3 – Acid/Base Equilibria – modified September 25, 2014

1] What is the pH of a solution containing 0.25 M sodium acetate, and 0.25 M CH_3COOH? K_a = 1.75e-5 [1]

2] Which of the following monoprotic acids would be best for creating a buffer system at pH 7.00? [2]

acid A Ka = 5.6e-4 acid B Ka = 7.7e-6

acid C Ka = 1.9e-8 acid D Ka = 7.3e-11

3] The weak acid, HA has K_a = 1.0e-5. What is the fraction, α_{A^-} at pH 7.00? [3]

4] What is the pH of a solution that is 0.10 M sodium acetate with 0.10 M acetic acid? K_a = 1.75e-5 [4]

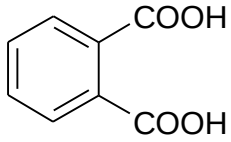
4] What is the pH of a solution of 0.100 M Na_2HA solution given the following: [5]

$H_3A = H_2A^- + H^+$ K_a = 2.8e-2

$H_2A^- = HA^{2-} + H^+$ K_a = 7.7e-5

$HA^{2-} = A^{3-} + H^+$ K_a = 9.3e-11

6] What is the pH of a solution of a 1.0 M phthalic acid solution? [6]



K_{a1} = 1.12e-3

K_{a2} = 3.90e-6

7] What is the mole fraction of HA^- at pH 3.00 given [7]

$H_2A = H^+ + HA^-$ K_{a1} = 1.0e-3

$HA^- = H^+ + A^{2-}$ K_{a2} = 1.0e-9

8] The mole fraction of H_2A can be calculated from which of the following expressions? [8]

$H_2A = H^+ + HA^-$ K_{a1} = 3.3e-5

$HA^- = H^+ + A^{2-}$ $K_{a2} = 4.2e\text{-}10$

9] What is the pH of a solution of 0.10 M $NaHCO_3$? [9]

$H_2CO_3 = HCO_3^- + H^+$ $K_{a1} = 4.45e\text{-}7$

$HCO_3^- = CO_3^{2-} + H^+$ $K_{a2} = 4.69e\text{-}11$

10] What is or are the simplifying assumption(s) that allow for the use of the Henderson-Hasselbalch equation? [10]

11] What is the pH of a solution consisting of 0.100 M CH_3COONa and 0.100 M CH_3COOH? [11]

12] An experimental protocol requires a buffer at a pH of 6.50. What is the molar ratio of [NaA]/[HA] required given: [12]

$HA = H^+ + A^-$ $K_a = 5.62e\text{-}7$

13] Write down the hydrolysis reaction for HCO_3^- demonstrating that it is a weak base. [13]

14] The K_b for dichloroacetate, Cl_2CHCOO^- is _____ [14]

$Cl_2CHCOOH$ $K_a = 5.0e\text{-}2$

15] The pH of solution of 0.050 M of a weak acid, HA is 5.69. What is K_a for this acid? [15]

16] The two K_a's for salicylic acid (H_2A) are 1.07e-3 and 1.82e-14. What is K_b for sodium salicylate (NaHA)? [16]

17] What is K_b for this reaction given the following K_a's? [17]

$HA^- + H_2O = H_2A + OH^-$ $K_b = ?$

$H_2A = HA^- + H^+$ $K_{a1} = 3.3e\text{-}5$

$HA^- = H^+ + A^{2-}$ $K_{a2} = 4.2e\text{-}10$

18] What is pH of solution containing 0.100 M HOCl (K_a = 3.0e-8) and 0.100 M NaOCl? [18]

19] What is the pH of solution that is 0.10 M NaH_2PO_3? [19]

$H_3PO_3 \rightleftarrows H_2PO_3^- + H^+$ $K_a = 3e\text{-}2$

$H_2PO_3^- \rightleftarrows HPO_3^{2-} + H^+$ $K_a = 1.62e\text{-}7$

20] Write the formula that describes the relative concentration of $H_2PO_3^-$ from a 0.10 F H_3PO_3 at pH 5.00 can be calculated from which formula? [20]

21] What is the pH of NaHA given the following? [21]

$H_2A = HA^- + H^+$ $K_{a1} = 3.3e\text{-}5$

$HA^- = H^+ + A^{2-}$ $K_{a2} = 4.2e\text{-}10$

22] What is the pH of 0.10 M H_2A given the following? [22]

$H_2A = HA^- + H^+$ $K_{a1} = 3.3e\text{-}5$

$HA^- = H^+ + A^{2-}$ $K_{a2} = 4.2e\text{-}10$

23] How many grams of ammonium chloride (NH_4Cl) and what volume (in mL) of 3.0 M NaOH solution should be added together to prepare a buffer of pH 9.50 with a final NH_4Cl salt concentration of 0.10 M and a final volume of 500-mL? [23]

