Investigation 9: Titration of a Diprotic Weak Acid

Question: How could we use a titration to determine the concentration and identity of an unknown protonated amino acid?

Pre-lab required reading

Atkins & Jones (6th ed.): Fundamentals J, L.3; Sections 13.5 – 13.7

Primers:
- Volumetric glassware use - Buret
- Volumetric glassware use – General
- Volumetric glassware use – volumetric flask
- Volumetric glassware use – volumetric pipet

Safety and Waste Disposal

- Eye protection should be worn at all times.
- All solutions used in this investigation can be washed down the drain with copious amounts of water.

Background

Recall that Amino acids are the building blocks of proteins. These building blocks contain two common functional groups that make up the backbone of proteins: 1) a carboxylic acid group and 2) a basic amino group. Figure 1 illustrates the forms of an amino acid with an R group representing the side chains that are different for each amino acid. Protein folding and catalysis depend on the properties of the R groups. The chemical properties provided by these R groups are also utilized to characterize and identify each amino acid.

Note that in acidic conditions, both the carboxyl group and the amino group are protonated and all amino acids are diprotic. When in neutral solution, just the amino group is protonated and in a basic situation both groups are deprotonated. What constitutes what is an acidic, neutral or basic solution depends on the acidity of the protons on each of the amino acids and varies depending on the influence of the R group (See Table 1).

\[
\begin{align*}
\text{acidic:} & \quad \text{COOH} \\
\text{neutral:} & \quad \text{COO}^- \\
\text{basic:} & \quad \text{COO}^-
\end{align*}
\]

Figure 1: Architecture of an amino acid under various conditions.

A sample of a protonated amino acid has been found in research lab at a small highly selective liberal arts college in northwestern Pennsylvania. The research students in the lab forgot to label the solution and would like your lab team at TitrationsRUs to determine the concentration and the identity of the amino acid. The only thing they wrote in their lab notebook: 5.577 g of protonated amino acid chloride salt was dissolved in 1 L of solution (not which amino acid was used). They don’t have time to figure it out since they are all working hard on their comprehensive projects, so they have hired you to do it for them. Your team has recently investigated the reaction of a monoprotic weak acid with standardized sodium hydroxide using a pH titration and successfully determined its identity. If the solution, the chloride salt of a protonated amino acid dissolved in pure water, can be titrated with standardized sodium hydroxide, how would you expect the titration curve to be similar to the one obtained for a monoprotic weak acid? How would it be different?
Table 1: The $pK_a$ values of Selected Amino acids. These are the amino acids used in the lab that hired your team.

<table>
<thead>
<tr>
<th>Amino Acid</th>
<th>R</th>
<th>$-\text{NH}_3^+$</th>
<th>$-\text{CO}_2\text{H}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glycine, Gly</td>
<td>-H</td>
<td>9.6</td>
<td>2.34</td>
</tr>
<tr>
<td>Phenylalanine, Phe</td>
<td>$-\text{CH}_2\text{-}$</td>
<td>9.13</td>
<td>1.83</td>
</tr>
<tr>
<td>Tryptophan, Trp</td>
<td>$\text{-CH}_2\text{-}$</td>
<td>9.39</td>
<td>2.38</td>
</tr>
<tr>
<td>Serine, Ser</td>
<td>CH$_2$OH</td>
<td>9.15</td>
<td>2.21</td>
</tr>
<tr>
<td>Threonine, Thr</td>
<td>CH(CH$_3$)-OH</td>
<td>10.43</td>
<td>2.63</td>
</tr>
<tr>
<td>Methionine, Met</td>
<td>CH$_2$CH$_2$SCH$_3$</td>
<td>9.21</td>
<td>2.28</td>
</tr>
<tr>
<td>Asparagine, Asn</td>
<td>CH$_2$CONH$_2$</td>
<td>8.08</td>
<td>2.02</td>
</tr>
<tr>
<td>Glutamine, Gln</td>
<td>CH$_2$CH$_2$CONH$_2$</td>
<td>9.13</td>
<td>2.17</td>
</tr>
<tr>
<td>Proline, Pro</td>
<td>$\text{-NH}$</td>
<td>10.60</td>
<td>1.99</td>
</tr>
</tbody>
</table>

Procedure

Devise a plan to use a pH titration to determine the initial concentration of the acid and the identity. The values in Table 1 of $pK_a$ values for amino acids can be used as a reference. Think about how many trials you should do and whether or not your team needs to standardize the sodium hydroxide solution provided.

References