JOURNAL OF CHEMICAL & ENGINEERING DATA

ARTICLE

pubs.acs.org/jced

Volumetric Properties of Binary Mixtures of 1,2-Dichloroethane with Polyethers from (283.15 to 333.15) K and at Atmospheric Pressure

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ABSTRACT: Densities of binary liquid mixtures of 1,2-dichloroethane (1,2-DCE) with ethylene glycol dimethyl ether (EGDME), diethylene glycol dimethyl ether (DEGDME), and diethylene glycol diethyl ether (DEGDEE) were measured at temperatures from (283.15 to 333.15) K and at atmospheric pressure, over the whole composition range, with an Anton Paar vibrating-tube densimeter. Excess molar volumes, V^E, were deduced from experimental densities and were fitted to the Redlich−Kister polynomial equation. The V^E values, for all these mixtures, are negative over the entire composition and temperature ranges. Values of V^E magnitude for mixtures of 1,2-DCE with EGDME or DEGDME are close and increase slightly as the temperature increases, whereas those for 1,2-DCE + DEGDEE decrease and are more important. Others volumetric properties such as thermal expansion coefficients, excess thermal expansion, partial molar volumes, apparent molar volumes, and partial molar excess volumes were also calculated. Composition and temperature dependences of V^E/x_1x_2 were explored. The capability of the Prigogine−Flory−Patterson theory (PFP) to model the V^E data, at T = 298.15 K, for the binary mixtures studied, was finally tested.

INTRODUCTION

Linear oxa-alkanes such as 2,5-dioxahexane (CH_3OCH_2-CH_2OCH_3), 2,5,8-trioxanonane ($CH_3O(CH_2CH_2O)_2CH_3$), and 3,6,9-trioxaundecane ($C_2H_5O(CH_2CH_2O)_2C_2H_5$), commonly known as ethylene glycol dimethyl ether (EGDME), diethylene glycol dimethyl ether (DEGDME), and diethylene glycol diethyl ether (DEGDEE), respectively, and chloroalkanes such as 1,2-dichloroethane (1,2-DCE), represent not only two classes of technically important compounds but also, from a theoretical point of view, two interesting families of molecules. Indeed, one of the major consequences of the substitution of ether groups for CH_2 groups in an alkane is that a large variety of homomorphic molecular species that differ by the number and relative positions of the same functional group can be obtained. So, mixtures with linear oxaalkanes make it possible to examine the influence of some interesting effects (i.e., the steric effect of alkyl groups, the proximity effect of two −O− groups and the effect of increasing number of oxyethylene groups) on their thermodynamic properties, as well as the capability of any theoretical model in predicting such properties. Moreover, the study of binary mixtures of linear oxaalkanes with an α,ω-chloroalkane is of interest, regarding to the specific interaction between the O and Cl atoms, where the donor ability of the oxygen atom corresponds to the σ acceptor ability of the chlorine atom.

In the present work, we are focused on the investigation on volumetric properties, for binary mixtures of 1,2-DCE with EGDME, DEGDME, or DEGDEE, with three major aims. The first is to provide some quantitative insight concerning the experimental volumetric behavior of these mixtures. The second is to study the effect of the addition of a $-OC_2H_4$-group in the middle of the ether molecule, the effect of increase of the alkyl chain end length of the polyether, on their volumetric properties, and the influence of the Cl- and O-groups on molecular interactions. The third is a test of capability of the Prigogine−Flory−Patterson (PFP) mechanical statistical theory[1−9] to predict the excess molar volume of these binary mixtures. We report, here, the densities of binary mixtures of 1,2-DCE with EGDME, DEGDME, and DEGDEE, including those of pure liquids, measured over a temperature range (283.15 to 333.15) K and at atmospheric pressure, in the whole composition range, with an Anton Paar vibrating-tube densimeter. The excess molar volumes, V^E, calculated from the experimental densities and fitted to the Redlich−Kister equation,[10] were also reported. Experimental density and V^E results were used to calculate other properties such as thermal expansion coefficients, α_i and α, for pure compounds and mixtures, respectively, excess thermal expansion, α^E, partial molar volumes, V_i, apparent molar volumes, $V_{\phi i}$, partial molar excess volumes, V_i^E, and their limiting values at infinite dilution, V_i^∞, $V_{\phi i}^\infty$, and $(V_i^E)^\infty$, respectively. Composition and temperature dependences of the quantity V^E/x_1x_2, for the binary systems studied, were also explored, and the results were examined in terms of molecular interactions. Results of the test of capability of the PFP theory[1−9] in predicting excess molar volume, V^E, at 298.15 K, for the binary mixtures studied, were finally reported.

