Problem 1: \[ \text{pH} = -\log (0.001 \text{ M}) \Rightarrow \text{pH} = 3 \]

\[ 1 \times 10^{-5} \text{ M} \]

\[ \text{pH} = -\log (1 \times 10^{-5} \text{ M}) \Rightarrow \text{pH} = 5 \]

\[ 1 \times 10^{-3} \text{ M} \]

Note: \( K_w \text{ of } [H^+] = 1 \times 10^{-7} \text{ M} \) *Since 1 \( \times 10^{-9} \text{ pH} \) is less than the \( K_w \text{ of water, } [H^+] \) from water becomes significant*

\[ \text{pH} = -\log (1 \times 10^{-8} \text{ M} + 1 \times 10^{-7} \text{ M}) \Rightarrow \text{pH} = 6.96 \]

Problem 2:

\[ \frac{1.045 \text{ g NaOH}}{40 \times \text{ mol H.W.}} = 0.026125 \text{ mol} \]

\[ \frac{0.026125 \text{ mol}}{0.5 \text{ L}} = 0.05225 \text{ M NaOH} \]

\[ \text{pOH} = -\log [\text{OH}^-] = -\log (0.05225) = 1.28 \]

\[ \text{pOH} + \text{pH} = 14 \]

\[ 14 - 1.28 = 12.72 \]

\[ 14 - \text{pOH} = \text{pH} \]

Problem 3:

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

\[ \text{pH} = 5.25 + \log \left( \frac{0.22}{0.78} \right) \]

\[ \Rightarrow \text{pH} = 4.7 \]

78% protonated

\[ [\text{HA}] = 78\% \]

\[ [\text{A}^-] = 100\% - 78\% = 22\% \]

\[ \frac{[\text{HA}]}{[\text{HA}] + [\text{A}^-]} = \frac{1}{1 + 0.1995} \]

% HA = \[ \frac{[\text{HA}]}{[\text{HA}] + [\text{A}^-]} = \frac{1}{1 + 0.1995} \]

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1.1995 = \[ [\text{A}^-] + [\text{HA}] \]

0.8337 = 83% protonated
Problem 5: Endpoint: when amount of base = amount of acid

\[
\frac{20 \text{ mmol NaOH}}{80 \text{ mmol acetic acid}} = \frac{1}{4} \Rightarrow 0.25
\]

At 0.25 equivalents of OH\(^-\), pH \approx 4.2 or 4.3

\[
pH = pK_a + \log \left( \frac{[A^-]}{[HA]} \right) \Rightarrow pH = 4.7 + \log \left( \frac{1}{3} \right)
\]

\[
pH = 4.22
\]

\[\Rightarrow pH \text{ calculation matches graph}\]

Problem 6:

![Graph showing pH vs. equiv of [A^-]](image)

\[pK_a = 8.30\]

Problem 7: \(pK_a = 4.7\)

\(\Rightarrow\) buffer is only effective when \(\pm 1.0\) pH unit away from \(pK_a\) because in this range the buffer can resist pH change by neutralizing the addition or removal of protons into solution. Once the buffer is outside this pH range, it can no longer effectively neutralize the excess of H\(^+\) or OH\(^-\) present and the buffer is ineffective.
**Problem 8:** \[ \text{pH} = pK_a + \log \frac{[A^-]}{[HA]} \]

\[
\begin{align*}
\text{pH 3.7} & \\
3.7 &= 4.7 + \log \frac{[A^-]}{[HA]} \\
-1.0 &= \log \frac{[A^-]}{[HA]} \\
10^{-1.0} &= \frac{[A^-]}{[HA]} \\
0.1 &= \frac{[A^-]}{[HA]} \\
\frac{10}{1} &= \frac{[HA]}{[A^-]} \\
3.7 &= \text{pH}
\end{align*}
\]

\[
\begin{align*}
\text{pH 5.7} & \\
5.7 &= 4.7 + \log \frac{[A^-]}{[HA]} \\
1.0 &= \log \frac{[A^-]}{[HA]} \\
10^{1.0} &= \frac{[A^-]}{[HA]} \\
10 &= \frac{[A^-]}{[HA]} \\
\frac{1}{10} &= \frac{[HA]}{[A^-]} \\
5.7 &= \text{pH}
\end{align*}
\]

**Problem 9:**

\[
\begin{align*}
\text{Buffer effective from 3.7 to 5.7} \\
\text{pK}_a = 4.7
\end{align*}
\]

**Problem 10:**

\[
\begin{align*}
\text{Find pH of buffer} \\
\text{pH} &= pK_a + \log \frac{[A^-]}{[HA]} \\
8.0 &= 8.30 + \log \frac{[A^-]}{[HA]} \\
-0.30 &= \log \frac{[A^-]}{[HA]} \\
10^{-0.30} &= \frac{[A^-]}{[HA]} \\
0.5012 &= \frac{[A^-]}{[HA]} \\
\Rightarrow 1 + 0.5012 &= \frac{[A^-]}{[HA]} + 1 \\
1.5012 &= \frac{[A^-] + [HA]}{[HA]} \\
0.5012 &= \frac{[A^-]}{[HA]} \\
1.5012 &= \frac{[HA]}{[HA] + [A^-]} \\
1.5012 &= \frac{[HA]}{[HA] + [A^-]} \\
1.5012 &= \frac{[HA]}{[HA] + [A^-]} \\
0.5012 &= \frac{[A^-]}{[HA]} \\
1.5012 &= \frac{[HA]}{[HA] + [A^-]} \\
\text{NaOH} &= 0.001 \text{ L} \\
&= 0.01 \text{ mol NaOH} \\
\text{[HA]} &= 0.666 - 0.01 = 0.656 \\
\text{[A]} &= 0.344 + 0.01 = 0.344 \\
\text{pH} &= pK_a + \log \frac{[A^-]}{[HA]} \\
8.3 + \log \frac{0.344}{0.656} &= \text{pH} \\
8.02 &= \text{pH}
\end{align*}
\]
Since $pH = pK_a$
this means $0.5 = [HA] = [A^-]$

$NaOH \Rightarrow 0.001 \text{ L} \cdot 10 M = 0.01 \text{ mol NaOH}$

$\frac{0.01 \text{ mol NaOH}}{1.001 \text{ L (total volume)}} = 0.01 \text{ M NaOH}$

$pOH = -\log [OH^-]$

$pOH = -\log [0.01]$

$pOH = 2$

$14 - pOH = pH \Rightarrow 14 - 2 = 12$

- Buffered Solution exhibits a slight change in pH to 8.02 but remains close to its starting pH because the tris can give up some protons to neutralize the strong base being added.
- The water jumps to pH 12 because there is no weak acid, buffer, or protons present to neutralize the influx of $OH^-$ that is added to the water.