KEY

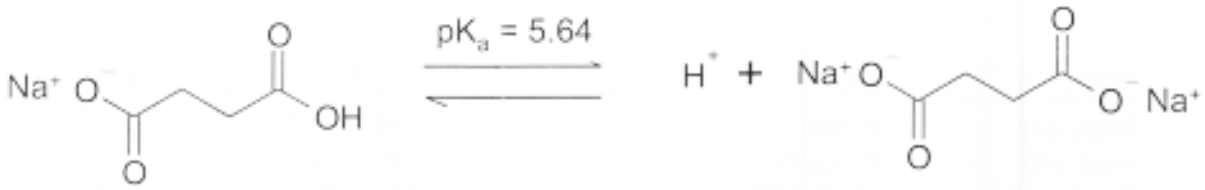
CHM116 Extra Credit Homework
Summer 2012
10 points

Due at the beginning of class on July 27, 2012

pKa 3.85

1. Find the pH of these buffer solutions using the information provided:
   a. 1 L solution containing 80 g of lactic acid (MW=90.8) and 120 g of sodium lactate (MW =112.06).
   b. 20 ml of 0.25 M HCl (hydrochloric acid) added to 1L of water.
   c. What is the resulting pH if you add 10 mL of 3 M HCl to the buffer in 5a?

2. How many grams of sodium succinate (MW = 140 g/mol) and disodium succinate (MW = 162 g/mol) must be added to 1 L of water to produce a solution with pH = 6.0 and a total solute concentration of 50 mM? The pKa is 5.64.



monosodium succinate disodium succinate

3. You have been hired in Dr. Hrycyna's lab and are asked to make a buffer with a **pH** of **11.8**.
   a. What acid/conjugate base pair is best for this solution? Why?
   b. Calculate the amounts (in grams) of acid/conjugate base you should combine to get 4L of a 0.25 M solution.

4. Buffers are important physiological compounds that resist a change in pH.

a. Calculate the pH of a buffer system that is 0.25 M benzoic acid and 0.75 M benzoate if the $pK_a = 4.2$

b. Calculate the number of moles of benzoate and benzoic acid that are required to make a liter of 0.5 M buffer solution at the pH calculated in part a.

5. a. If 5mL of 0.1 M NaOH (a strong base) is added to 100 mL of 0.05M phosphate buffer (phosphoric acid = H_3PO_4), pH 7.1, what is the resulting pH? (Ignore the volume change)

Clearly identify the appropriate acid and conjugate base and determine their concentrations in the final solution.

b. What would the resulting pH be if instead you added 5 mL of 0.25M HCl? (Ignore the volume change)

Acid	HA	K_a	pK_a
Formic acid	HCOOH	1.78×10^{-4}	3.75
Acetic acid	CH_3COOH	1.76×10^{-5}	4.75
Pyruvic acid	$CH_3COCOOH$	3.16×10^{-3}	2.50
Lactic acid	$CH_3CHOHCOOH$	1.38×10^{-4}	3.85
Malic acid	$HOOC-CH_2-CHOH-COOH$	(1) 3.98×10^{-4}	3.40
		(2) 5.5×10^{-6}	5.26
Citric acid	$HOOC-CH_2-C(OH)(COOH)-CH_2-COOH$	(1) 8.14×10^{-4}	3.09
		(2) 1.78×10^{-5}	4.75
		(3) 3.9×10^{-6}	5.41
Carbonic acid	H_2CO_3	(1) 4.3×10^{-7}	6.4
		(2) 5.6×10^{-11}	10.2
Phosphoric acid	H_3PO_4	(1) 7.25×10^{-3}	2.14
		(2) 6.31×10^{-8}	7.20
		(3) 3.98×10^{-13}	12.4
Ammonium ion	NH_4^+	5.6×10^{-10}	9.25

1a) $80\,g/LA \times \frac{1\,mol}{90.8\,g} = \frac{0.881\,mol}{1L} = 0.881\,M\,LA$

(1)

a. $120\,g/SL \times \frac{1\,mol}{117.06\,g} = \frac{1.07\,mol}{1L} = 1.07\,M\,SL$

$pH = pK_a + \log \frac{A^-}{HA}$

$= 3.85 + \log \frac{1.07}{0.881}$

$= 3.93$

b) $\frac{0.25\,mol}{L} \times 0.02L = \frac{5 \times 10^{-3}\,mol}{1.02L}$

$pH = -\log [H_3O^+]$

$= -\log [4.9 \times 10^{-3}]$

$= 2.30$

c. $\frac{3\,mol}{L} \times 0.01L = 0.03\,mol\,HCl$ Add acid [HA]↑ [A⁻]↓

$pH = 3.85 + \log \frac{(1.07 - 0.03)}{(0.881 + 0.03)} \quad \frac{1.04}{0.91}$

$= 3.91$ stated at 3.93 in part A.