A survey of the open literature reveals many reports[11−23] regarding the volumetric properties of binary mixtures containing EGDME, DEGDME, or DEGDEE, confirming the interest for these chemicals. To our best knowledge, no density and V^E

Special Issue: John M. Prausnitz Festschrift

Received: December 30, 2010
Accepted: March 3, 2011
Published: March 15, 2011

Table 1. Comparison of Experimental Densities ρ of Pure Components with Literature Values, at Different Temperatures Ranging from (288.15 to 333.15) K

		$\rho/(g\cdot cm^{-3})$	
component	T/K	exptl	lit.
EGDME	288.15	0.87223	0.8724[a] ; 0.87218[c] ; 0.87205[h]
	298.15	0.86132	0.8615[a] ; 0.86150[b] ; 0.86124[c] ; 0.86447[d] ; 0.86182[e]0.8626[f] ; 0.86114[h] ; 0.86370[l]
	308.15	0.85024	0.8502[a] ; 0.85068[b] ; 0.85019[c]; 0.85028[g] ; 0.85011[h]
	318.15	0.83904	0.8390[a] ; 0.83957[b] ; 0.83892[h]
	323.15	0.83336	0.8333[a]
	328.15	0.82763	0.8275[a] ; 0.82824[b] ; 0.82753[h]
	333.15	0.82186	0.8218[a] ; 0.87205[h]
DEGDME	288.15	0.94872	09484[a] ; 0.94864[c] ; 0.94872[h]
	298.15	0.93880	0.9385[a] ; 0.93873[c] ; 0.93910[d] ; 0.9389[f] ; 0.93883[h]; 0.93840[l]
	308.15	0.92883	0.9285[a] ; 0.92880[c] ; 0.92888[h]
	318.15	0.91879	0.9186[a] ; 0.91931[h]
	328.15	0.90867	0.9085[a] ; 0.90921[h]
	333.15	0.90359	0.9035[a]
DEGDEE	288.15	0.91153	0.9117[a]
	298.15	0.90188	0.9021[a] ; 0.90190[e] ; 0.9035[f] ; 0.90147[l]
	308.15	0.89221	0.8925[a] ; 0.89308[g]
	318.15	0.88251	0.8828[a]
	328.15	0.87281	0.8731[a]
1,2-DCE	288.15	1.26015	1.25969[b]
	298.15	1.24561	1.24551[b]; 1.2456[i]; 1.24670[k];1.24580[l]
	303.15	1.23829	1.23765[b] ; 1.2399[i] ; 1.23829[j] ; 1.24080[k] ; 1.23837[m]
	308.15	1.23095	1.23380[i]; 1.23049[k]
	313.15	1.22357	1.22290[b]; 1.2261[i]; 1.22560[k]
	318.15	1.21616	1.2201[i]
	323.15	1.20870	1.20809[b]

[a] Ref 11. [b] Ref 12. [c] Ref 13. [d] Ref 14. [e] Ref 15. [f] Ref 16. [g] Ref 17. [h] Ref 18. [i] Ref 19. [j] Ref 20. [k] Ref 21. [l] Ref 22. [m] Ref 23.

data have been reported yet, for the binary mixtures investigated, except for the 1,2-DCE + EGDME binary system.[12]

EXPERIMENTAL SECTION

Materials. Synthesis grade 1,2-DCE (> 0.998 mole fraction), EGDME (> 0.99 mole fraction), DEGDME (0.99 mole fraction), DEGDEE (> 0.98 mole fraction) were purchased from Acros Organics and were used without further purification. Densities of these compounds were measured and well-compared with the literature values[11−23] at different temperatures in a range from (283.15 to 333.15) K in Table 1.

