# Excess Enthalpies of the Ternary Mixtures Diisopropyl Ether + 3-Methylpentane + (Octane or Decane) at 298.15 K

**Zhaohui Wang, George C. Benson,* and Benjamin C.-Y. Lu**

Department of Chemical Engineering, University of Ottawa, Ottawa, Ontario, Canada K1N 6N5

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Excess molar enthalpies, measured at 298.15 K in a flow microcalorimeter, are reported for diisopropyl ether + 3-methylpentane + octane and for diisopropyl ether + 3-methylpentane + decane. Smooth representations of the results are described and used to construct constant excess molar enthalpy contours on Roozeboom diagrams. The latter are compared with diagrams obtained when the model of Liebermann and Fried is used to estimate the excess molar enthalpies of the ternary mixtures from the physical properties of the components and the excess molar enthalpies of their constituent binary mixtures.

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## Introduction

Recent papers from our laboratory have reported excess molar enthalpies of some binary and ternary mixtures formed by mixing an oxygenate with various hydrocarbons. Most recently, excess molar enthalpies of the systems tetrahydrofuran (THF) + 3-methylpentane (3MP) + {octane (nC8) or decane (nC10)} were reported.[1] As a continuation of that investigation, similar calorimetric measurements at 298.15 K have been made for the two ternary systems formed when the THF was replaced by diisopropyl ether (DIPE).

## Experimental Section

The DIPE, nC8, and nC10 used in the present work were obtained from the Aldrich Chemical Co. The 3MP was Research Grade material from the Phillips Chemical Co. In all cases the purities stated by the manufacturers were at least 99 mol %. Apart from partial degassing, the components were used without further purification. Densities, $\rho/\text{kg}\cdot\text{m}^{-3}$, measured with a precision of 0.03 $\text{kg}\cdot\text{m}^{-3}$ at 298.15 K in an Anton-Paar digital densimeter, were 718.70, 659.94, 698.72, and 726.30, for DIPE, 3MP, nC8, and nC10, respectively. These results are in reasonable agreement with values in the literature.[2,3]

An LKB flow microcalorimeter (model 10700-1), thermostated at (298.150 ± 0.003) K, was used to measure the excess molar enthalpies $H^{\text{E}}_{\text{m}}$. Details of the equipment and its operation have been described previously.[4,5]

In studying the ternary systems, the excess molar enthalpy $H^{\text{E}}_{\text{m},1+23}$ was determined for several pseudo binary mixtures in which component 1 (DIPE) was added to binary mixtures of component 2 (3MP) and 3 (either nC8 or nC10). For this purpose, binaries with fixed mole ratios, $x_2/x_3$, were prepared by mass. The excess molar enthalpy $H^{\text{E}}_{\text{m},123}$ of the ternary mixture was then obtained from the relation

$$H^{\text{E}}_{\text{m},123} = H^{\text{E}}_{\text{m},1+23} + (1 - x_1)H^{\text{E}}_{\text{m},23} \qquad (1)$$

where $x_1$ is the mole fraction of DIPE and $H^{\text{E}}_{\text{m},23}$ is the excess molar enthalpy of the particular binary mixture. Over most of the mole fraction range, the errors of the excess molar enthalpies and the mole fractions of the final mixtures are estimated to be less than 0.5% and $5 \times 10^{-4}$, respectively.

## Results and Discussion

Excess molar enthalpies $H^{\text{E}}_{\text{m},ij}$ ($i < j$), measured at 298.15 K, for four of the five constituent binaries of present interest have been reported previously: DIPE (1) + nC8 (3),[6] 3MP (2) + nC8 (3),[7] DIPE (1) + nC10 (3),[6] and 3MP (2) + nC10 (3).[8] In the course of the present investigation, excess molar enthalpies at 298.15 K were determined for the fifth constituent binary, DIPE (1) + 3MP (2). These results are listed in Table 1.

The smoothing function

$$H^{\text{E}}_{\text{m},ij}/\text{J}\cdot\text{mol}^{-1} = x_i(1 - x_i)\sum_{k=1}^{n} h_k(1 - 2x_i)^{k-1} \quad (i < j) \qquad (2)$$

was fitted to the results in Table 1 by a least-squares method, with all points weighted equally. Values of the coefficients $h_k$ are listed in Table 2, along with the standard deviation $s$ for the representation. For convenience, the coefficients and standard deviations for the representations of $H^{\text{E}}_{\text{m},ij}$ for the four other binary mixtures are also included in Table 2.

