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Excess Enthalpies of Ternary Mixtures Consisting of a Normal Alkane, Methyl *tert*-Butyl Ether, and *tert*-Amyl Methyl Ether

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Excess molar enthalpies, measured at 298.15 K in a flow microcalorimeter, are reported for the two ternary systems heptane + methyl *tert*-butyl ether + *tert*-amyl methyl ether and decane + methyl *tert*-butyl ether + *tert*-amyl methyl ether. Smooth representations of the results and analyses in terms of the Flory theory are presented.

Introduction

The thermodynamic properties of hydrocarbon + ether mixtures are of interest in view of the use of ethers as oxygenating agents in gasoline technology. Previous papers from our laboratory have reported excess enthalpies of mixtures of alkanes with methyl *tert*-butyl ether (MTBE) (Wang *et al*., 1992, 1993; Zhu *et al*., 1994c) and with *tert*-amyl methyl ether (TAME) (Zhu *et al*., 1994a,b; Knežević-Stevanović *et al*., 1995a,b,c). As an extension of those earlier investigations we have now measured excess enthalpies at 298.15 K for two ternary systems formed by mixing either heptane (nC7) or decane (nC10) with binary mixtures of MTBE and TAME.

Experimental Section

The nC7 used in the present work was Pure Grade material from Phillips Chemical Co.; nC10 was obtained from Sigma Chemical Co. MTBE was HPLC Grade from Aldrich Chemical Co. The purities stated by the manufacturers of these materials were at least 99 mol %. TAME (Fluka, purum) had a stated purity exceeding 97 mol %. All of the components were used without further purification. Densities, measured at 298.15 K in an Anton-Paar digital densimeter, were 679.70, 726.28, 735.84, and 766.26 kg·m^{-3} for nC7, nC10, MTBE, and TAME, respectively. These are comparable with the literature values 679.46, 726.35, 735.3, and 765.6 kg·m^{-3} (TRC, 1988a,b).

Excess molar enthalpies H_m^E were determined in an LKB flow microcalorimeter (Model 10700-1) at 298.15 K, maintained within ±0.002 K. Details of the equipment and its operation have been described previously (Tanaka *et al*., 1975; Kimura *et al*., 1983).

In studying the ternary systems, the excess molar enthalpy $H_{m,1+23}^E$ was determined for several pseudobinary systems in which component 1 (nC7 or nC10) was added to binary mixtures of components 2 (MTBE) and 3 (TAME), having fixed compositions. These binaries were prepared by mass. The excess molar enthalpies $H_{m,123}^E$ of the ternary mixtures were then obtained from the relation

$$H_{m,123}^E = H_{m,1+23}^E + (1 - x_1)H_{m,23}^E \tag{1}$$

where x_1 is the alkane mole fraction and $H_{m,23}^E$ is the excess molar enthalpy of the particular binary mixture of MTBE and TAME. The errors of $H_{m,1+23}^E$ are estimated to be less than 0.5% over most of the alkane mole fraction

Table 1. Experimental Mole Fractions, x_i, and Excess Molar Enthalpies, $H_{m,ij}^E$ ($i < j$), at 298.15 K for nC7 (1) + MTBE (2), nC7 (1) + TAME (3), and MTBE (2) + TAME (3)

