.88}{55.5}$
C	-x		+x	+x
E	0.0385-x		x	0.0342+x

$$K_a = 1.3\times10^{-5} = \frac{(x)(0.0342 \cancel{+x})}{0.0385 \cancel{-x}}$$

$x = 1.46\times10^{-5}$ (check

$pH = -\log(1.46\times10^{-5})$

$= 4.83$

d) Calculate the pH at the equivalent point?

mmol ^-OH = 32.0ml × 0.125M = 4.00mmol

Neutralization

	HPr +	^-OH →	H_2O +	Pr^-
I	4.00	4.00		0
C	-4.00	-4.00		+4.00
E	0	0		4.00

Hydrolysis of Pr^-

	Pr^- +	H_2O ⇌	OH^- +	HPr
I	$\frac{4.00}{72.0ml}$		0	0
C	-x		+x	+x
E	0.0556-x		x	x

$$K_b = \frac{1.0\times10^{-14}}{1.3\times10^{-5}} = 7.6\times10^{-10}$$

$$K_b = 7.6\times10^{-10} = \frac{x^2}{0.0556 \cancel{-x}}$$

$x = 6.5\times10^{-6} = [^-OH]$

$pOH = -\log(6.5\times10^{-6})$

$= 5.18$

$pH = 14.00 - 5.18$

$= 8.82$

$V_a = \frac{(25.0\,ml)(0.065\,M)}{0.050\,M} = 32.5\,ml$

2. What is the pH of the solution obtained when 25.0 mL of 0.065M benzylamine, $C_7H_7NH_2$, is titrated to the equivalence point with 0.050 M HCl. $K_b = 4.7 \times 10^{-10}$

mmol $C_7H_7NH_2 = 25.0\,ml \times 0.065\,M = 1.6$ mmol

mmol $H_3O^+ = 32.5\,ml \times 0.050\,M = 1.6$ mmol

Neutralization

$C_7H_7NH_2 + H_3O^+ \rightarrow H_2O + C_7H_7NH_3^+$

	$C_7H_7NH_2$	H_3O^+	H_2O	$C_7H_7NH_3^+$
I	1.6	1.6		0
C	−1.6	−1.6		+1.6
E	0	0		1.6

$K_a = \frac{1.0 \times 10^{-14}}{4.7 \times 10^{-10}} = 2.1 \times 10^{-5}$

Hydrolysis of $C_7H_7NH_3^+$

$C_7H_7NH_3^+ + H_2O \rightleftharpoons H_3O^+ + C_7H_7NH_2$

	$C_7H_7NH_3^+$	H_2O	H_3O^+	$C_7H_7NH_2$
I	$\frac{1.6}{57.5}$		0	0
C	−x		+x	+x
E	0.028 − x		x	x

$2.1 \times 10^{-5} = \frac{x^2}{0.028 - x}$

$\sqrt{5.9 \times 10^{-7}} = \sqrt{x^2}$

$x = 7.7 \times 10^{-4}$

$pH = -\log(7.7 \times 10^{-4})$

$= 3.11$

What is the pH at the midpoint?

$pH = pK_a$

$= -\log(2.1 \times 10^{-5})$

$= 4.68$

What is the pH after 45.0ml of titrant was added?

mmol $H_3O^+ = 45.0\,ml \times 0.050\,M = 2.25$ mmol

Neutralization

$C_7H_7NH_2 + H_3O^+ \rightarrow H_2O + C_7H_7NH_3^+$

	$C_7H_7NH_2$	H_3O^+	H_2O	$C_7H_7NH_3^+$
I	1.6	2.25		0
C	−1.6	−1.6		+1.6
E	0	0.7 stronger acid		1.6

$[H_3O^+] = \frac{0.7\,mmol}{85.0\,ml} = 0.008\,M$

1 sf

$pH = -\log(0.008\,M)$

$= 2.1$