Show all your work for full credit. You may use a calculator on this exam and any equations you need are on the equation sheet.

1. (3 pts) Dr. Richmond identified a new weak acid in the lab. If a 0.95 M solution of the new weak acid has a pH of 3.9, what is its $K_a$?

\[
\begin{align*}
\text{pH} & = 3.9 \\
10^{-\text{pH}} & = 10^{-3.9} = 1.259 \times 10^{-4} \text{ M} = [\text{H}^+] \\
K_a & = \frac{(x)(x)}{0.95-x} = \frac{(1.259 \times 10^{-4} \text{ M})^2}{(0.95-1.259 \times 10^{-4} \text{ M})} \\
\therefore K_a & = \frac{1.585 \times 10^{-9}}{0.9478} = 1.67 \times 10^{-8}
\end{align*}
\]

2. (3 pts) Calculate the pH of a 0.240 M solution of methyl amine, CH$_3$NH$_2$, with a $K_b$=4.4x10$^{-4}$. (Is the 5% rule of approximations upheld?)

\[
\begin{align*}
K_b & = 4.4 \times 10^{-4} = \frac{(x)(x)}{(0.240 \text{ M})} \\
\text{I} & = 0.240 \text{ M} \\
C & = -x \\
E & = 0.240- x \\
x & = 0.0103 \text{ M} = [\text{OH}^-] \\
x & = 0.240-x
\end{align*}
\]

\[
\begin{align*}
\frac{x}{0.240} & = 4.18\% \text{ (barely ok with 5% rule)} \\
x & = [\text{OH}^-] \\
-\log x & = \text{pOH} = 1.987 \\
pH & = 14 - \text{pOH} = 14 - 1.987 \\
pH & = 12.013
\end{align*}
\]

3. (3 pts) Calculate the pH of a 0.500 M solution of ascorbic acid, H$_2$C$_6$H$_8$O$_6$. ($K_{a1}$=1.0x10$^{-5}$ and $K_{a2}$=5.0x10$^{-12}$).

\[
\begin{align*}
\text{I} & = 0.500 \\
C & = -x \\
E & = 0.500-x \\
\end{align*}
\]

\[
\begin{align*}
K_{a1} & = \frac{x^2}{0.500-x} \\
x & = 0.00224 \text{ M} = [\text{H}^+] \\
\text{pH} & = -\log x = 2.65
\end{align*}
\]

Since $K_{a2} \ll K_{a1}$, we don't need to worry about it affecting the pH any further.

4. (1 pt) Rank the following salts in order of pH. (for HSO$_4$: $K_a$=1.3x10$^{-2}$ and for HS$^-$: $K_a$=10$^{-19}$)

\[
\begin{align*}
\text{KNO}_3 & \quad \text{K}_2\text{SO}_4 & \quad \text{K}_2\text{S} \\
\text{Garbage} & \quad \text{SO}_4^{2-} \quad \text{a very weak base} & \quad \text{S}^2- \quad \text{is a very strong base} \\
\text{pH} & = 7 & \quad \text{pH (least +) = KNO}_3 < K_2\text{SO}_4 < K_2\text{S} \\
\text{not basic} & \quad \text{a little basic} & \quad \text{very basic}
\end{align*}
\]
6. (3 pts) A 0.10 M solution of KOOC₆H₅ has a pH of 11.40. Calculate the percent dissociation.

\[
\text{pH} = 11.40 \\
\text{pOH} = 14 - 11.40 \\
\text{pH} = 2.60 \\
10^{\text{pOH}} = [OH^-] \\
10^{-2.60} = 0.00251 \text{ M} \\
\%	ext{ Dissociation} = \frac{[OH^-]}{0.10} = 2.51\%
\]

7a. (3 pts) What is the pH of a buffer formed from 30 mL of 15.0 M NH₃ and 40 mL of 10.0 M NH₄Cl? (NH₃ has a Kᵦb = 1.8 × 10⁻⁵)

\[
\text{pH} = \frac{\text{pKₐ} + \log\left(\frac{[\text{base}]}{[\text{acid}]}\right)}{2} \\
15.0 \text{ M} \times 30 \text{ mL} = 450 \text{ mmol NH}_3 \\
4.0 \text{ M} \times 10.0 \text{ M} = 400 \text{ mmol NH}_4^+ \\
\text{pKₐ} = 1.8 \times 10^{-5} \\
\text{Kₐ} = \frac{K_w}{Kᵦ_b} \\
\text{Kₐ} = 5.56 \times 10^{-10} \\
\text{pH} = 9.255 + \log \left(\frac{450 \text{ mmol}}{70 \text{ mL}} \times \frac{400 \text{ mmol}}{4.0 \text{ M}}\right) = 9.30
\]

7b. (2 pts) What is the pH of this solution after 0.150 moles of RbOH are added to it?

\[
\text{OH}^- \text{ reacts with conj. acid to make conj. base} \\
\text{OH}^- + \text{NH}_4^+ \rightarrow \text{NH}_3 + \text{H}_2\text{O} \\
\]

\[
0.00 \text{ mol} \times 0.150 \text{ mol} = 0.015 \text{ mol} \\
0.150 \text{ mol} \times 0.070 = 0.0105 \text{ mol} \\
\text{pH} = \text{pKₐ} + \log \left(\frac{\text{base}}{\text{acid}}\right) = 9.255 + \log \left(\frac{0.010}{0.015}\right) = 9.635
\]

8. (2 pts) What volume of 1.0 M KOH must be added to 100.0 mL of 3.0 M HCl (Kₐ = 3.5 × 10⁻³) to prepare a buffer with a pH of 7.46?

\[
\text{pH} = \text{pKₐ} + \log \left(\frac{\text{base}}{\text{acid}}\right) \\
\text{pH} = \log 3.5 \times 10^{-3} + \log \left(\frac{\text{base}}{\text{acid}}\right) \\
\text{pH} = 7.46 + \log \left(\frac{\text{base}}{\text{acid}}\right) \\
0 = \log \left(\frac{\text{base}}{\text{acid}}\right) = 0 \\
\text{pH} = \text{pKₐ} \\
\frac{\text{base}}{\text{acid}} = 1
\]

\[
100.0 \text{ mL} \times 3.0 \text{ M HCl} = 300 \text{ mmole HCl} \\
\text{To get } [\text{base}] = [\text{acid}] \\
\text{We must convert } \frac{1}{2} \text{ the HCl to OCl⁻. So 150 mmol. Low KOH} \\
V_b \times 1.0 \text{ M KOH} = 150 \text{ mmole} \\
V_b = 150 \text{ mL}
\]