x_i	$H_{m,ij}^E$/J·mol^{-1}	x_i	$H_{m,ij}^E$/J·mol^{-1}	x_i	$H_{m,ij}^E$/J·mol^{-1}	x_i	$H_{m,ij}^E$/J·mol^{-1}
			nC7 (1) + MTBE (2)				
0.0500	79.4	0.2995	355.3	0.5501	410.8	0.7999	263.8
0.1000	154.5	0.3497	384.0	0.5999	396.4	0.8500	210.0
0.1499	219.5	0.3996	401.8	0.6499	375.9	0.8997	149.8
0.1998	273.6	0.4496	411.5	0.6999	345.1	0.9499	81.2
0.2498	319.0	0.5000	416.5	0.7498	308.4		
			nC7 (1) + TAME (3)				
0.0500	53.8	0.2998	247.2	0.4997	293.6	0.7499	222.0
0.1000	104.9	0.3497	267.8	0.5498	290.7	0.7999	190.8
0.1498	149.3	0.4000	282.7	0.5998	282.4	0.8499	152.2
0.1998	187.7	0.4500	291.2	0.6499	267.8	0.8999	107.4
0.2500	220.8	0.4996	293.8	0.6999	247.4	0.9499	56.7
			MTBE (2) + TAME (3)				
0.0500	0.231	0.2998	0.860	0.5000	1.003	0.7500	0.771
0.0500	0.239	0.3001	0.807	0.5000	0.992	0.7500	0.797
0.1000	0.390	0.3500	0.897	0.5500	1.000	0.8000	0.687
0.1000	0.450	0.3501	0.913	0.5500	1.014	0.8501	0.517
0.1500	0.546	0.3998	0.956	0.6000	0.965	0.8501	0.496
0.1500	0.582	0.4001	0.931	0.6501	0.928	0.9000	0.353
0.1999	0.676	0.4492	0.988	0.6502	0.963	0.9000	0.359
0.2000	0.682	0.4498	0.976	0.6998	0.883	0.9500	0.195
0.2500	0.745	0.4998	1.003	0.7001	0.862	0.9500	0.209
0.2500	0.759	0.4999	1.007				

Table 2. Coefficients, h_k, and Standard Deviations, s, for the Representation of $H^E_{m,ij}$ at 298.15 K for the Constituent Binary Mixtures (Eq 2)

component							
i	j	h_1	h_2	h_3	h_4	h_5	s
nC7	MTBE	1662.94	70.87	42.38	−58.64		1.06
nC7	TAME	1176.17	4.48	10.07	−41.00		0.53
MTBE	TAME	3.999	−0.433	0.513	1.308		0.016
nC10	MTBE[a]	2000.50	313.32	110.94	100.36	−87.36	1.17
nC10	TAME[b]	1525.57	166.24	147.24	6.11	−90.84	1.01

[a] Wang *et al.* (1993). [b] Zhu *et al.* (1994b).

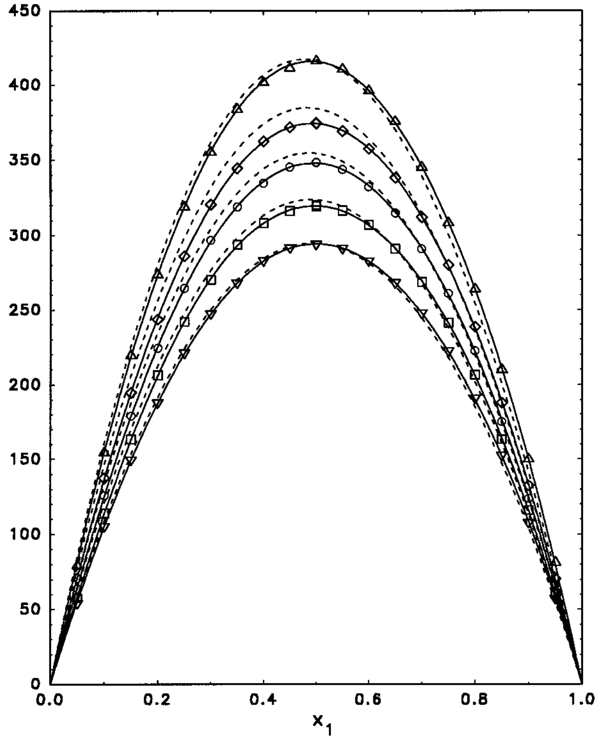

Figure 1. Excess molar enthalpies, $H^E_{m,1+23}$, for nC7 (1) + MTBE TAME (3) mixtures at 298.15 K. Experimental results: (▽) 0, nC7 + TAME; (□) $x_2/x_3 = 0.3334$; (○) $x_2/x_3 = 1.0200$; (◇) = 2.9532; (△) $x_1 + x_2 = 1$, nC7 + MTBE. Curves: (—) calculated from eq 3 with $H^E_{m,T}$ from the footnote of Table 3; (---) calculated from the Flory theory.

range. Errors in the mole fractions of the final ternary mixtures are estimated to be less than 5 × 10^{-4}.

