Chemistry 350 **Name**_____
Spring 2018 **100 Points**
Exam 2

This take-home problem will account for 15 possible points on this exam.
Due by noon April 3, 2018

You must complete the following individually. You may use your textbook and notes, but may not receive assistance from your classmates or anyone other than Dr. Lamp. *This signed sheet must accompany the completed problem*. By signing below, you certify that you completed the problems in accordance with these rules. No credit will be given to unsigned papers. If you choose to use a computer-based approach, attach any computer output to this sheet and show other work in the space below.

Signature(s)_____ Date_____

Consider a solution prepared by mixing 0.020 mol benzoic acid (C_6H_5COOH, $pK_a = 4.20$) and 0.025 mol glycolic acid (CHOCOOH, $pK_a = 3.46$) in 500.0 mL of solution.

1. Use the systematic approach to determine the pH of this solution. You may ignore activities, but you must account for the autoprotolysis of water.

2. What is the fraction of dissociation for each acid at the pH you determined in part 1?

1. Let's call glycolic acid HA and benzoic acid HB.

$$HB \rightleftharpoons B^- + H^+ \qquad K_{ab} = 10^{-3.46} = [B^-][H^+]/[HB]$$
$$HA \rightleftharpoons A^- + H^+ \qquad K_{aa} = 10^{-4.20} = [A][H^+]/[HA]$$
$$H_2O \rightleftharpoons OH^- + H^+ \qquad K_w = [H^+][OH^-]$$

Charge Balance: **$[H^+] = [OH^-] + [A^-] + [B^-]$**

Mass Balance for benzoic acid: $[B]_{Total} = 0.040\ M = [HB] + [B^-]$
Mass Balance for glycolic acid: $[A]_{Total} = 0.050\ M = [HA] + [A^-]$

One strategy is to get everything ultimately in terms of $[H^+]$ so that we can "guess" and $[H^+]$ and solve the problem iteratively.

$$\mathbf{[OH^-] = K_w/[H^+]}$$

Working with HB:

$$\mathbf{[HB] = 0.040 - [B^-]} \text{ and } K_{ab} = [B^-][H^+]/[HB], \text{ so}$$
$$K_{ab} = [B^-][H^+]/(0.040-[B^-])$$

Rearranging:

$$\mathbf{[B^-] = 0.040K_{ab}/(K_{ab} + [H^+])}$$

Similarly with A^-:

$$\mathbf{[A^-] = 0.050K_{aa}/(K_{aa} + [H^+])} \text{ and } \mathbf{[HA] = 0.050 - [A^-]}$$

Now, we can "guess" a concentration of H^+ and calculate concentrations of HA, A^-, HB, B^- and OH^- and use the charge balance expression to determine if we have reached the correct solution. Lather, rinse, repeat and iterate until we have arrived at a solution.

Spreadsheet output is on the next page. Final **$pH = 2.857_3$** (btw this is way too many sig figs)

pKa (Glycolic)	3.46	HA					
pKa (Benzoic)	4	HB					
Ka (HA)	0.000346737						
Ka (HB)	6.30957E-05						
Kw	1.00E-14						
[HA]	0.05	M					
[HB]	0.04	M					
pH	[H+]	A-	HA	B-	HB	OH-	Charge
1	0.1	0.0001728	0.049827	2.52224E-05	0.039975	1E-13	0.099802
2	0.01	0.0016756	0.048324	0.0002508	0.039749	1E-12	0.008074
3	0.001	0.0128732	0.037127	0.002374038	0.037626	1E-11	-0.01425
2.5	0.003162278	0.0049407	0.045059	0.000782492	0.039218	3.16E-12	-0.00256
2.2	0.006309573	0.0026046	0.047395	0.00039604	0.039604	1.58E-12	0.003309
2.3	0.005011872	0.0032353	0.046765	0.000497309	0.039503	2E-12	0.001279
2.4	0.003981072	0.0040059	0.045994	0.000624066	0.039376	2.51E-12	-0.00065
2.35	0.004466836	0.0036017	0.046398	0.000557145	0.039443	2.24E-12	0.000308
2.38	0.004168694	0.0038395	0.046161	0.000596398	0.039404	2.4E-12	-0.00027
2.36	0.004365158	0.0036794	0.046321	0.000569938	0.03943	2.29E-12	0.000116
2.37	0.004265795	0.0037586	0.046241	0.00058302	0.039417	2.34E-12	-7.6E-05
2.365	0.004315191	0.0037188	0.046281	0.000576442	0.039424	2.32E-12	1.99E-05
2.367	0.004295364	0.0037347	0.046265	0.000579064	0.039421	2.33E-12	-1.8E-05
Using Solver							
2.366039979	0.00430487	0.0037271	0.046273	0.000577804	0.039422	2.32E-12	0
Alpha A-	0.074541309						
Alpha B-	0.014445108						

2. To determine the alphas, we need to take the ratio of $[A^-]$/0.020M and [B-]/0.030 M at equilibrium:

$$\alpha_{A^-} = \frac{0.0037271\ M}{0.050\ M} = 0.0745$$

$$\alpha_{B^-} = \frac{0.0057906\ M}{0.040\ M} = 0.0144$$