The experimental results for $H^{\text{E}}_{\text{m},1+23}$ and the corresponding values of $H^{\text{E}}_{\text{m},123}$ calculated from eq 1 are listed in Tables 3 and 4 against the mole fraction $x_1$ for the ternary systems containing nC8 and nC10, respectively. For a selected value of $x_2/x_3$ in these tables, the maximum values of $H^{\text{E}}_{\text{m},1+23}$ and $H^{\text{E}}_{\text{m},123}$ occur near $x_1 = 0.5$. For both systems at constant $x_1$, the enthalpies decrease as $x_2/x_3$ increases.

The experimental values of $H^{\text{E}}_{\text{m},1+23}$ from Tables 3 and 4 are plotted in Figures 1 and 2, respectively. Also shown in these figures are the results for DIPE (1) + 3MP (2) given in Table 1 and the results for DIPE (1) + nC8 (3) and DIPE (1) + nC10 (3) reported by Zhu et al.[6] In both figures, it can be seen that the results for the three ternary mixtures fall between those for the two constituent binaries.

The values of $H^{\text{E}}_{\text{m},1+23}$ were represented as a sum of binary terms[9] with an added ternary contribution:

$$H^{\text{E}}_{\text{m},1+23} = [x_2/(1 - x_1)]H^{\text{E}}_{\text{m},12} + [x_3/(1 - x_1)]H^{\text{E}}_{\text{m},13} + H^{\text{E}}_{\text{m},T} \qquad (3)$$

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* Corresponding author. Telephone: +1-613-562-5800 (6118). Fax: +1-613-562-5172. E-mail: gbenson@eng.uottawa.ca.

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**Table 1. Experimental Mole Fractions, $x_1$, and Excess Molar Enthalpies, $H^{E}_{m,ij}$, for the Mixture DIPE (1) + 3MP (2) at 298.15 K**

| $x_1$ | $H^{E}_{m,ij}$/J·mol$^{-1}$ | $x_1$ | $H^{E}_{m,ij}$/J·mol$^{-1}$ | $x_1$ | $H^{E}_{m,ij}$/J·mol$^{-1}$ | $x_1$ | $H^{E}_{m,ij}$/J·mol$^{-1}$ | $x_1$ | $H^{E}_{m,ij}$/J·mol$^{-1}$ |
|---|---|---|---|---|---|---|---|---|---|
| 0.0500 | 42.23 | 0.2503 | 155.55 | 0.4500 | 197.43 | 0.6500 | 176.75 | 0.8500 | 93.71 |
| 0.1000 | 78.58 | 0.2998 | 171.60 | 0.5003 | 197.63 | 0.7002 | 162.13 | 0.9000 | 65.94 |
| 0.1499 | 109.67 | 0.3501 | 183.83 | 0.5502 | 193.77 | 0.7501 | 143.57 | 0.9500 | 35.79 |
| 0.2000 | 136.10 | 0.3997 | 192.31 | 0.5998 | 187.30 | 0.8003 | 121.54 | | |

**Table 2. Coefficients, $h_k$, and Standard Deviations, $s$, for the Representation of $H^{E}_{m,ij}$ ($i < j$) by Eq 2 for the Constituent Binary Mixtures at 298.15 K**

| component | | | | | | | $s$ |
|---|---|---|---|---|---|---|---|
| $i$ | $j$ | $h_1$ | $h_2$ | $h_3$ | $h_4$ | $h_5$ | J·mol$^{-1}$ |
| DIPE | 3MP[a] | 790.32 | 51.08 | 26.96 | 58.27 | | 0.73 |
| DIPE | nC8[b] | 1102.00 | −49.71 | 53.24 | 2.16 | −121.37 | 1.29 |
| 3MP | nC8[c] | 65.33 | −2.71 | | | | 0.046 |
| DIPE | nC10[b] | 1357.07 | −109.31 | 162.86 | −58.25 | −202.62 | 0.88 |
| 3MP | nC10[d] | 162.42 | −1.51 | −1.63 | | | 0.07 |

[a] Present work. [b] Zhu et al.[6] [c] Hamam et al.[7] [d] Hamam and Benson.[8]