Results and Discussion

Table 1 summarizes the experimental values of x_i and $_{ij}$ for the three binary systems nC7 + MTBE, nC7 + TAME, and MTBE + TAME. The smoothing function

$$H^E_{m,ij}/\mathrm{J{\cdot}mol^{-1}} = x_i(1 - x_i)\sum_{k=1}^{m} h_k(1 - 2x_i)^{k-1} \qquad (2)$$

was fitted to each set of results in Table 1 by the method of least squares with all points assigned equal weight. The values of the coefficients h_k obtained from the analyses are listed in Table 2, along with the standard deviation s for each representation. Our previous papers have reported the excess molar enthalpies of the other constituent binaries nC10 + MTBE (Wang *et al.*, 1993) and nC10 + TAME (Zhu *et al.*, 1994b). The coefficients for the representations of those results are also included in Table 2.

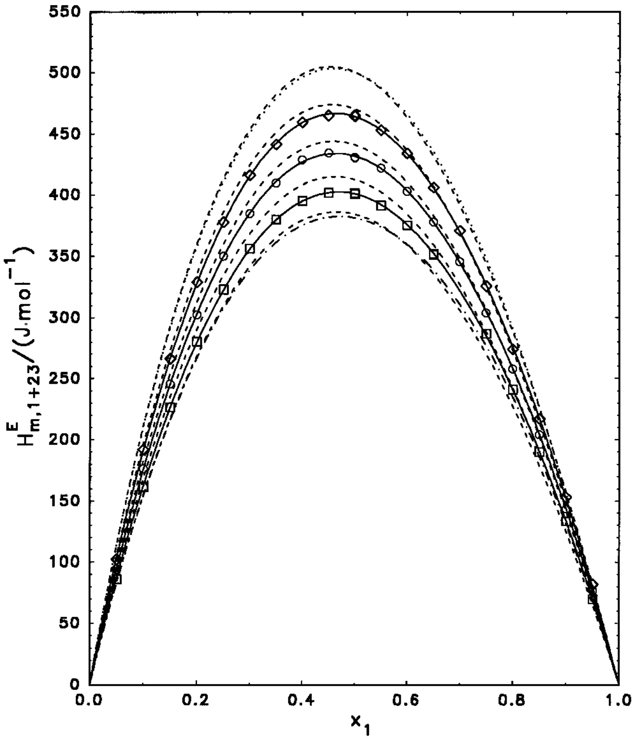

Figure 2. Excess molar enthalpies, $H^E_{m,1+23}$, for nC10 (1) + MTBE (2) + TAME (3) mixtures at 298.15 K. Experimental results: (•—•—) $x_2 = 0$, nC10 + TAME (Zhu *et al.*, 1994b); (□) $x_2/x_3 = 0.3336$; (○) $x_2/x_3 = 0.9991$; (◇) $x_2/x_3 = 2.9705$; (•••) $x_1 + x_2 = 1$, nC10 + MTBE (Wang *et al.*, 1993). Curves: (—) calculated from eq 3 with $H^E_{m,T}$ from the footnote of Table 4; (---) calculated from the Flory theory.