24] How many mL of 0.500 M NaOH should be added to 10.0 g of HA (157.597 g/mol) to give a pH 7.60 in a final volume of 250 mL? $K_a = 8.41e\text{-}9$ [24]

Answers

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[1] pH = pKa + log [base]/[acid] = 4.757

[2] acid C

[3] 0.99

[4] $1.75e\text{-}5 = [H^+]\ 0.10 / 0.10$ $[H^+] = 1.75e\text{-}5$ pH = 4.757

[5] pH = ½(-log7.7e-5 + -log9.3e-11) = 7.07

[6] 1.48 only K_{a1} is important. $x^2/(1.0\text{-}x) = 1.12e\text{-}3$; x = 0.0335

[7] 0.50, $D = [1.0e\text{-}3]^2 + [1.0e\text{-}3]^2 + [1.0e\text{-}3*1.0e\text{-}9] = 2.0e\text{-}6$, $N = [1.0e\text{-}3]^2 = 1.0e\text{-}6$, $\alpha = 0.50$

[8] $\alpha_{H2A} = [H^+]^2 / [H^+]^2 + K_{a1}[H^+] + K_{a1}K_{a2}$

[9] $8.34 = ½ (pK_{a1} + pK_{a2})$

[10] formal concentrations of A^- & HA are the same as equilibrium concentrations

[11] 4.757 pH = pK_a watch S.F.

[12] $K_a = [H^+][A^-] / [HA]$ $[H+] = 10^{-6.50} = 3.16e\text{-}7$ M

5.62e-7 / 3.16e-7 = $[A^-] / [HA]$ = KHP

[13] $HCO_3^- + H_2O \rightarrow H_2CO_3 + OH^-$

[14] $K_b = K_w/K_a = 2.0e\text{-}13$

[15] $[H^+] = 2.0e\text{-}6$ M

HA	=	H^+	+	A^-
0.050-x		x		x

$K_a = x^2 / (0.050\text{-}x) \cong 2.0e\text{-}6^2 / 0.050 = 8.3e\text{-}11$

[16] $HA^- + H_2O \rightleftarrows H_2A + OH^-$ $K_aK_b = K_w$

$K_b = K_w/K_a =$ 1.00e-14 / 1.07e-3 = 9.35e-12

[17] K_b = 1.00e-14 / 3.3e-5 = 3.0e-10

[18] $K_a = [H^+][OCl^-] / [HOCl]$ $[H^+] = K_a [HOCl] / [OCl^-]$ $[H^+]$ = 3.0e-8 pH = 7.52

[19] pH = ½ (pK_{a1} + pK_{a2}) = ½ (1.5 + 6.790) = 4.1

[20] $$\frac{K_{a1}[H^+]}{[H^+]^2 + K_{a1}[H^+] + K_{a1}K_{a2}}$$

[21] pH = ½(pKa1 + pKa2) pKa1 = -log(3.3e-5) = 4.48 pKa2 = -log(4.2e-10) = 9.38

pH = 6.93

[22] only K_{a1} will be important as $K_{a1} >> K_{a2}$, so

H_2A	=	HA^-	+	H^+			
0.10 M		0		0			
-x		+x		+x	$K_{a1} = 3.3e\text{-}5 \cong x^2 / 0.10$	x = 1.8e-3	**pH = 2.74**

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[23] $[H^+]$ = 3.2e-10 M

$NH_4^+ = NH_3 + H^+$ K_a = 5.70e-10

$K_a = [H^+][NH_3]/[NH_4^+]$

First calculate the ratio $[NH_3]/[NH_4^+]$

$[NH_3]/[NH_4^+] = K_a/[H^+]$ = 5.70e-10 / 3.2e-10 M = 1.8

If $[NH_4Cl]$ = 0.10 M, then $[NH_3]$ = 0.18 M

MBE: **Initial $[NH_4Cl]$** = $[NH_4Cl] + [NH_3]$ = 0.10 + 0.18 = 0.28 M

Mass **Initial $[NH_4Cl]$** = 0.28 M * 0.500 L * (53.5 g) **= 7.49 g NH_4Cl**

For the reaction: $NH_4Cl + NaOH = NH_3 + NaCl + H_2O$

Add vol NaOH = 0.18 M * 0.500 L * 1/3.0 M * 1000 mL/L **= 30 mL NaOH**

[24] Mol HA = 10.0 g * (mol / 157.597 g) = 6.35e-2

Rxn:	HA+	OH^-=	A^-+	H_2O
Mol:	6.35e-2	x	0	
	-x	-x	+x	

$[HA]$ = (6.35e-2 – x) &
$[OH^-] = [A^-]$ = x

$[H^+]$ = 2.51e-8 M

$K_a = [H^+][A^-] / [HA]$
8.41e-9 = 2.51e-8 x / (6.35e-2 – x)

x = 1.59e-2 mol

1.59e-2 mol * (L / 0.500 mol) = 31.9 mL