Effects of Potassium Ions on the Viscosities in the Potassium Chloride-Glucose-Water Ternary System

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The viscosity of potassium chloride-glucose-water ternary system with varying concentrations was investigated in this study. The density of the ternary system was measured with a Gay-Lussac-type pycnometer. The flow time of the ternary system was measured with an Ubbelohde viscometer. The viscosity of the solutions was calculated from the density and the flow time. All measurements were conducted at 25.0 ± 0.01°C. The viscosity curve is not simple. It decreases at lower KCl concentration then increase gradually with increasing KCl concentration. The tendency is emphasized with increasing glucose concentration. An increase or decrease in the dependence of viscosity on KCl concentration is seen in the binary KCl-water system as a function of temperature.

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INTRODUCTION

Many electrolytes, including sodium and potassium chloride, exist in mammal’s living body. Despite the chemical similarities of the sodium and potassium ion, their cellular distributions are different and asymmetric; the extracellular concentration of sodium ions exceeds their intracellular concentration, the reverse being the case for potassium ions, suggesting that the ions have differing functions in the cell. The saccharides are also important tissue components that influence tissue fluid behavior. To clarify the roles sodium ions and potassium ions in living bodies, in our previous research we examined the physicochemical characteristics of each ion in the alkali halide-glucose-water ternary system by measuring its solubility and freezing-thawing behavior. In the experiment on solubility, sodium chloride in alkali halide-glucose-water ternary system has both salting-out and salting-in effects on the solubility of glucose, whereas potassium chloride has only salting-out effects on the solubility of glucose. The freeze-thaw experiment showed that when the concentration of glucose is low in the NaCl-glucose-water ternary system the eutectic elements vitrify. When the glucose concentration is high, only the water vitrifies. The results are comparable in the KCl-glucose-water ternary system.

The viscosity has been employed previously as physicochemical index, often related to potential

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solution structural changes. Jones and Dole found B coefficients that have an inherent numerical value in a low concentrated ionic solution. There are many reports about the ternary system of alkali metal-saccharide-water. There are some researches that examine the structure of the solution and the behavior of the ion by measuring viscosities. Mohanty et. al., have studied the KCl-water-sucrose system, using viscosity to show that KCl is able to break the structure of water, while Kaminsky suggested that breakdown of the structure of water can arise either from sucrose or KCl. There are studies on viscosity behavior of concentrated alkali halides in aqueous glucose solution, different ions show structure-breaking behavior in 0.50 M glucose solution in the order: I⁻ > Br⁻ > Cl⁻ > K⁺ > Na⁺.

Fig. 1 shows the viscosity of the binary KCl-water system as a function of temperature. The viscosity decreases with increasing KCl concentration below 20°C. The tendency is emphasized with a lower temperature. The viscosity of the system keeps almost a constant value at 20°C. The viscosity increases with increasing KCl concentration above 20°C. Potassium ion is thought to decrease the viscosity when water viscosity is high and increase it when water viscosity is low consequently.

In this study of KCl-glucose-water ternary system, the influence of potassium ions on solution viscosities was studied as a potential structure probe.

MATERIALS AND METHODS

Glucose and KCl were purchased from Wako Pure Chemical Industries (Osaka, Japan) and used without further purification. Pure water was used in all experiments. The density of the KCl-glucose-water ternary system was measured with a Gay-Lussac-type pycnometer. The flow time of the ternary system was measured with an Ubbelohde viscometer. Both measurements were carried out at least three times. All measurements were carried out in a temperature-controlled water bath (25.0 ± 0.01°C). The viscosity of the solutions was calculated by using the density and the flow-time results. The concentrations of the KCl-glucose in solution were expresses in molal (mol of KCl or glucose kg⁻¹ water).

RESULTS AND DISCUSSION

Densities and viscosities of the KCl-glucose-water ternary system at 25°C are shown in Table 1. The viscosities of binary systems, aqueous KCl solutions, were agreed with those in the bibliographic reference. The densities increase with increasing glucose and KCl concentrations. But viscosities found to be minimum at intermediate KCl concentration. At constant glucose concentration the viscosities decrease with increasing KCl concentration at first, then they increase with increasing KCl concentration. The tendency is emphasized with increasing glucose concentration.
concentration above 20°C. Potassium ion is thought to break the structure of water, while Kaminsky et al. have studied the KCl-water-sucrose system, using viscosity to show that KCl is able to break the structure of water. It was calculated by using the density and the viscosity coefficients that have an inherent numerical value in a low concentrated ionic solution. Jones and Dole found B coefficients that have an inherent numerical value in a low concentrated solution structural changes. In this study of KCl-glucose-water ternary system, the viscosity behavior is more complex. It decreases at lower KCl concentration then increases gradually with increasing KCl concentration. The tendency is emphasized with increasing glucose concentration. An increase or decrease in the dependence of viscosity on KCl concentration is seen in the binary KCl-water system as a function of temperature.