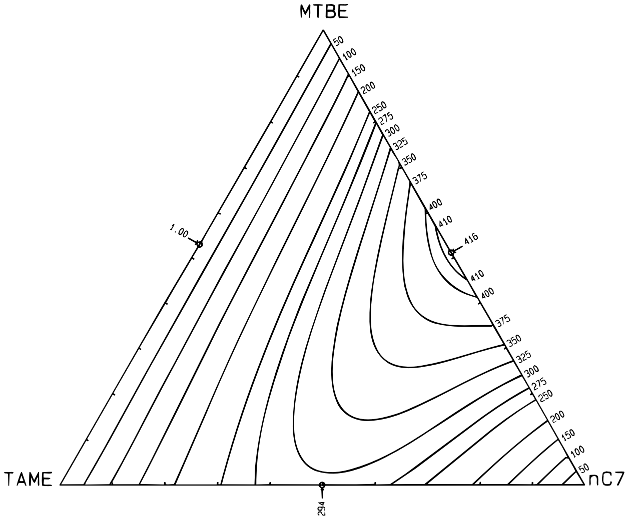

Figure 3. Contours for constant values of $H^E_{m,123}/\mathrm{J{\cdot}mol^{-1}}$ for nC7 (1) + MTBE (2) + TAME (3) at 298.15 K obtained from the representation of the experimental results by eqs 1−4 with $H^E_{m,T}$ from the footnote of Table 3.

For all of the systems in Table 1, the excess molar enthalpies are positive throughout the mole fraction range and nearly symmetrical about $x_i = 0.5$. The thermal effect of mixing the two ethers is quite small, reflecting their molecular similarity. Tusel-Langer *et al.* (1991) have reported values of $H^E_{m,12}$ for nC7 + MTBE. In general, their results are lower than ours; for an equimolar mixture the difference is approximately 30 J·mol^{-1}. We are unaware of other directly comparable results for these systems.

Experimental results for $H^E_{m,1+23}$ and the corresponding values of $H^E_{m,123}$ are listed in Tables 3 and 4 for the two ternary systems. The values of $H^E_{m,1+23}$ are plotted in Figures 1 and 2. The results for the pure binary systems

Table 3. Experimental Excess Molar Enthalpies $H^{E}_{m,1+23}$ at 298.15 K for the Addition of nC7 to MTBE + TAME To Form nC7 (1) + MTBE (2) + TAME (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}
$x_2/x_3 = 0.3334$, $H^{E}_{m,23}$/J·mol^{-1} = 0.76								
0.0500	57.3	58.0	0.4001	308.2	308.6	0.7001	268.3	268.5
0.1000	113.8	114.5	0.4498	316.2	316.6	0.7500	241.0	241.2
0.1499	163.1	163.8	0.4997	320.2	320.6	0.8000	206.5	206.6
0.2000	206.2	206.8	0.5004	319.2	319.6	0.8500	163.0	163.2
0.2500	241.9	242.5	0.5501	316.4	316.8	0.9000	115.6	115.7
0.2998	270.1	270.6	0.5997	306.9	307.2	0.9500	60.3	60.4
0.3501	293.4	293.9	0.6498	290.7	291.0			
$x_2/x_3 = 1.0200$, $H^{E}_{m,23}$/J·mol^{-1} = 1.00								
0.0501	64.1	65.0	0.3999	334.6	335.2	0.6999	290.7	291.0
0.1000	125.7	126.6	0.4498	345.1	345.7	0.7502	260.9	261.2
0.1501	179.0	179.9	0.4998	348.4	348.9	0.8000	222.4	222.6
0.2000	224.4	225.2	0.5000	348.3	348.8	0.8501	175.0	175.2
0.2497	264.5	265.3	0.5501	343.5	344.0	0.9000	123.7	123.8
0.3000	296.6	297.3	0.6001	332.1	332.5	0.9500	66.4	66.4
0.3504	319.0	319.6	0.6500	314.8	315.2			
$x_2/x_3 = 2.9532$, $H^{E}_{m,23}$/J·mol^{-1} = 0.79								
0.0500	70.8	71.6	0.3998	362.4	362.9	0.7000	311.9	312.1
0.1000	137.3	138.0	0.4499	371.8	372.2	0.7501	279.8	280.0
0.1499	194.7	195.4	0.5000	374.8	375.2	0.8001	238.2	238.4
0.1999	243.6	244.2	0.5000	374.4	374.8	0.8501	187.7	187.8
0.2498	285.8	286.4	0.5501	369.3	369.6	0.9000	132.3	132.3
0.2998	320.4	320.9	0.6000	357.3	357.6	0.9500	70.5	70.6
0.3499	344.2	344.7	0.6501	337.9	338.2			