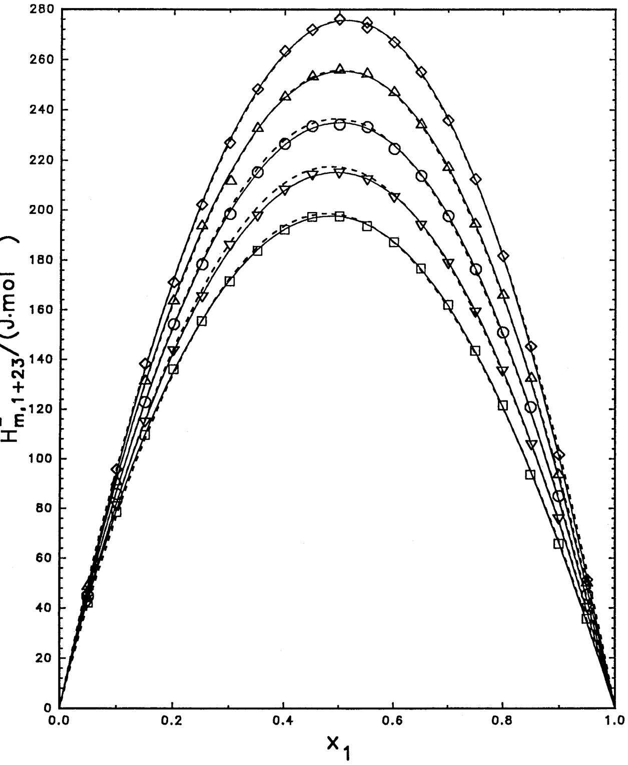

**Figure 1.** Excess molar enthalpies, $H^{E}_{m,1+23}$, for DIPE (1) + 3MP (2) + nC8 (3) at 298.15 K. Experimental results: △, $x_2/x_3 = 0.3332$; ○, $x_2/x_3 = 1.0002$; ▽, $x_2/x_3 = 2.9995$; ◇, $x_2 = 0$, Zhu et al.;[6] □, $x_3 = 0$. Curves: —, calculated from the representation of the results by eqs 1−4, using the ternary term $H^{E}_{m,T}$ given in the footnote of Table 3; - - -, estimated by means of the Liebermann−Fried model.

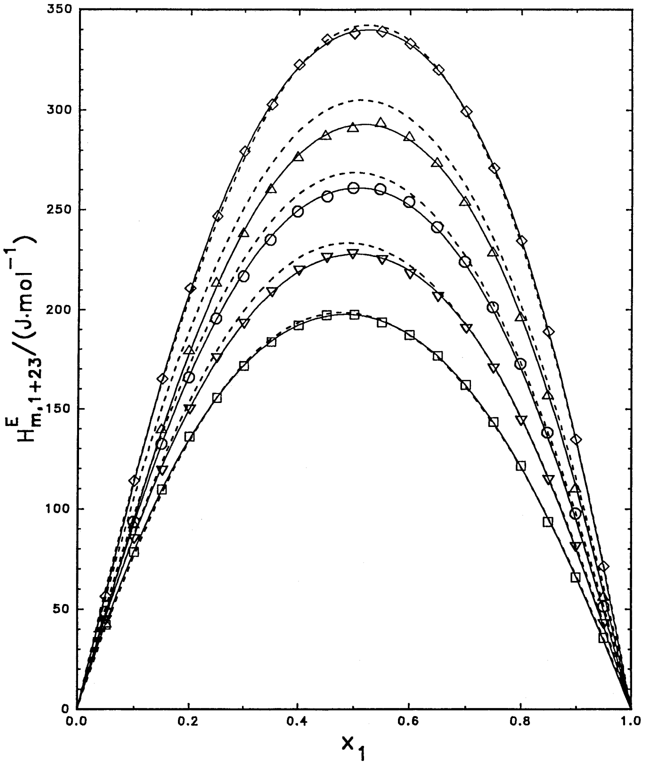

**Figure 2.** Excess molar enthalpies, $H^{E}_{m,1+23}$, for DIPE (1) + 3MP (2) + nC10 (3) at 298.15 K. Experimental results: △, $x_2/x_3 = 0.3333$; ○, $x_2/x_3 = 0.9994$; ▽, $x_2/x_3 = 3.0013$; ◇, $x_2 = 0$, Zhu et al.;[6] □, $x_3 = 0$. Curves: —, calculated from the representation of the results by eqs 1−4, using the ternary term $H^{E}_{m,T}$ given in the footnote of Table 4; - - -, estimated by means of the Liebermann−Fried model.

where the values of $H^{E}_{m,ij}$ were calculated from the appropriate smoothing functions.

The form

$$H^{E}_{m,T}/\mathrm{J{\cdot}mol^{-1}} = [x_1x_2x_3/(1 + b\{x_2 - x_1\})](c_0 + c_1x_1 + c_2x_2 + c_3x_1^2 + c_4x_1x_2 + c_5x_2^2 + c_6x_1^3 + c_7x_1^2x_2 + c_8x_1x_2^2 + c_9x_2^3) \quad (4)$$

which was adopted for the latter contribution is similar to the form used by Morris et al.[10] with the possibility of having an extra skewing factor $\{1 + b(x_2 - x_1)\}^{-1}$ for a nonzero value of $b$. Values of the parameters $c_i$ were obtained from least-squares analyses in which eqs 3 and 4 were fitted to the values of $H^{E}_{m,1+23}$ in Tables 3 and 4, with $b = 0$ for the nC8 system and $b = 1$ for the nC10 system. The resulting representations of $H^{E}_{m,T}$ are given in the footnotes of the tables, along with the standard deviations $s$ of the fits. The solid curves for $H^{E}_{m,1+23}$ in Figures 1 and 2 were calculated from eq 3, using these representations.

