Cation exchange capacity determination: Comparative study of three methods

Lilie Tech • Dr. Alyx Franzen
Department of Chemistry & Biochemistry
Stephen F. Austin State University

Abstract

The cation exchange capacity (CEC) of clay minerals is a fundamental property. During formation, clays undergo isomorphous substitution resulting in a net negative charge, corresponding to the number of cations required to balance the charge; this is the CEC. The CEC of four standard clays has been determined using three different methods: ammonium gas sensing ion selective electrode (ISE), ultra-violet visible light spectrophotometry (UV-vis), and atomic absorption spectrophotometry (AA). UV-vis and AA determination methods rely on measuring the absorbance of the cations remaining in solution after exchange with the clay. The ISE method of determination relies on the exchange of ammonium cations through the saturation of the exchangeable cation sites in the layers. Comparison of the three methods on hectorite clay from California, and montmorillonite clays from Texas, Wyoming, and Arizona was done to determine the accuracy of the three individual methods. The UV-vis method was performed on clays exchanged with Cu²⁺, Co²⁺, and Ni²⁺. The AA method was performed on clays exchanged with Cu²⁺ and Ni²⁺. The CEC of the four clays was determined via all three methods and the results compared back to the literature values. The three methods appear to be equally poor for making accurate measurements of the CEC; however, UV-vis and AA seem to be the most precise across the board.

Method

Clay was purified in an eight step process. Sedimentation removed non-clay impurities and allowed only clay to be processed. Decarbonation and metal removal allowed for the isolation of clay from carbonates and metals on the surface of the clay. Oxidation was followed by exchange to sodium, and then clay was put through dialysis to remove excess. Finally, clay was dried.

Ammonium Electrode Method: Dried sodium clay was exchanged with ammonium chloride to 200% saturation and put in dialyso to remove excess ions. The ammonium clay was then dried. Data consists of 5 measurements per data set. Standards were created from serial dilutions of 0.1M ammonium chloride. A 10M sodium hydroxide solution was used to cause reaction. The ammonium generated via reaction was monitored using an ammonia electrode. NH₄⁺ + NaOH(æq) → NH₄(æq) + H₂O + Na⁺

Spectroscopic Method: Suspensions of the clays were prepared with copper (II) and nickel (II) chloride. Standards for the UV-vis and AA were made using copper (II) chloride and nickel (II) chloride. Standards for the AA were made using a 1000 ppm copper and nickel standard.

Results

<table>
<thead>
<tr>
<th>Clay Type</th>
<th>SHC-1</th>
<th>SWy-2</th>
<th>Słx-1b</th>
<th>SAz-1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Accepted CEC (meq/100 g)</strong></td>
<td></td>
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<tr>
<td><strong>UV-Vis Method</strong></td>
<td></td>
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<tr>
<td></td>
<td>44</td>
<td>80</td>
<td>88</td>
<td>120</td>
</tr>
<tr>
<td><strong>% Error</strong></td>
<td>18.16</td>
<td>51.32</td>
<td>58.63</td>
<td>41.39</td>
</tr>
<tr>
<td><strong>AA Method</strong></td>
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<tr>
<td></td>
<td>293.8</td>
<td>41.9</td>
<td>293.4</td>
<td>131.6</td>
</tr>
<tr>
<td><strong>% Error</strong></td>
<td>567.8</td>
<td>52.4</td>
<td>233.4</td>
<td>9.67</td>
</tr>
</tbody>
</table>

Future Research

Spectroscopic analyses will be repeated, utilizing 5 samples from each exchange and utilizing cobalt (II) chloride. Ammonia gas sensing electrode method will be repeated by creating a uniform particle size and enclosing the system to reduce the loss of ammonia gas during the reaction.

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References