Ternary term for representation of $H^{E}_{m,1+23}$ by eqs 2−4: $H^{E}_{m,T}$/J·mol^{-1} = $x_1x_2x_3(-844.06 + 3247.75x_1 + 2027.54x_2 - 3551.29x_1^2 - 4370.63x_1x_2 - 1875.78x_2^2)$, $s = 1.72$.

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

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}
$x_2/x_3 = 0.3336$, $H^{E}_{m,23}$/J·mol^{-1} = 0.76								
0.0500	85.9	86.6	0.4000	395.0	395.5	0.6502	351.7	352.0
0.1000	161.5	162.2	0.4500	401.7	402.1	0.7500	286.6	286.8
0.1499	226.5	227.1	0.4996	401.6	402.0	0.8001	241.0	241.2
0.1998	280.1	280.7	0.5000	400.8	401.2	0.8501	189.9	190.0
0.2500	323.0	323.6	0.5499	391.4	391.7	0.9000	133.0	133.1
0.3000	356.3	356.8	0.5998	375.3	375.6	0.9500	69.8	69.8
0.3497	380.0	380.4	0.6500	351.3	351.6			
$x_2/x_3 = 0.9991$, $H^{E}_{m,23}$/J·mol^{-1} = 1.00								
0.0500	94.3	95.2	0.3999	428.8	429.4	0.6999	345.7	346.0
0.1000	176.5	177.4	0.4500	434.6	435.1	0.7498	304.1	304.3
0.1499	245.6	246.5	0.4999	430.3	430.8	0.7999	257.6	257.8
0.2001	302.6	303.4	0.4999	430.8	431.3	0.8500	204.0	204.2
0.2500	350.1	350.9	0.5500	422.0	422.5	0.9000	143.6	143.7
0.3002	385.1	385.8	0.5997	403.0	403.4	0.9500	76.9	76.9
0.3500	409.9	410.5	0.6500	378.0	378.4			
$x_2/x_3 = 2.9705$, $H^{E}_{m,23}$/J·mol^{-1} = 0.79								
0.0500	102.1	102.9	0.4001	459.5	460.0	0.7001	370.7	370.9
0.1000	191.9	192.6	0.4499	465.1	465.5	0.7499	325.6	325.8
0.1499	266.0	266.7	0.5000	464.4	464.8	0.8000	273.8	273.9
0.2002	329.0	329.6	0.5001	465.2	465.6	0.8500	216.9	217.1
0.2500	378.0	378.5	0.5500	453.0	453.3	0.9000	153.0	153.1
0.3001	416.0	416.6	0.5997	433.9	434.2	0.9500	81.8	81.8
0.3501	441.4	441.9	0.6500	405.9	406.2			

[a] Ternary term for representation of $H^{E}_{m,1+23}$ by eqs 2−4: $H^{E}_{m,T}$/J·mol^{-1} = $x_1x_2x_3(-821.97 + 862.51x_1 + 1873.54x_2 - 1112.12x_1^2 + 58.17x_1x_2 - 2039.95x_2^2)$, $s = 1.72$.

nC7 + MTBE and nC7 + TAME and their representations by eq 2 are also included in Figure 1. The representations of our earlier results for nC10 with MTBE and TAME are plotted in Figure 2. In all cases, the maximum values of $H^{E}_{m,1+23}$ and $H^{E}_{m,123}$ occur near $x_1 = 0.5$, and for comparable values of the ratio x_2/x_3, the maximum is larger for the mixture containing nC10. For both systems at constant x_1, the enthalpies increase as the proportion of MTBE increases.