Equations 1−4 were also used to calculate the constant $H^{E}_{m,123}$ contours plotted on the Roozeboom diagrams in Figures 3a and 4a. The general characteristics of these are similar. In both figures, all of the contours extend to the

**Table 3. Experimental Excess Molar Enthalpies, $H^{E}_{m,1+23}$, Measured at 298.15 K, for the Addition of DIPE to 3MP + nC8 Mixtures To Form DIPE (1) + 3MP (2) + nC8 (3), and Values of $H^{E}_{m,123}$ Calculated from Eq 1**

| $x_1$ | $H^{E}_{m,1+23}$ [a] / J·mol$^{-1}$ | $H^{E}_{m,123}$ / J·mol$^{-1}$ | $x_1$ | $H^{E}_{m,1+23}$ [a] / J·mol$^{-1}$ | $H^{E}_{m,123}$ / J·mol$^{-1}$ | $x_1$ | $H^{E}_{m,1+23}$ [a] / J·mol$^{-1}$ | $H^{E}_{m,123}$ / J·mol$^{-1}$ |
|---|---|---|---|---|---|---|---|---|
| $x_2/x_3 = 0.3332$; $H^{E}_{m,23}$(J·mol$^{-1}$) = 11.99 | | | | | | | | |
| 0.0501 | 48.81 | 60.20 | 0.3999 | 245.49 | 252.69 | 0.6998 | 217.29 | 220.89 |
| 0.1000 | 90.79 | 101.58 | 0.4504 | 253.55 | 260.14 | 0.7498 | 194.63 | 197.63 |
| 0.1500 | 131.45 | 141.64 | 0.5000 | 256.21 | 262.21 | 0.8004 | 166.06 | 168.45 |
| 0.1999 | 163.70 | 173.30 | 0.5501 | 254.59 | 259.99 | 0.8508 | 132.53 | 134.32 |
| 0.2501 | 193.86 | 202.85 | 0.6000 | 247.22 | 252.02 | 0.8999 | 93.75 | 94.95 |
| 0.3017 | 211.88 | 220.26 | 0.6502 | 234.32 | 238.52 | 0.9499 | 50.22 | 50.82 |
| 0.3498 | 232.96 | 240.76 | | | | | | |
| $x_2/x_3 = 1.0002$; $H^{E}_{m,23}$(J·mol$^{-1}$) = 16.33 | | | | | | | | |
| 0.0499 | 44.78 | 60.30 | 0.4001 | 226.62 | 236.42 | 0.7000 | 197.57 | 202.47 |
| 0.1000 | 85.76 | 100.46 | 0.4500 | 233.63 | 242.61 | 0.7504 | 176.34 | 180.42 |
| 0.1500 | 122.77 | 136.65 | 0.5001 | 234.18 | 242.34 | 0.7999 | 150.93 | 154.20 |
| 0.2002 | 154.18 | 167.24 | 0.5503 | 233.20 | 240.54 | 0.8500 | 120.83 | 123.28 |
| 0.2503 | 178.31 | 190.55 | 0.6003 | 224.62 | 231.15 | 0.8999 | 84.98 | 86.61 |
| 0.3007 | 198.49 | 209.91 | 0.6500 | 213.74 | 219.46 | 0.9499 | 45.44 | 46.26 |
| 0.3502 | 215.29 | 225.90 | | | | | | |
| $x_2/x_3 = 2.9995$; $H^{E}_{m,23}$(J·mol$^{-1}$) = 12.50 | | | | | | | | |
| 0.0500 | 42.58 | 54.46 | 0.3995 | 208.36 | 215.87 | 0.7000 | 178.87 | 182.62 |
| 0.1000 | 81.33 | 92.58 | 0.4501 | 214.40 | 221.28 | 0.7500 | 159.38 | 162.51 |
| 0.1500 | 115.05 | 125.68 | 0.4994 | 215.21 | 221.47 | 0.7992 | 135.53 | 138.04 |
| 0.1999 | 143.71 | 153.72 | 0.5503 | 212.50 | 218.12 | 0.8517 | 105.98 | 107.83 |
| 0.2508 | 165.46 | 174.83 | 0.5999 | 205.39 | 210.39 | 0.8998 | 75.97 | 77.22 |
| 0.3004 | 186.18 | 194.93 | 0.6497 | 194.19 | 198.57 | 0.9499 | 40.42 | 41.05 |
| 0.3498 | 197.97 | 206.10 | | | | | | |

[a] Ternary term for representation of $H^{E}_{m,1+23}$ by eqs 3 and 4: $H^{E}_{m,T}/\text{J·mol}^{-1} = x_1x_2x_3(141.72 - 250.27x_1 - 254.17x_2)$, $s = 1.03$ J·mol$^{-1}$.

