1. Consider the titration of 25.0 mL of 0.30 M HBr with 0.10 M KOH.

   a) What is the initial pH of the HBr solution? (Before any base is added?) [2 pts]

\[
[H_3O^+] = 0.30 M \\
pH = -\log[H_3O^+] = 0.52
\]

   b) How many milliliters of KOH must be added to reach the equivalence point? [2 pts]

\[
0.30 \text{ mol/L} \times 0.0250 \text{ L} = 0.0075 \text{ mol HBr}
\]

Because the mole ratio between HBr and KOH is 1:1, the moles of KOH at the equivalence point are also 0.0075 mole.

\[
M = \frac{\text{mol}}{L} \\
0.10 \text{ mol/L} = \frac{0.0075 \text{ mol}}{? L} \\
? L = 0.0750 \text{ L} = 75.0 \text{ mL}
\]

   c) What is the pH after 10.0 mL of KOH is added to the acid? [5 pts]

\[
\text{Initial (mol):} \quad 0.0075 \quad 0.0010 \\
\text{Change (mol):} \quad -0.0010 \quad -0.0010 \\
\text{Final (mol):} \quad 0.0065 \quad 0
\]

\[
M = \frac{\text{mol}}{L} = \frac{0.0065 \text{ mol}}{0.0350 \text{ L}} = 0.186 M
\]

Because HBr is a strong acid, \([H_3O^+]\) also equals 0.186 M.

\[
pH = -\log[H_3O^+] = 0.730
\]

d) What is the pH at the equivalence point? [2 pts]

For a strong acid/strong base titration, \(pH = 7\) at the equivalence point.

2. A sample of 0.1511 g of an unknown monoprotic acid was titrated with a 0.0633 M NaOH solution. The volume of base required to reach the equivalence point was 19.4 mL. Calculate the molar mass of the acid. [Hint: What is the definition of molar mass?] [4 pts]

\[
\text{molar mass} = \frac{\text{g substance}}{\text{mol substance}}
\]
Grams of the acid are given in the problem, so we need to find moles of acid.

\[
\frac{0.0633 \text{ mol NaOH}}{1 \text{ L soln}} \times 0.0194 \text{ L} = 0.00123 \text{ mol NaOH}
\]

Because the unknown acid is monoprotic, the mole ratio between it and NaOH will be 1:1. The moles of unknown acid at the equivalence point are 0.00123 mole.

\[
\text{molar mass} = \frac{\text{g substance}}{\text{mol substance}} = \frac{0.1511 \text{ g}}{0.00123 \text{ mol}} = 123 \text{ g/mol}
\]

3. Consider the titration of the weak base, \( \text{NH}_3 \), with the strong acid, \( \text{HNO}_3 \) at 25°C.

a) Is the \( \text{pH} \) at the equivalence point equal to, greater than, or less than 7? [2 pts]

\( \text{pH} < 7 \)

b) What species in solution, other than water, affects the \( \text{pH} \) at the equivalence point? [2 pts]

\( \text{NH}_4^+ \)

c) You search the reagent bench in the 152 lab for an appropriate indicator for this titration. You find the following three indicators. Of the three, which would be the best for this titration? [2 pts]

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Color In Acid</th>
<th>Color In Base</th>
<th>( K_a ) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methyl red</td>
<td>Red</td>
<td>Yellow</td>
<td>( 6.3 \times 10^{-6} )</td>
</tr>
<tr>
<td>Phenolphthalein</td>
<td>Colorless</td>
<td>Pink</td>
<td>( 1.0 \times 10^{-9} )</td>
</tr>
<tr>
<td>Cresol Red</td>
<td>Yellow</td>
<td>Red</td>
<td>( 1.0 \times 10^{-8} )</td>
</tr>
</tbody>
</table>

\( pK_a \) of methyl red is 5.2. This is the \( \text{pH} \) at which methyl red will change color, which is appropriate for this titration.

4. The solubility product, \( K_{sp} \), for \( \text{Cr(OH)}_3 \) is \( 3.0 \times 10^{-29} \) at 25°C.

a) Calculate the molar solubility. [4 pts]

\[
\text{Cr(OH)}_3(s) \rightleftharpoons \text{Cr}^{3+}(aq) + 3 \text{OH}^-(aq)
\]

Initial (\( M \)): \( ? \) \( 0 \) \( 0 \)

Change (\( M \)): \(-x\) \(+x\) \(+3x\)

Equilibrium (\( M \)): \( ? - x \) \( x \) \( 3x \)

\[
K_{sp} = [\text{Cr}^{3+}] [\text{OH}^-]^3 \]

\[
3.0 \times 10^{-29} = (x)(3x)^3 = 27x^4
\]

\[
x = \text{molar solubility} = 3.2 \times 10^{-8} \text{ M}
\]

b) Calculate the solubility in units of g/L. [2 pts]

\[
\frac{3.2 \times 10^{-8} \text{ mol}}{1 \text{ L}} \times \frac{103.02 \text{ g Cr(OH)}_3}{1 \text{ mol Cr(OH)}_3} = 3.3 \times 10^{-6} \text{ g/L}
\]