1. A 2.5 M solution of a weak monoprotic acid is 0.52% ionized. What is $K_a$ for this acid?

$$\text{HA} \rightleftharpoons H^+ + A^-$$

$$2.5 - x \quad x \quad x$$

$$\% \text{ ionized} = \frac{x}{[\text{HA}]_{initial}} \cdot 100$$

$$0.52 = \frac{x}{2.5} \cdot 100 \quad x = 0.013$$

$$K_a = \frac{x^2}{2.5 - x} = \frac{(0.013)^2}{2.5 - 0.013} = 6.8 \times 10^{-5}$$

2. Put the following salts in order of lowest to highest pH: KNO$_3$, HC$_5$H$_5$NCl, NaHCO$_3$, NH$_4$I

$$\text{lowest pH} \quad \rightarrow \quad \text{highest pH}$$

HC$_5$H$_5$NCl  \quad NH$_4$I  \quad KNO$_3$  \quad NaHCO$_3$  \quad $\text{HCO}_3^-$ = amphoteric but more basic than acidic \quad $K_b > K_a$

(HC$_5$H$_5$N$^+$ stronger acid than NH$_4^+$) \quad Neutral

3. Which of the following would form a buffer?
   a. HCl and KCl \quad \text{NO}

   b. HNO$_2$ and NaNO$_2$ \quad HNO$_2$ = weak acid, NO$_2^-$ = conjugate base

   c. NH$_3$ and NH$_4$Br \quad NH$_3$ = weak base, NH$_4^+$ = conjugate acid

   d. HClO$_2$ and NaClO$_3$ \quad \text{NO}

4. Calculate the pH of a 1.00 L solution of 1.00 M HNO$_2$ and 1.50 M NaNO$_2$

\text{Two ways to find pH of buffer:}

\text{1) weak acid eqn}

$$\text{HNO}_2 \rightleftharpoons H^+ + \text{NO}_2^-$$

$$K_a = 4 \times 10^{-4} = \frac{x}{(1.00)}$$

$$\frac{1}{x} = \frac{1.50}{x} = \frac{1.50}{x} = \frac{1.50}{x} = \frac{2.67 \times 10^{-4}}{x}$$

$$x = 2.67 \times 10^{-4}$$

$$\text{pH} = -\log (2.67 \times 10^{-4}) = 3.574$$

\text{2) H-H eqn}

$$\text{pH} = pK_a + \log \frac{[\text{A}^-]}{[\text{HA}]} = 3.40 + \log \frac{1.50}{1.00} = 3.576$$
5. Calculate the pH of the above solution if 0.200 moles HCl are added to it.

\[
\text{HCl} \rightarrow \text{H}^+ + \text{Cl}^- \quad \text{H}^+ \text{ reacts with NO}_2^- \ \text{of buffer, reaction goes to completion}
\]

\[
\begin{array}{c|c|c}
\text{H}^+ + \text{NO}_2^- & \rightarrow & \text{HNO}_2 \\
0.2 & 1.5 & 1.00 \text{ mol} \\
-0.2 & -0.2 & +0.2 \\
\hline
0 & 1.3 & 1.2 \text{ mol}
\end{array}
\]

\[
\text{pH} = \text{p}K_a + \log \left(\frac{[A^-]}{[HA]}\right) = 3.40 + \log \left(\frac{1.2}{1.3}\right) = 3.435
\]

6. Consider the following buffers:
   (1) 0.1 M NaF and 0.1 M HF
   (2) 1.0 M NaF and 1.0 M HF
   (3) 0.01 M NaF and 0.01 M HF

Which buffer has the highest pH? Which buffer has the greatest "capacity"?

- All have the same pH (pH = pK_a)
- Buffer (2) has greatest capacity because highest concentrations of HA + A^- (ability to absorb most added acid or base)

7. What volumes of 0.22 M CH₃COOH and 0.46 M NaCH₃COO must be mixed to prepare a 1.00 L solution buffered at pH = 5.00?

\[
\text{pH} = \text{p}K_a + \log \left(\frac{[A^-]}{[HA]}\right)
\]

\[
5.00 = 4.75 + \log \left(\frac{[A^-]}{[HA]}\right) \quad \log \left(\frac{[A^-]}{[HA]}\right) = 0.25 \quad \frac{[A^-]}{[HA]} = 10^{0.25} = 1.78
\]

\[\begin{align*}
x &= \text{volume of CH}_3\text{COOH} \\
y &= \text{volume of NaCH}_3\text{COO}
\end{align*}\]

\[
\frac{[A^-]}{[HA]} \Rightarrow \frac{(y)(0.46 \text{ M})}{(x)(0.22 \text{ M})} = 1.78 \quad x + y = 1 \text{ L total}
\]

\[
\frac{0.46 - 0.46x}{0.22x} = 1.78
\]

\[0.46 - 0.46x = 0.392x \quad 0.46 = 0.852x
\]

\[x = 0.54 \quad y = 1 - 0.54 = 0.46\]

[0.54 L of CH₃COOH, 0.46 L of NaCH₃COO]