Density Measurements. The densities of pure compounds and mixtures were measured at temperatures ranging from (283.15 to 333.15) K and at atmospheric pressure, with a DMA5000 vibrating-tube densimeter (Anton Paar, Austria). The experimental equipment and procedure are the same as in previous studies;[24,25] therefore, only a few essentials are given here. The densimeter, certified precise to within $1\cdot10^{-5}$ g·cm^{-3}, whose temperature is controlled to within ± 0.01 K by a built-in Peltier device, was calibrated at 293.15 K and at atmospheric pressure by using dry air and degassed bidistilled ultra pure water. After calibration, the accuracy in the determination of the density, ρ, is estimated to be less than $\pm\ 1\cdot10^{-5}$ g·cm^{-3}. Mixtures were prepared by weighing, with the uncertainty in mole fraction estimated as less than $3\cdot10^{-4}$. All weighing performed in the experimental work was carried out using a Metler balance, with a precision of $\pm\ 1\cdot10^{-4}$ g. The uncertainty of the excess molar volumes is estimated to be less than $\pm\ 2\cdot10^{-3}$ cm^3·mol^{-1}.

RESULTS AND DISCUSSION

Volumetric Properties. As it can be shown in Table 1, our experimental pure compound density results, at various temperatures, compare well to the corresponding literature data.[11−23] The overall experimental density results, for the pure compounds, are summarized in Table 2.

Experimental densities, ρ, for the binary mixtures studied, at temperatures ranging from (283.15 to 333.15) K, are reported in Tables 3 to 5 and were used to calculate the excess molar volumes, V^E, according to:

$$V^E = \left[\frac{x_1M_1 + x_2M_2}{\rho}\right] - \frac{x_1M_1}{\rho_1} - \frac{x_2M_2}{\rho_2} \qquad (1)$$

where x_1 and x_2, M_1 and M_2, and ρ_1 and ρ_2 represent the mole fractions, molar masses, and densities of 1,2-DCE (1) and polyether (2), respectively. ρ stands for the mixture density.

The experimental V^E values were fitted by unweighted least-squares polynomial regression to the Redlich−Kister equation[10]

$$V^E = x_1x_2\sum_{i=0}^{i=n} A_i(x_1 - x_2)^i \qquad (2)$$

Table 2. Experimental Densities, ρ_i, of Pure Components as a Function of Temperature

T/K	ρ/(g·cm^{-3})				T/K	ρ/(g·cm^{-3})			
	12,DCE	EGDME	DEGDME	DEGDEE		12,DCE	EGDME	DEGDME	DEGDEE
283.15	1.26739	0.87764	0.95366	0.91636	309.15	1.22947	0.84913	0.92782	0.89125
284.15	1.26595	0.87656	0.95267	0.91539	310.15	1.22800	0.84802	0.92683	0.89028
285.15	1.26450	0.87548	0.95169	0.91443	311.15	1.22653	0.84690	0.92582	0.88931
286.15	1.26305	0.87440	0.95070	0.91346	312.15	1.22505	0.84579	0.92482	0.88834
287.15	1.26160	0.87331	0.94971	0.91250	313.15	1.22357	0.84467	0.92382	0.88737
288.15	1.26015	0.87223	0.94872	0.91153	314.15	1.22209	0.84355	0.92281	0.88640
289.15	1.25870	0.87114	0.94773	0.91057	315.15	1.22061	0.84242	0.92181	0.88543
290.15	1.25725	0.87005	0.94674	0.90960	316.15	1.21913	0.84129	0.92080	0.88446
291.15	1.25580	0.86896	0.94575	0.90863	317.15	1.21764	0.84017	0.91980	0.88348
292.15	1.25435	0.86787	0.94476	0.90767	318.15	1.21616	0.83904	0.91879	0.88251
293.15	1.25289	0.86679	0.94376	0.90671	319.15	1.21467	0.83791	0.91778	0.88154
294.15	1.25144	0.86570	0.94279	0.90575	320.15	1.21318	0.83677	0.91678	0.88057
295.15	1.24998	0.86461	0.94179	0.90478	321.15	1.21169	0.83564	0.91577	0.87960
296.15	1.24852	0.86351	0.94079	0.90381	322.15	1.21020	0.83450	0.91475	0.87863
297.15	1.24707	0.86242	0.93980	0.90285	323.15	1.20870	0.83336	0.91375	0.87766
298.15	1.24561	0.86132	0.93880	0.90188	324.15	1.20721	0.83222	0.91273	0.87670
299.15	1.24415	0.86022	0.93780	0.90092	325.15	1.20571	0.83108	0.91172	0.87573
300.15	1.24269	0.85912	0.93681	0.89995	326.15	1.20421	0.82993	0.91070	0.87475
301.15	1.24122	0.85801	0.93581	0.89898	327.15	1.20271	0.82878	0.90969	0.87378
302.15	1.23976	0.85691	0.93482	0.89802	328.15	1.20121	0.82763	0.90867	0.87281
303.15	1.23829	0.85580	0.93382	0.89705	329.15	1.19970	0.82648	0.90765	0.87184
304.15	1.23683	0.85469	0.93282	0.89608	330.15	1.19819	0.82533	0.90663	0.87087
305.15	1.23536	0.85358	0.93182	0.89512	331.15	1.19669	0.82417	0.90562	0.86989
306.15	1.23389	0.85246	0.93082	0.89415	332.15	1.19518	0.82302	0.90460	0.86892
307.15	1.23242	0.85135	0.92983	0.89318	333.15	1.19366	0.82186	0.90359	0.86794
308.15	1.23095	0.85024	0.92883	0.89221					