) sodium succinate MW = 140 g/mol – HA

disodium succinate MW = 162 g/mol – A^-

(2)

1L pH = 6.0 [total] = 50 mM pK_a 5.64

$$pH = pK_a + \log \frac{A^-}{HA}$$

$$6.0 = 5.64 + \log \frac{A^-}{HA}$$

$$0.36 = \log \frac{A^-}{HA}$$

$$2.29 = \frac{A^-}{HA} = \frac{2.29}{1.0} \qquad 2.29 + 1.0 = 3.29$$

A^-: 2.29/3.29 = 70% of 0.05 M = 0.035 mol/L

HA: 1/3.29 = 30% of 0.05 M = 0.015 mol/L

A^-: $\frac{0.035 \text{ mol}}{1 \text{ L}} \times 1 \text{ L} \times \frac{162 \text{ g}}{\text{mol}}$ = 5.67 g disodium succinate

HA: $\frac{0.015 \text{ mol}}{1 \text{ L}} \times 1 \text{ L} \times \frac{140 \text{ g}}{\text{mol}}$ = 2.10 g sodium succinate

3) a) PO_4^{3-} and HPO_4^{2-} because the pka is closest to 11.8.

PO_4^{3-} MW = 95 g/mol

HPO_4^{2-} MW = 96 g/mol

b) $11.8 = 12.4 + \log \frac{[PO_4^{3-}]}{[HPO_4^{2-}]}$

$-0.6 = \log \frac{[PO_4^{3-}]}{[HPO_4^{2-}]}$

$\frac{0.25}{1} = \frac{[PO_4^{3-}]}{[HPO_4^{2-}]}$ $\quad 0.25 + 1 = 1.25$

PO_4^{3-} : $0.25/1.25 = 20\% \times 0.25\ M = \frac{0.05\ mol}{L} \times 4L = 0.2\ m$

HPO_4^{2-} : $1.0/1.25 = 80\% \times 0.25\ M = \frac{0.2\ mol}{L} \times 4L = 0.8\ m$

$PO_4^{3-} = 0.2\ mol \times \frac{95\ g}{mol} = \boxed{19.0\ g\ PO_4^{3-}}$

$HPO_4^{2-} = 0.8\ mol \times \frac{96\ g}{mol} = \boxed{76.8\ g\ HPO_4^{2-}}$

7) a) $pH = pK_a + \log \frac{A^-}{HA}$

$pH = 4.2 + \log \frac{0.75}{0.25}$

$= 4.7$

(4)

b) Ratio : $\frac{A^-}{HA} = \frac{0.75}{0.25}$ $0.75 + 0.25 = 1.00$

A^- : $\frac{0.75}{1.00} = 75\% \times 0.5M = \frac{0.375 mol}{1L} \times 1L$

$=$ 0.38 mol benzoate

$HA = \frac{0.25}{1.00} = 25\% \times 0.5M = \frac{0.125 mol}{1L} \times 1L$

$=$ 0.13 mol benzoic acid

$pH = pK_a + \log \frac{A^-}{HA}$

5 a

$7.1 = 7.2 + \log \frac{A^-}{HA}$

$\frac{0.794}{1.00} = \frac{\{A^-\}}{\{HA\}}$

$\frac{0.1\ mol}{1\ L} \times 0.005\ L = 5 \times 10^{-4}$ mol

A^-: $\frac{0.794}{1.794} = 44.3\% \times \frac{0.05\ mol}{L} = \frac{0.0221\ mol}{L} \times 0.1\ L = 2.21 \times$

HA: $\frac{1.00}{1.794} = 55.7\% \times \frac{0.05\ mol}{L} = \frac{0.028\ mol}{L} \times 0.1\ L = 2.78 \times 10^{-3}$

$pH = 7.2 + \log \frac{(2.21 \times 10^{-3} + 5 \times 10^{-4})}{(2.78 \times 10^{-3} - 5 \times 10^{-4})}$

$= 7.2 + \log \frac{2.71 \times 10^{-3}}{2.28 \times 10^{-3}}$

$= 7.28$

$H_2PO_4^- + OH^- \rightleftharpoons HPO_4^{2-} + H_2O$

$H_2PO_4^-$ → HA

HPO_4^{2-} → A^-

c) $H^+ + HPO_4^{2-} \rightleftharpoons H_2PO_4^-$ 5b

$$\frac{0.25\ mol}{L} \times 0.005L = 1.25 \times 10^{-3}\ mol$$

$$pH = 7.2 + \log \frac{(2.21 \times 10^{-3} - 1.25 \times 10^{-3})}{(2.78 \times 10^{-3} + 1.25 \times 10^{-3})}$$

$$= 7.2 + \log \frac{9.6 \times 10^{-4}}{4.03 \times 10^{-3}}$$

$$= 6.58$$