**Table 4. Experimental Excess Molar Enthalpies, $H^{E}_{m,1+23}$, Measured at 298.15 K, for the Addition of DIPE to 3MP + nC10 Mixtures To Form DIPE (1) + 3MP (2) + nC10 (3), and Values of $H^{E}_{m,123}$ Calculated from Eq 1**

| $x_1$ | $H^{E}_{m,1+23}$ [a] / J·mol$^{-1}$ | $H^{E}_{m,123}$ / J·mol$^{-1}$ | $x_1$ | $H^{E}_{m,1+23}$ [a] / J·mol$^{-1}$ | $H^{E}_{m,123}$ / J·mol$^{-1}$ | $x_1$ | $H^{E}_{m,1+23}$ [a] / J·mol$^{-1}$ | $H^{E}_{m,123}$ / J·mol$^{-1}$ |
|---|---|---|---|---|---|---|---|---|
| $x_2/x_3 = 0.3333$; $H^{E}_{m,23}$(J·mol$^{-1}$) = 30.23 | | | | | | | | |
| 0.0496 | 42.86 | 71.60 | 0.3973 | 276.61 | 294.83 | 0.6977 | 254.04 | 263.18 |
| 0.0990 | 92.27 | 119.51 | 0.4470 | 287.24 | 303.96 | 0.7478 | 228.81 | 236.44 |
| 0.1485 | 139.74 | 165.48 | 0.4963 | 291.20 | 306.43 | 0.7984 | 196.39 | 202.48 |
| 0.1983 | 179.35 | 203.59 | 0.5467 | 293.70 | 307.41 | 0.8489 | 156.81 | 161.38 |
| 0.2478 | 213.64 | 236.38 | 0.5979 | 286.65 | 298.81 | 0.8989 | 110.24 | 113.30 |
| 0.2977 | 238.45 | 259.69 | 0.6472 | 273.58 | 284.25 | 0.9494 | 56.19 | 57.72 |
| 0.3477 | 260.44 | 280.16 | | | | | | |
| $x_2/x_3 = 0.9994$; $H^{E}_{m,23}$(J·mol$^{-1}$) = 40.60 | | | | | | | | |
| 0.0495 | 48.78 | 87.37 | 0.3971 | 249.27 | 273.75 | 0.6972 | 224.00 | 236.29 |
| 0.0990 | 93.66 | 130.25 | 0.4503 | 256.79 | 279.11 | 0.7477 | 201.24 | 211.49 |
| 0.1485 | 132.45 | 167.03 | 0.4971 | 260.91 | 281.33 | 0.7982 | 172.65 | 180.85 |
| 0.1982 | 165.70 | 198.26 | 0.5461 | 260.30 | 278.73 | 0.8481 | 138.12 | 144.29 |
| 0.2477 | 195.71 | 226.26 | 0.5975 | 253.86 | 270.20 | 0.8990 | 97.68 | 101.78 |
| 0.2976 | 216.77 | 245.29 | 0.6475 | 241.42 | 255.73 | 0.9494 | 51.35 | 53.41 |
| 0.3469 | 235.12 | 261.64 | | | | | | |
| $x_2/x_3 = 3.0013$; $H^{E}_{m,23}$(J·mol$^{-1}$) = 30.51 | | | | | | | | |
| 0.0499 | 45.11 | 74.10 | 0.3999 | 220.16 | 238.47 | 0.7007 | 190.95 | 200.08 |
| 0.0998 | 85.53 | 113.00 | 0.4501 | 226.66 | 243.44 | 0.7497 | 170.86 | 178.50 |
| 0.1500 | 119.47 | 145.40 | 0.4966 | 228.45 | 243.81 | 0.8001 | 144.66 | 150.76 |
| 0.2000 | 150.24 | 174.65 | 0.5500 | 225.57 | 239.30 | 0.8503 | 114.95 | 119.52 |
| 0.2498 | 176.08 | 198.97 | 0.6001 | 218.46 | 230.66 | 0.8998 | 81.61 | 84.67 |
| 0.2996 | 193.52 | 214.89 | 0.6497 | 207.05 | 217.74 | 0.9499 | 43.20 | 44.73 |
| 0.3502 | 209.35 | 229.18 | | | | | | |