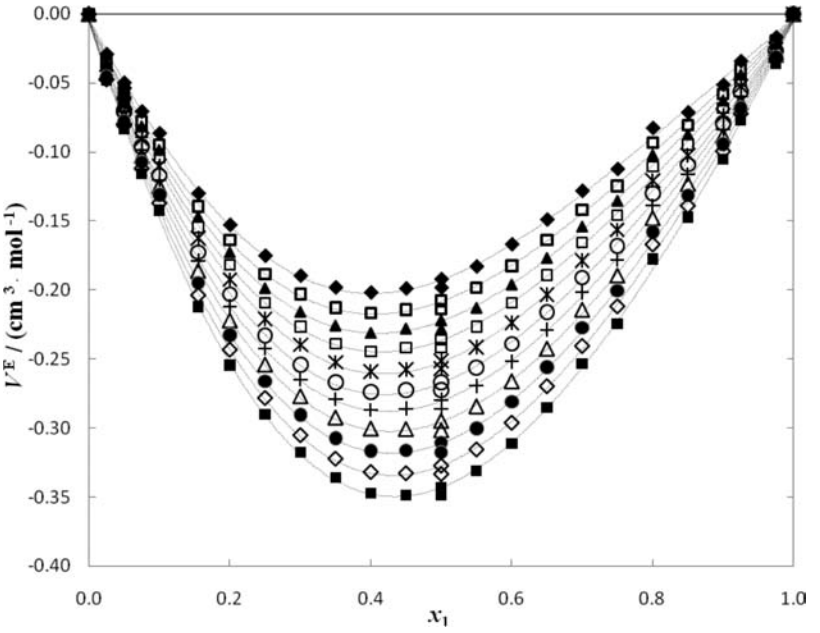

Figure 1. Plot of excess molar volume, V^E, for the system 1,2-DCE (1) + EGDME (2), against the mole fraction, x_1, at different temperatures. Symbols: experimental values (◆, 283.15 K; □, 288.15 K; ▲, 293.15 K; □, 298.15 K; ∗, 303.15 K; ○, 308.15 K; +, 313.15 K; △, 318.15 K; ●, 323.15 K; ◇, 328.15 K; ■, 333.15 K). Dashed lines: Redlich−Kister correlation.

dx.doi.org/10.1021/je101361u |J. Chem. Eng. Data 2011, 56, 1629–1657

Table 3. Experimental Densities, ρ, Excess Molar Volumes, V^E, Partial Molar Volumes, V_i, Partial Molar Excess Volumes, V_i^E, and Apparent Molar Volumes, $V_{\phi i}$, for the 1,2-DCE + EGDME Binary System

