Electro-osmotic permeation and separation studies on methanol-benzene binary mixtures

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Received 11 October 1993; revised and accepted 6 December 1993

Permeation across a pyrex membrane impregnated with aluminium hydroxide using binary methanol-benzene mixtures has been investigated to explore the possibility of accomplishing electroosmotic separations. The results indicate that membrane pore radius is a crucial parameter which needs to be controlled to obtain detectable separations.

Electroosmotically driven separations, in principle, are possible when the membrane has unequal affinity for the constituents of the permeating mixture. The extent to which a membrane may discriminate between the permeating species is expected to depend on the nature and dimensional characteristics of the membrane in addition to the nature of the species undergoing electrodriven permeation. We have chosen to study electroosmotic permeation of mixture made up of constituents having widely different polar characters and ionizabilities. Aluminium hydroxide has been chosen because of its ability to form hydrogen bonded structures with one of the permeating species which may facilitate electroosmotic separation.

Experimental

A pyrex glass membrane (NPL, New Delhi) was impregnated with Al(OH)_3 by keeping equimolar solutions of AlCl_3 and NaOH in contact through the membrane for about 24 h. The solutions were then exchanged and impregnation was continued for another 24 h. Thereafter, this membrane was repeatedly washed with distilled water to ensure removal of the electrolytes used. The membrane was equilibrated with the experimental liquid and solutions were renewed before the commencement of measurements.

The experimental set up reported elsewhere was used for hydrodynamic and electroosmotic permeability measurements. Electrical potential difference across the membrane was applied from an electronically operated power supply (Hindustan Powertronix, India) using coiled platinum electrode placed in contact with the two faces of the membrane. Analytical grade methanol and benzene (both B.D.H.) were used without further purification. All the measurements were carried out at 30 ± 0.5°C.

Results and discussion

Pyrex membrane used in the present investigation has average pore radius of the order of 10⁻³ cm. Its impregnation with Al(OH)_3 is expected to reduce this parameter. For the determination of average pore radius of the Al(OH)_3 - pyrex membranes, this composite system was equilibrated with 0.1 M sodium chloride solution. Pressure driven flux and membrane conductance were measured to obtain equivalent pore radius, using the relationship

\[ r = \left( \frac{8 \eta \nu L}{L_{22}} \right)^{1/2} \]  

where, \( \frac{J}{\Delta P} \rvert_{\Delta \phi = 0} = L_{11} \) and \( \frac{I}{\Delta \phi} \) = \( L_{22} \)

\( J \) = volumetric flux, \( I \) = current flow, \( \eta \) = viscosity coefficient and \( \nu \) is the specific conductivity of the solution. \( \Delta P \) and \( \Delta \phi \) respectively, denote pressure difference and potential difference. \( \frac{J}{\Delta P} \rvert_{\Delta \phi = 0} \) represents hydrodynamic permeability while \( \frac{I}{\Delta \phi} \rvert_{\Delta P = 0} \) denotes membrane conductance. The average pore radius values obtained using different equimolar solutions are given in Table 1. Suitability of these impregnated membrane systems for bringing about electroosmotic driven separations was tested using benzene-methanol system. Benzene is electroosmotically inactive. It is therefore expected that preferential electroosmotic migration of methanol will take place. To test this, binary mixtures of methanol-benzene were subjected to electroosmosis for a period of three hours under comparable conditions. The separations achieved were ascertained by refractive index measurements and are included in Table 1. With lowering of the membrane pore radius brought about by progressively increased impregnation of the pyrex membrane, enhanced elec-
Table 1 - Average pore radii and electro-driven separations obtained using pyrex membrane impregnated with Al(OH)₃

<table>
<thead>
<tr>
<th>Equimolar concentration of AlCl₃/NaOH solutions used for pyrex-membrane impregnation</th>
<th>Conductance in 0.1 M NaCl solution (ohm⁻¹)</th>
<th>(J/ΔP)₀₋₅₀</th>
<th>Pore-radius (cm)</th>
<th>Separation of methanol (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.825 x 10⁻¹</td>
<td>4.88 x 10⁻³</td>
<td>6.56 x 10⁻³</td>
<td>ND</td>
</tr>
<tr>
<td>0.01</td>
<td>0.950 x 10⁻¹</td>
<td>4.75 x 10⁻³</td>
<td>5.95 x 10⁻³</td>
<td>ND</td>
</tr>
<tr>
<td>0.025</td>
<td>0.975 x 10⁻¹</td>
<td>2.25 x 10⁻¹</td>
<td>4.15 x 10⁻¹</td>
<td>1.0</td>
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<tr>
<td>0.05</td>
<td>1.00 x 10⁻¹</td>
<td>2.40 x 10⁻¹</td>
<td>1.45 x 10⁻¹</td>
<td>1.0</td>
</tr>
<tr>
<td>0.08</td>
<td>1.00 x 10⁻¹</td>
<td>0.875 x 10⁻¹</td>
<td>0.797 x 10⁻¹</td>
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<tr>
<td>0.10</td>
<td>1.45 x 10⁻¹</td>
<td>4.65 x 10⁻¹</td>
<td>0.153 x 10⁻¹</td>
<td>1.5</td>
</tr>
</tbody>
</table>

ND = Not detected

Aerosonic separation is observed. Further reduction in pore radius may perhaps result in more pronounced separations.

Acknowledgement
We are thankful to the CSIR, New Delhi for financial assistance.

References