[a] Ternary term for representation of $H^{E}_{m,1+23}$ by eqs 3 and 4: $H^{E}_{m,T}/\text{J·mol}^{-1} = [x_1x_2x_3/(1 - x_1 + x_2)](-2299.60 + 7663.10x_1 + 6132.61x_2 - 10725.92x_1^2 - 12730.74x_1x_2 - 4033.34x_2^2 + 4867.66x_1^3 + 10774.47x_1^2x_2)$, $s = 1.52$ J·mol$^{-1}$.

edges of the triangle, and there is no indication of an internal maximum.

Recent work[11,12] indicates that an extension of the model of Liebermann and Fried[13,14] can be useful in representing the excess enthalpies of binary mixtures and also has the potential for estimating the enthalpies of ternary mixtures from data for the pure components and their binary mixtures. It is therefore of interest to examine how well the Liebermann−Fried model can represent the enthalpies of the present ternary systems.

The equations used in this application have been outlined by Wang et al.[12] Values of the Liebermann−Fried interaction parameters, $A_{ij}$ and $A_{ji}$, for each of the binary mixtures are given in Table 5. These were obtained by fitting the Liebermann−Fried formula for $H^{E}_{m,ij}$ to the primary experimental results in Table 1 and those reported

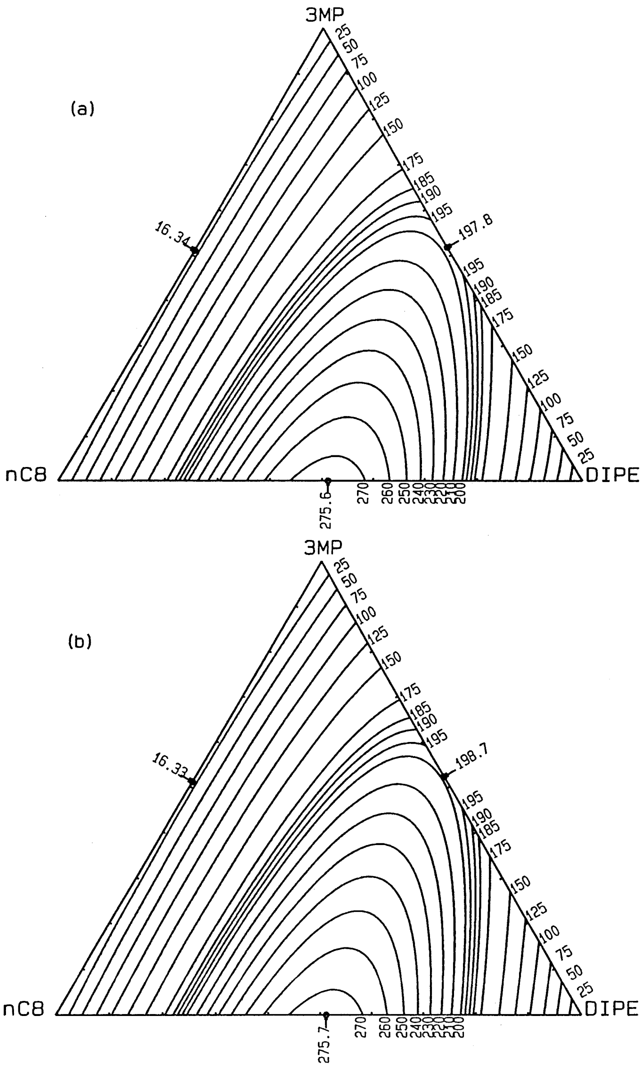

**Figure 3.** Contours for constant values of $H^{E}_{m,123}$/J·mol$^{-1}$ for DIPE (1) + 3MP (2) + nC8 (3) at 298.15 K: a, calculated from the representation of the experimental results by eqs 1−4 with $H^{E}_{m,T}$ from the footnote of Table 3; b, estimated by means of the Liebermann−Fried model.

for the other relevant binaries by Zhu et al.,[6] Hamam et al.,[7] and Hamam and Benson.[8] Also included in Table 5 are values of the standard deviations *s* achieved in the fitting process and values[2,15,16] of the isobaric thermal expansivities $\alpha_p$ of the components, used in evaluating the contributions due to different molecular sizes.