x_1	ρ / g·cm^{-3}	V^E / cm^3·mol^{-1}	V_1 / cm^3·mol^{-1}	V_1^E / cm^3·mol^{-1}	V_2 / cm^3·mol^{-1}	V_2^E / cm^3·mol^{-1}	V_{ϕ_1} / cm^3·mol^{-1}	V_{ϕ_2} / cm^3·mol^{-1}
				T/K = 283.15				
0.0251	0.88537	−0.029	77.609	−0.473	102.684	0.000	76.932	102.655
0.0500	0.89306	−0.050	77.619	−0.462	102.684	−0.001	77.090	102.632
0.0501	0.89314	−0.053	77.619	−0.462	102.684	−0.001	77.016	102.628
0.0750	0.90090	−0.070	77.627	−0.454	102.683	−0.001	77.143	102.608
0.1000	0.90878	−0.086	77.634	−0.448	102.683	−0.002	77.219	102.589
0.1552	0.92663	−0.130	77.644	−0.438	102.681	−0.003	77.245	102.531
0.2001	0.94140	−0.153	77.651	−0.430	102.680	−0.005	77.318	102.493
0.2501	0.95823	−0.175	77.662	−0.420	102.676	−0.008	77.382	102.451
0.3002	0.97546	−0.190	77.678	−0.404	102.671	−0.014	77.450	102.413
0.3500	0.99296	−0.198	77.699	−0.383	102.660	−0.024	77.516	102.380
0.4001	1.01098	−0.202	77.726	−0.356	102.644	−0.041	77.577	102.348
0.4500	1.02937	−0.199	77.759	−0.323	102.620	−0.065	77.640	102.323
0.5000	1.04822	−0.192	77.796	−0.286	102.586	−0.099	77.697	102.300
0.5001	1.04832	−0.198	77.796	−0.286	102.586	−0.099	77.685	102.288
0.5500	1.06759	−0.183	77.837	−0.245	102.541	−0.144	77.749	102.278
0.6001	1.08741	−0.167	77.879	−0.203	102.483	−0.201	77.804	102.267
0.6500	1.10773	−0.149	77.921	−0.161	102.413	−0.272	77.853	102.259
0.7000	1.12860	−0.128	77.961	−0.121	102.330	−0.355	77.899	102.258
0.7500	1.15014	−0.112	77.997	−0.084	102.234	−0.450	77.932	102.236
0.8000	1.17213	−0.082	78.028	−0.054	102.128	−0.557	77.979	102.272
0.8500	1.19503	−0.071	78.052	−0.029	102.014	−0.671	77.998	102.210
0.9000	1.21848	−0.051	78.069	−0.012	101.895	−0.789	78.025	102.174
0.9250	1.23036	−0.034	78.075	−0.007	101.836	−0.848	78.045	102.233
0.9750	1.25494	−0.017	78.081	−0.001	101.721	−0.963	78.065	102.023
				T/K = 288.15				
0.0251	0.87996	−0.034	77.983	−0.547	103.321	0.000	77.188	103.287
0.0500	0.88761	−0.054	77.999	−0.531	103.321	−0.001	77.442	103.264
0.0501	0.88769	−0.058	77.999	−0.531	103.321	−0.001	77.366	103.260
0.0750	0.89543	−0.078	78.012	−0.518	103.320	−0.002	77.496	103.237
0.1000	0.90328	−0.095	78.024	−0.507	103.319	−0.003	77.584	103.216
0.1552	0.92105	−0.139	78.044	−0.486	103.316	−0.006	77.632	103.156
0.2001	0.93576	−0.164	78.060	−0.471	103.312	−0.009	77.712	103.117
0.2501	0.95253	−0.188	78.078	−0.452	103.307	−0.014	77.777	103.070
0.3002	0.96968	−0.203	78.100	−0.431	103.299	−0.023	77.854	103.031
0.3500	0.98711	−0.213	78.125	−0.405	103.286	−0.035	77.922	102.994
0.4001	1.00505	−0.217	78.156	−0.374	103.268	−0.054	77.988	102.960
0.4500	1.02336	−0.214	78.191	−0.339	103.241	−0.080	78.054	102.932
0.5000	1.04213	−0.208	78.230	−0.300	103.206	−0.115	78.115	102.906
0.5001	1.04223	−0.214	78.231	−0.300	103.206	−0.115	78.102	102.893
0.5500	1.06141	−0.198	78.272	−0.258	103.160	−0.162	78.170	102.881
0.6001	1.08115	−0.183	78.316	−0.215	103.101	−0.221	78.226	102.865
0.6500	1.10137	−0.164	78.359	−0.172	103.029	−0.292	78.279	102.854
0.7000	1.12214	−0.142	78.400	−0.130	102.943	−0.378	78.328	102.849
0.7500	1.14357	−0.125	78.437	−0.093	102.844	−0.477	78.364	102.823
0.8000	1.16545	−0.093	78.470	−0.060	102.732	−0.590	78.414	102.854
0.8500	1.18823	−0.080	78.496	−0.034	102.608	−0.714	78.436	102.785
0.9000	1.21155	−0.058	78.515	−0.015	102.474	−0.847	78.466	102.741
0.9250	1.22337	−0.040	78.522	−0.008	102.405	−0.916	78.487	102.786
0.9750	1.24780	−0.020	78.529	−0.001	102.265	−1.057	78.510	102.536