The values of $H^{E}_{m,1+23}$ were represented as a sum of binary terms (Tsao and Smith, 1953) with an added ternary term

$$H^{E}_{m,1+23} = \left(\frac{x_2}{1 - x_1}\right)H^{E}_{m,12} + \left(\frac{x_3}{1 - x_1}\right)H^{E}_{m,13} + H^{E}_{m,T} \quad (3)$$

and following Morris *et al.* (1975) the form

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

was adopted for the latter. Least-squares analyses in

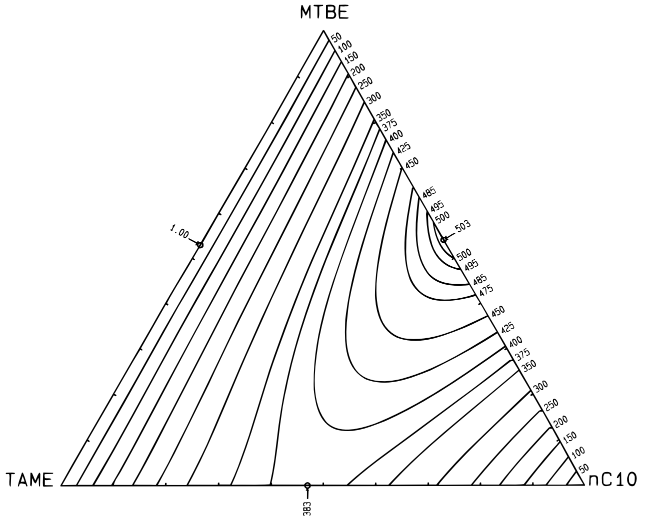

Figure 4. Contours for constant values of $H^{E}_{m,123}$/J·mol^{-1} for nC10 (1) + MTBE (2) + TAME (3) at 298.15 K obtained from the representation of the experimental results by eqs 1−4 with from the footnote of Table 4.

Table 5. Parameters Used in Flory Calculations at T = 298.15 K for [nC7 (1) + MTBE (2) + TAME (3)]^{a} and [nC10 + MTBE (2) + TAME (3)]^{b}

component	p^*/J·cm^{-3}	V^*_m/cm^3·mol^{-1}	T^*/K	ref
nC7	431.9	113.60	4648.1	Wang *et al.*, 1989
nC10	447.0	155.75	5091.4	Wang *et al.*, 1989
MTBE	442.9	90.20	4385.0	Wang *et al.*, 1993
TAME	456.1	103.32	4714.8	Zhu *et al.*, 1994b

Interchange energy parameters X_{ij}/J·cm^{-3}: $X_{12} = 15.062$, X_{13} 10.122, from fit of data in Table 1. $X_{23} = 0.2886$ from fit of data in Table 1. [b] Interchange energy parameters X_{ij}/J·cm^{-3}:X_{12} 15.651 (Wang *et al.*, 1993), $X_{13} = 11.076$ (Zhu *et al.*, 1994b). X_{23} 0.2886 from fit of data in Table 1.

which eqs 3 and 4 were fitted to the values of $H^{E}_{m,1+23}$ indicated that adequate representations of the present results were obtained with six adjustable coefficients c_i. These representations are given in the footnotes of Tables 3 and 4, along with their standard deviations s. Curves calculated from these representations are shown in Figures 1 and 2. Equations 1−4 were used to calculate the constant $_{m,123}$ contours plotted on the Roozeboom diagrams in Figures 3 and 4. The general characteristics of these are very similar. All of the contours extend to the edges of the triangle, and there is no indication of an extremum lying within the triangle.