Using the values of the parameters given in Table 5, $H^{E}_{m,1+23}$ and $H^{E}_{m,123}$ were calculated for the present mixtures. The resulting values of $H^{E}_{m,1+23}$ for the ternary mixtures and $H^{E}_{m,ij}$ for the constituent binaries were used to plot the dashed curves in Figures 1 and 2. It can be seen from these that the fits of the data for the constituent binaries are relatively good. In the case of the mixtures with nC8, the Liebermann−Fried model predicts the ternary enthalpies quite well. In the case of the mixtures with nC10, the model tends to overestimate the ternary enthalpies. The mean absolute relative deviations between the 57 experimental and estimated values of $H^{E}_{m,1+23}$ in Tables 3 and 4 amount to 0.8% and 3.6%, respectively.

Constant $H^{E}_{m,123}$ contours were also estimated on the basis of the Liebermann−Fried model and are shown in parts b of Figures 3 and 4. Although differing in detail, the overall characteristics of these are similar to those in parts a, which were derived from the representations of the experimental data for the ternary mixtures. It is evident from these comparisons that the Liebermann−Fried model provides useful predictions of the ternary enthalpy behavior without requiring the direct investigation of the excess enthalpies of any ternary mixtures.

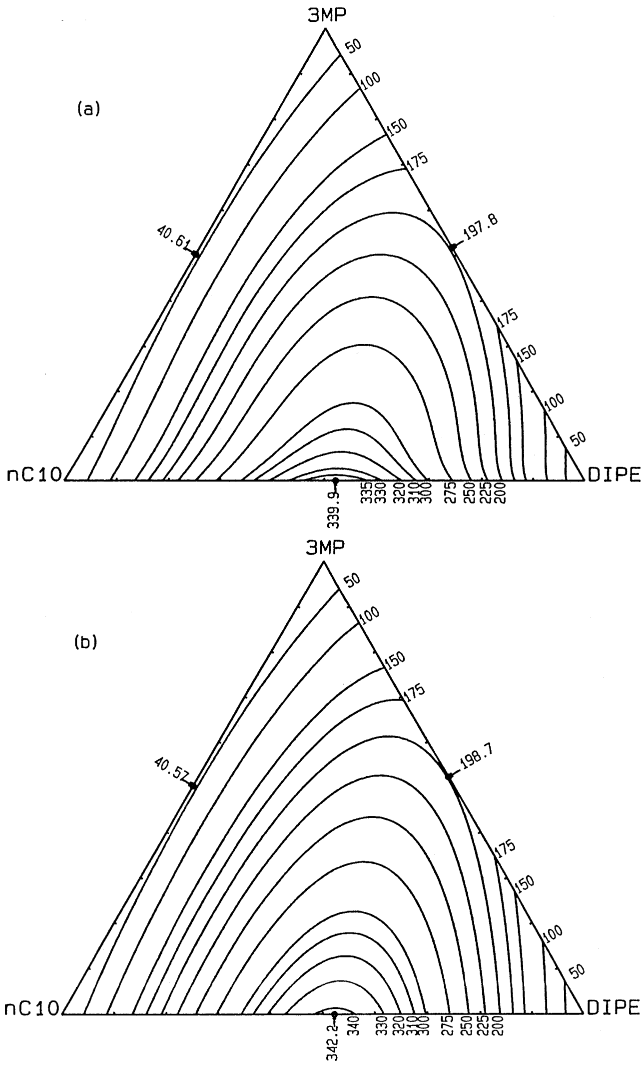

**Figure 4.** Contours for constant values of $H^{E}_{m,123}$/J·mol$^{-1}$ for DIPE (1) + 3MP (2) + nC10 (3) at 298.15 K: a, calculated from the representation of the experimental results by eqs 1−4 with $H^{E}_{m,T}$ from the footnote of Table 4; b, estimated by means of the Liebermann−Fried model.

**Table 5. Values of the Interaction Parameters, $A_{ij}$ and $A_{ji}$, Standard Deviations, *s*, and Isobaric Thermal Expansivities, $\alpha_p$, at 298.15 K for Liebermann−Fried Model Calculations**

| component | | | | *s* | $\alpha_p$ (kK$^{-1}$) | |
|---|---|---|---|---|---|---|
| *i* | *j* | $A_{ij}$ | $A_{ji}$ | J·mol$^{-1}$ | *i* | *j* |
| DIPE | 3MP | 0.8486 | 1.0156 | 1.27 | 1.455[a] | 1.396[b] |
| DIPE | nC8 | 0.9429 | 0.8618 | 1.60 | 1.455[a] | 1.164[c] |
| 3MP | nC8 | 1.0588 | 0.9251 | 0.05 | 1.396[b] | 1.164[c] |
| DIPE | nC10 | 0.9689 | 0.7941 | 2.07 | 1.455[a] | 1.051[c] |
| 3MP | nC10 | 1.0597 | 0.8958 | 0.07 | 1.396[b] | 1.051[c] |

[a] Obama et al.[2] [b] Riddick et al.[15] See page 96. [c] Benson et al.[16]

## Literature Cited

(1) Wang, Z.; Benson, G. C.; Lu, B. C.-Y. Excess Enthalpies of the Ternary Mixtures: {Tetrahydrofuran + 3-Methylpentane + (Octane or Decane)} at 298.15 K. *J. Chem. Thermodyn.*, in press.