dx.doi.org/10.1021/je101361u |J. Chem. Eng. Data 2011, 56, 1629–1657

Table 3. Continued

x_1	ρ / g·cm^{-3}	V^E / cm^3·mol^{-1}	V_1 / cm^3·mol^{-1}	V_1^E / cm^3·mol^{-1}	V_2 / cm^3·mol^{-1}	V_2^E / cm^3·mol^{-1}	V_{ϕ_1} / cm^3·mol^{-1}	V_{ϕ_2} / cm^3·mol^{-1}
				T/K = 293.15				
0.0251	0.87449	−0.035	78.387	−0.599	103.970	0.000	77.586	103.934
0.0500	0.88211	−0.057	78.405	−0.581	103.969	−0.001	77.844	103.910
0.0501	0.88219	−0.061	78.405	−0.581	103.969	−0.001	77.767	103.906
0.0750	0.88990	−0.082	78.420	−0.565	103.968	−0.002	77.898	103.882
0.1000	0.89771	−0.099	78.433	−0.552	103.967	−0.003	78.000	103.860
0.1552	0.91542	−0.147	78.459	−0.527	103.963	−0.007	78.039	103.796
0.2001	0.93007	−0.173	78.478	−0.508	103.959	−0.011	78.122	103.754
0.2501	0.94677	−0.199	78.500	−0.485	103.952	−0.018	78.191	103.705
0.3002	0.96386	−0.216	78.526	−0.460	103.942	−0.027	78.267	103.662
0.3500	0.98121	−0.226	78.555	−0.430	103.928	−0.042	78.340	103.622
0.4001	0.99908	−0.231	78.590	−0.396	103.907	−0.062	78.408	103.585
0.4500	1.01730	−0.228	78.629	−0.357	103.879	−0.091	78.479	103.555
0.5000	1.03599	−0.222	78.671	−0.315	103.840	−0.130	78.542	103.526
0.5001	1.03609	−0.228	78.671	−0.314	103.840	−0.130	78.529	103.513
0.5500	1.05519	−0.213	78.716	−0.270	103.791	−0.179	78.598	103.497
0.6001	1.07483	−0.196	78.762	−0.224	103.728	−0.242	78.659	103.480
0.6500	1.09496	−0.177	78.807	−0.178	103.652	−0.317	78.713	103.465
0.7000	1.11563	−0.154	78.850	−0.135	103.563	−0.407	78.765	103.456
0.7500	1.13695	−0.135	78.889	−0.096	103.459	−0.511	78.805	103.428
0.8000	1.15871	−0.102	78.923	−0.062	103.342	−0.627	78.858	103.459
0.8500	1.18137	−0.087	78.951	−0.035	103.214	−0.756	78.883	103.388
0.9000	1.20456	−0.063	78.970	−0.015	103.077	−0.893	78.916	103.343
0.9250	1.21632	−0.044	78.977	−0.008	103.006	−0.964	78.938	103.384
0.9750	1.24062	−0.022	78.984	−0.001	102.863	−1.107	78.963	103.107
				T/K = 298.15				
0.0251	0.86899	−0.037	78.793	−0.654	104.630	0.000	77.990	104.593
0.0500	0.87659	−0.061	78.814	−0.633	104.629	−0.001	78.228	104.566
0.0501	0.87666	−0.064	78.814	−0.633	104.629	−0.001	78.173	104.563
0.0750	0.88434	−0.086	78.833	−0.614	104.628	−0.002	78.307	104.538
0.1000	0.89212	−0.104	78.850	−0.597	104.626	−0.004	78.409	104.515
0.1552	0.90976	−0.155	78.881	−0.566	104.622	−0.009	78.451	104.447
0.2001	0.92435	−0.182	78.905	−0.542	104.616	−0.014	78.538	104.403
0.2501	0.94098	−0.209	78.932	−0.515	104.609	−0.022	78.611	104.351
0.3002	0.95799	−0.227	78.961	−0.486	104.597	−0.033	78.692	104.306
0.3500	0.97528	−0.239	78.994	−0.453	104.581	−0.049	78.765	104.263
0.4001	0.99307	−0.245	79.032	−0.415	104.559	−0.071	78.836	104.223
0.4500	1.01121	−0.242	79.074	−0.373	104.528	−0.102	78.910	104.191
0.5000	1.02982	−0.236	79.119	−0.328	104.487	−0.143	78.975	104.158
0.5001	1.02991	−0.242	79.119	−0.328	104.487	−0.143	78.964	104.147
0.5500	1.04893	−0.227	79.166	−0.281	104.435	−0.195	79.035	104.126
0.6001	1.06848	−0.209	79.214	−0.233	104.369	−0.261	79.098	104.106
0.6500	1.08851	−0.189	79.261	−0.186	104.290	−0.340	79.156	104.090
0.7000	1.10908	−0.165	79.306	−0.141	104.197	−0.433	79.211	104.078
0.7500	1.13030	−0.146	79.347	−0.100	104.089	−0.541	79.252	104.046
0.8000	1.15194	−0.110	79.382	−0.065	103.968	−0.662	79.309	104.078
0.8500	1.17449	−0.095	79.411	−0.036	103.834	−0.796	79.336	103.999
0.9000	1.19756	−0.068	79.431	−0.016	103.691	−0.939	79.371	103.948
0.9250	1.20925	−0.048	79.438	−0.009	103.617	−1.013	79.395	103.990
0.9750	1.23342	−0.024	79.446	−0.001	103.466	−1.164	79.423	103.687
				T/K = 303.15				
0.0251	0.86345	−0.039	79.206	−0.710	105.305	0.000	78.353	105.265