Previously it has been shown (Wang *et al*., 1993; Zhu *et* ., 1994c; Knežević-Stevanović *et al*., 1995a,b) that the Flory theory (Flory, 1965; Abe and Flory, 1965) as extended to ternary mixtures by Brostow and Sochanski (1975) could provide reasonable estimates of the ternary excess molar enthalpies for mixtures containing alkanes and an ether, when only properties of the pure components and their binary mixtures were used. The same approach was investigated for the present systems. The equations for the treatment have been outlined by Wang *et al*. (1993). The parameters used in the calculations are summarized in Table 5. The characteristic pressures p^*, molar volumes V^*_m and temperatures T^* were taken from our previous publications, as indicated in the last column of the table. In evaluating s_i/s_j, the ratio of the molecular surface areas of contact per segment between components i and j, it was assumed that the molecules were spherical. The values of the interchange energy parameters X_{ij} for nC7 + MTBE, nC7 + TAME, and MTBE + TAME were obtained by fitting the Flory formula for $H^{E}_{m,ij}$ to the smooth representations of the results in Table 1. As indicated in the footnotes of Table 5, the values of X_{ij} for nC10 + MTBE and nC10 + TAME were taken from our previous work.

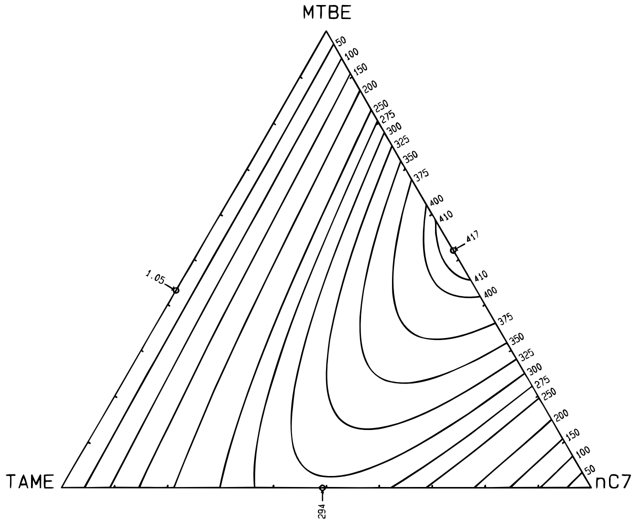

Figure 5. Contours for constant values of $H^{E}_{m,123}$/J·mol^{-1} for nC7 (1) + MTBE (2) + TAME (3) at 298.15 K estimated by the Flory theory.

The Flory estimates of $H^{E}_{m,1+23}$ are shown as dashed curves in Figures 1 and 2. In general, these estimates tend to be higher than the experimental results at low alkane mole fractions and to fall below the results at higher mole fractions. The mean absolute relative deviations for the 99 experimental points of the nC7 system and the 60 points of the nC10 system amount to 2.6% and 2.3%, respectively. Constant $H^{E}_{m,123}$ contours were also estimated on the basis of the Flory theory. The overall characteristics of these were quite similar to those derived from the smooth representations of the experimental data. The results of the calculations for the nC7 system are shown on the Roozeboom diagram in Figure 5. It is clear from a comparison of this with Figure 3, that the Flory theory provides useful estimates of $H^{E}_{m,123}$ without requiring the direct investigation of the excess enthalpies of any ternary mixtures.

Literature Cited

Abe, A.; Flory, P. J. The Thermodynamic Properties of Mixtures of Small, Nonpolar Molecules. *J. Am. Chem. Soc.* **1965**, *87*, 1838−1846.

Brostow, W.; Sochanski, J. S. Prediction of Thermodynamic Properties of Ternary Liquid Solutions Including Metal Alloys. *J. Mater. Sci.* **1975**, *10*, 2134−2145.

Flory, P. J. Statistical Thermodynamics of Liquid Mixtures. *J. Am. Chem. Soc.* **1965**, *87*, 1833−1838.

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.

