varied among these authors. This may be due to the difficulty in choosing optimal nutritional conditions for the induction as reported in this communication. In addition to trp promoter, the control of glucose is necessary for induction of the gene expression from lac promoter of E. coli and suc promoter of S. cerevisiae, especially in fermenter level culture. We are now trying to apply this on-line measuring system for glucose to these promoters.

Acknowledgment
This work was supported in part by a Grant-in-Aid (No. 62470112) for Scientific Research from the Ministry of Education, Science and Culture of Japan and by the Asahi Glass Foundation for Industrial Technology.

Literature Cited

LIQUID–LIQUID EQUILIBRIA FOR THE SYSTEM OF WATER, ETHANOL AND 1,1-DIFLUOROETHANE

TAKASHI NAKAYAMA AND HIROSHI SAGARA
Research & Development Division, JGC Corporation, Yokohama 223

KUNIO ARAI AND SHOZABURO SAITO
Department of Chemical Engineering, Tohoku University, Sendai 980

Key Words: Liquid-Liquid Equilibrium, 1,1-Difluoroethane, Ethanol, Water, Loose-Packed Solution (LPACS) Model

Introduction
In a previous study,2) liquefied 1,1-difluoroethane (DFE) was found to be a better extraction solvent than some supercritical or liquefied gases such as carbon dioxide for the enrichment of ethanol from low-concentration fermentation broths. For the selection of optimum extraction conditions, it is essential to have liquid–liquid equilibrium data over a wider range of conditions.

In this work, we report ternary liquid–liquid equilibrium data for the water (H₂O)-ethanol (EtOH)-1,1-difluoroethane system at 303.2 K and 0.81 MPa and at 338.2 K and 1.82 MPa. In addition, the data are correlated with the UNIQUAC¹ model and the loose-packed solution (LPACS) model proposed in a previous paper,4) which was derived by considering the expansion of liquid in the solution structure.

1. Experimental Results
The experimental apparatus and procedure,3) and the materials used²) are the same as those reported in earlier papers. Liquid–liquid equilibria for the H₂O–EtOH–DFE system at temperatures of 303.2 and 338.2 K are listed in Table 1 and shown in Figs. 1 and
### Table 1. Liquid-liquid equilibria for the H\textsubscript{2}O-EtOH-DFE system

<table>
<thead>
<tr>
<th>Temperature [K]</th>
<th>Pressure [MPa]</th>
<th>Mole fraction [-]</th>
<th>H\textsubscript{2}O</th>
<th>EtOH</th>
<th>DFE</th>
<th>H\textsubscript{2}O</th>
<th>EtOH</th>
<th>DFE</th>
</tr>
</thead>
<tbody>
<tr>
<td>303.2</td>
<td>0.81</td>
<td></td>
<td>0.9961</td>
<td>0.0000</td>
<td>0.0039</td>
<td>0.0074</td>
<td>0.0000</td>
<td>0.9926</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.9700</td>
<td>0.0257</td>
<td>0.0043</td>
<td>0.0094</td>
<td>0.0086</td>
<td>0.9820</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.9175</td>
<td>0.0776</td>
<td>0.0049</td>
<td>0.0121</td>
<td>0.0330</td>
<td>0.9549</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.7947</td>
<td>0.1873</td>
<td>0.0180</td>
<td>0.0468</td>
<td>0.1091</td>
<td>0.8441</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.6221</td>
<td>0.2984</td>
<td>0.0795</td>
<td>0.0980</td>
<td>0.1843</td>
<td>0.7177</td>
</tr>
<tr>
<td>338.2</td>
<td>1.82</td>
<td></td>
<td>0.9955</td>
<td>0.0000</td>
<td>0.0045</td>
<td>0.0171</td>
<td>0.0000</td>
<td>0.9829</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.9689</td>
<td>0.0261</td>
<td>0.0050</td>
<td>0.0230</td>
<td>0.0190</td>
<td>0.9580</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.9169</td>
<td>0.0751</td>
<td>0.0080</td>
<td>0.0436</td>
<td>0.0653</td>
<td>0.8911</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.8121</td>
<td>0.1631</td>
<td>0.0248</td>
<td>0.1021</td>
<td>0.1708</td>
<td>0.7271</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.6156</td>
<td>0.2721</td>
<td>0.1123</td>
<td>0.2590</td>
<td>0.2816</td>
<td>0.4594</td>
</tr>
</tbody>
</table>

2. The pressures were chosen to be 0.1-0.2 MPa greater than the vapor pressure of pure 1,1-difluoroethane.

2. Effect of Temperature on Ethanol Distribution and Selectivity

Ethanol distribution curves and selectivity curves at
Table 2. Binary parameters in the LPACS and UNIQUAC equations for the H₂O(1)-EtOH(2)-DFE(3) system

<table>
<thead>
<tr>
<th>Temp [K]</th>
<th>Press [MPa]</th>
<th>LPACS</th>
<th>UNIQUAC</th>
<th>Parameter estimation</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>303.2</td>
<td>0.81</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 2</td>
<td>0*</td>
<td>12.780</td>
<td>105.66 VLB 5)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 3</td>
<td>1.0</td>
<td>434.57</td>
<td>778.23 LLB This work</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 3</td>
<td>0.4</td>
<td>10.237</td>
<td>335.56 LLT</td>
</tr>
<tr>
<td>338.2</td>
<td>1.82</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 2</td>
<td>0*</td>
<td>176.68</td>
<td>-25.611 VLB 6)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 3</td>
<td>1.4</td>
<td>479.17</td>
<td>699.32 LLB This work</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 3</td>
<td>0.0</td>
<td>52.408</td>
<td>295.45 LLT</td>
</tr>
</tbody>
</table>


* The t₁₂ had a much lower sensitivity than t₁₃ and t₂₃.

Temperatures of 303.2 K, 323.2 K and 338.2 K are shown by the full lines in Figs. 3 and 4, respectively. As the temperature is raised, the ethanol distribution in the 1,1-difluoroethane phase increases while the selectivity decreases.

3. Correlation of Data

The data were correlated with the UNIQUAC and LPACS models. The procedure of parameter estimation is given in a previous work. The binary parameters are listed in Table 2. Mutual solubility curves calculated by the solution models and tie-lines calculated by the LPACS model are shown in Figs. 1 and 2. Ethanol distribution curves and selectivity curves predicted by the solution models are shown in Figs. 3 and 4, respectively. The LPACS equation is in better agreement with the experimental results than the UNIQUAC equation at each temperature. The temperature dependence of the UNIQUAC equation is represented by Boltzmann factors, while that of the LPACS equation is represented by Boltzmann factors and the hole fraction due to solution expansion. These calculated results suggest that the LPACS equation can give a better representation of the effect of temperature on liquid-liquid equilibrium than the UNIQUAC equation.

Nomenclature

Aᵢⱼ = binary interaction parameter defined by

\[(uᵢᵢ - uᵢᵢ)/R \] [K]

R = gas constant [J/mol·K]

sᵢ = pair solution structure parameter [-]

Aᵢ = UNIQUAC binary interaction parameter [J/mol]

X = water-phase weight fraction [-]

Y = solvent-phase weight fraction [-]

(Subscripts)

i,j = component numbers

(Superscripts)

p = close-packed state

Literature Cited


(A part of this work was presented at the Gunma Meeting of The Society of Chemical Engineers, Japan, at Minakami, July, 1986.)