(2) Obama, M.; Oodera, Y.; Kohama, N.; Yanase, T.; Saito, Y.; Kusano, K. Densities, Molar Volumes, and Cubic Expansion Coefficients of 78 Aliphatic Ethers. *J. Chem. Eng. Data* **1985**, *30*, 1−5.

(3) *TRC Thermodynamic Tables − Hydrocarbons*; Thermodynamic Research Center, The Texas A&M University System: College Station, TX, 1996; 1952 loose-leaf data sheet 23-2-(1.201)-a; 1995 loose-leaf data sheet 23-2-(1.10100)-a, page 1.

(4) Tanaka, R.; D'Arcy, P. J.; Benson, G. C. Application of a Flow Microcalorimeter to Determine the Excess Enthalpies of Binary Mixtures of Nonelectrolytes. *Thermochim. Acta* **1975**, *11*, 163−175.

(5) Kimura, F.; Benson, G. C.; Halpin, C. J. Excess Enthalpies of Binary Mixtures of *n*-Heptane with Hexane Isomers. *Fluid Phase Equilib.* **1983**, *11*, 245−250.

(6) Zhu, S.; Shen, S.; Benson, G. C.; Lu, B. C.-Y. Excess Enthalpies of (2,4-Dimethyl-3-Oxapentane + one or more *n*-Alkanes) at the Temperature 298.15 K. Part I: Binary Mixtures. *J. Chem. Thermodyn.* **1994**, *26*, 415−420.

(7) Hamam, S. E. M.; Kumaran, M. K.; Benson, G. C. Excess Enthalpies of Binary Mixtures of *n*-Octane with Each of the Hexane Isomers at 298.15 K. *Fluid Phase Equilib.* **1984**, *18*, 147−153.

(8) Hamam, S. E. M.; Benson, G. C. Excess Enthalpies of Binary Mixtures of *n*-Decane with Hexane Isomers. *J. Chem. Eng. Data* **1986**, *31*, 45−47.

(9) Tsao, C. C.; Smith, J. M. Heats of Mixing of Liquids. *Chem. Eng. Prog., Symp. Ser. No. 7* **1953**, *49*, 107−117.

(10) Morris, J. W.; Mulvey, P. J.; Abbott, M. M.; Van Ness, H. C. Excess Thermodynamic Functions for Ternary Systems I. Acetone-Chloroform-Methanol at 50 °C. *J. Chem. Eng. Data* **1975**, *20*, 403−405.

(11) Peng, D.-Y.; Wang, Z.; Benson, G. C.; Lu, B. C.-Y. Excess Enthalpies and (Vapor + Liquid) Equilibrium for (Oxygenated Additive + *n*-Alkane). *J. Chem. Thermodyn.* **2001**, *33*, 83−93.

(12) Wang, Z.; Peng, D.-Y.; Benson, G. C.; Lu, B. C.-Y. Excess Enthalpies of {Ethyl *tert*-Butyl Ether + Hexane + Heptane, or Octane} at the Temperature 298.15 K. *J. Chem. Thermodyn.* **2001**, *33*, 1181−1191.

(13) Liebermann, E.; Fried, V. Estimation of the Excess Gibbs Free Energy and Enthalpy of Mixing of Binary Nonassociated Mixtures. *Ind. Eng. Chem. Fundam.* **1972**, *11*, 350−354.

(14) Liebermann, E.; Fried, V. The Temperature Dependence of the Gibbs Free Energy of Binary Nonassociated Mixtures. *Ind. Eng. Chem. Fundam.* **1972**, *11*, 354−355.

(15) Riddick, J. A.; Bunger, W. B.; Sakano, T. K. *Techniques of Chemistry, Volume II, Organic Solvents*, 4th ed.; Wiley: New York, 1986; see p 96.

(16) Benson, G. C.; Luo, B.; Lu, B. C.-Y. Excess Enthalpies of Dibutyl Ether + *n*-Alkane Mixtures at 298.15 K. *Can. J. Chem.* **1988**, *66*, 531−534.

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