Knežević-Stevanović, A.; Benson, G. C.; Lu, B. C.-Y. Excess Enthalpies of (Methyl 1,1-Dimethylpropyl Ether + 2,3-Dimethylbutane or Cyclohexane + Decane) at the Temperature 298.15 K. *J. Chem. Thermodyn.* **1995a**, *27*, 531−539.

Knežević-Stevanović, A.; Jin, Z.-L.; Benson, G. C.; Lu, B. C.-Y. Excess Enthalpies of (Methyl 1,1-Dimethylpropyl Ether + Hexane + Decane or Dodecane) at the Temperature 298.15 K. *J. Chem. Thermodyn.* **1995b**, *27*, 423−430.

Knežević-Stevanović, A.; Jin, Z.-L.; Benson, G. C.; Lu, B. C.-Y. Excess Enthalpies of Binary Mixtures of Methyl 1,1-Dimethylpropyl Ether with Hexane Isomers. *J. Chem. Eng. Data* **1995c**, *40*, 340−342.

Morris, J. W.; Mulvey, P. J.; Abbott, M. M.; Van Ness, H. C. Excess Thermodynamic Functions for Ternary Systems. 1. Acetone−Chloroform−Methanol at 50 °C. *J. Chem. Eng. Data* **1975**, *20*, 403−405.

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

TRC Thermodynamic Tables—Hydrocarbons; Thermodynamic Research Center, The Texas A&M University System: College Station, TX, 1988a: 1977, loose-leaf data sheet 23-2-[1.101]-a, p 1.

TRC Thermodynamic Tables—Non-Hydrocarbons; Thermodynamic Research Center, The Texas A&M University System: College Station, TX, 1988b: 1963, loose-leaf data sheets 23-2-1-[1.2120]-a and 23-2-1-[1.2121]-a.

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

Tusel-Langer, E.; Garcia Alonso, J. M.; Villamañan Olfos, M. A.; Lichtenthaler, R. N. Excess Enthalpies of Mixtures Containing n-Heptane, Methanol and Methyl tert-Butyl Ether (MTBE). *J. Solution Chem.* **1991**, *20*, 153−163.

Wang, L.; Benson, G. C.; Lu, B. C.-Y. Excess Enthalpies of Binary Mixtures of Di-n-Pentyl Ether with n-Alkanes at 298.15 K *Fluid Phase Equilib.* **1989**, *46*, 211−221.

Wang, L.; Benson, G. C.; Lu, B. C.-Y. Excess Enthalpies of {(Ethanol or Propan-1-ol or Methyl 1,1-Dimethylethyl Ether) + (2,3-Dimethylbutane or 2,2,4-Trimethylpentane)}. *J. Chem Thermodyn.* **1992**, *24*, 1305−1310.

Wang, L.; Benson, G. C.; Lu, B. C.-Y. Excess Molar Enthalpies of Methyl *tert*-Butyl Ether + *n*-Hexane + (*n*-Decane or *n*-Dodecane) Ternary Mixtures at 298.15 K. *Thermochim. Acta* **1993**, *213*, 83−93.

Zhu, S.; Shen, S.; Benson, G. C.; Lu, B. C.-Y. Excess Enthalpies of Methyl 1,1-Dimethylpropyl Ether + a C_6 Hydrocarbon at 298.15 K. *J. Chem. Eng. Data* **1994a**, *39*, 302−303.

Zhu, S.; Shen, S.; Benson, G. C.; Lu, B. C.-Y. Excess Enthalpies of (Methyl 1,1-Dimethylpropyl Ether + an *n*-Alkane) at the Temperature 298.15 K. *J. Chem. Thermodyn.* **1994b**, *26*, 35−39.

Zhu, S.; Shen, S.; Benson, G. C.; Lu, B. C.-Y. Excess Molar Enthalpies of Methyl *tert*-Butyl Ether + (Cyclohexane or 2,3-Dimethylbutane) + *n*-Decane Ternary Mixtures at 298.15 K. *Thermochim. Acta* **1994c**, *235*, 161−169.

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