In the NaCl-glucose-water system, viscosity increased with increasing NaCl concentration (data not shown). This result agrees with the tendency reported previously. From the results, potassium ion has the effect of increase or decrease in viscosity, whereas sodium ion has only the effect of increase in viscosity.

### Table 1. Densities (g cm⁻³) and viscosities (mPa s) of KCl-glucose-water ternary system at various molalities (mol kg⁻¹) at 25°C

<table>
<thead>
<tr>
<th>Glucose (mol kg⁻¹)</th>
<th>0</th>
<th>0.671</th>
<th>1.34</th>
<th>2.01</th>
<th>2.68</th>
<th>3.35</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>0.997</td>
<td>0.890</td>
<td>1.027</td>
<td>0.904±0.001</td>
<td>1.056</td>
<td>0.906±0.001</td>
</tr>
<tr>
<td>Viscosity</td>
<td>1.016</td>
<td>1.007±0.001</td>
<td>1.044</td>
<td>1.003±0.001</td>
<td>1.071</td>
<td>1.004±0.001</td>
</tr>
<tr>
<td>Density</td>
<td>0.933</td>
<td>1.140±0.002</td>
<td>1.060</td>
<td>1.138±0.002</td>
<td>1.086</td>
<td>1.137±0.001</td>
</tr>
<tr>
<td>Viscosity</td>
<td>1.049</td>
<td>1.296±0.001</td>
<td>1.075</td>
<td>1.288±0.001</td>
<td>1.099</td>
<td>1.282±0.001</td>
</tr>
<tr>
<td>Density</td>
<td>1.104</td>
<td>1.467±0.002</td>
<td>1.089</td>
<td>1.460±0.002</td>
<td>1.112</td>
<td>1.454±0.002</td>
</tr>
<tr>
<td>Viscosity</td>
<td>1.078</td>
<td>1.664±0.002</td>
<td>1.102</td>
<td>1.653±0.001</td>
<td>1.124</td>
<td>1.642±0.003</td>
</tr>
<tr>
<td>Density</td>
<td>1.092</td>
<td>1.879±0.001</td>
<td>1.115</td>
<td>1.865±0.002</td>
<td>1.136</td>
<td>1.852±0.002</td>
</tr>
<tr>
<td>Viscosity</td>
<td>1.104</td>
<td>2.126±0.002</td>
<td>1.127</td>
<td>2.105±0.002</td>
<td>1.147</td>
<td>2.096±0.003</td>
</tr>
<tr>
<td>Density</td>
<td>1.139</td>
<td>3.036±0.005</td>
<td>1.158</td>
<td>3.006±0.005</td>
<td>1.177</td>
<td>2.985±0.003</td>
</tr>
<tr>
<td>Viscosity</td>
<td>1.177</td>
<td>4.872±0.009</td>
<td>1.194</td>
<td>4.807±0.007</td>
<td>1.210</td>
<td>4.764±0.005</td>
</tr>
<tr>
<td>Density</td>
<td>1.208</td>
<td>7.690±0.014</td>
<td>1.223</td>
<td>7.592±0.011</td>
<td>1.237</td>
<td>7.466±0.018</td>
</tr>
</tbody>
</table>

**Fig. 2.** Differences in viscosities of KCl-glucose-water ternary systems as a function of KCl concentration at a constant glucose concentration. Glucose concentrations represent as following symbols: △: 0 mol kg⁻¹, ○: 0.555 mol kg⁻¹, □: 1.66 mol kg⁻¹, ▲: 2.77 mol kg⁻¹, ●: 3.88 mol kg⁻¹, ■: 4.99 mol kg⁻¹, respectively.
CONCLUSIONS

The viscosity curve of KCl-glucose-water ternary system is not simple because the viscosity decreases slightly at lower KCl concentration then increases gradually with increases KCl concentration at lower glucose concentration. An increase or decrease in the dependence of viscosity on KCl concentration is seen in the binary KCl-water system as a function of temperature.

REFERENCES