dx.doi.org/10.1021/je101361u |*J. Chem. Eng. Data* 2011, 56, 1629–1657

Table 3. Continued

x_1	ρ / g·cm^{-3}	V^E / cm^3·mol^{-1}	V_1 / cm^3·mol^{-1}	V_1^E / cm^3·mol^{-1}	V_2 / cm^3·mol^{-1}	V_2^E / cm^3·mol^{-1}	V_{ϕ_1} / cm^3·mol^{-1}	V_{ϕ_2} / cm^3·mol^{-1}
0.0500	0.87102	−0.065	79.230	−0.687	105.304	−0.001	78.619	105.237
0.0501	0.87108	−0.067	79.230	−0.687	105.304	−0.001	78.586	105.235
0.0750	0.87874	−0.091	79.250	−0.666	105.302	−0.003	78.706	105.207
0.1000	0.88649	−0.110	79.269	−0.647	105.301	−0.004	78.813	105.182
0.1552	0.90405	−0.162	79.306	−0.610	105.295	−0.010	78.870	105.113
0.2001	0.91859	−0.192	79.335	−0.582	105.289	−0.016	78.956	105.065
0.2501	0.93515	−0.221	79.367	−0.550	105.280	−0.025	79.033	105.010
0.3002	0.95209	−0.240	79.401	−0.516	105.267	−0.038	79.118	104.962
0.3500	0.96930	−0.252	79.439	−0.478	105.248	−0.057	79.196	104.917
0.4001	0.98702	−0.259	79.480	−0.437	105.223	−0.082	79.269	104.873
0.4500	1.00509	−0.258	79.525	−0.391	105.190	−0.115	79.344	104.837
0.5000	1.02361	−0.251	79.573	−0.344	105.147	−0.158	79.414	104.802
0.5001	1.02370	−0.257	79.573	−0.344	105.147	−0.158	79.403	104.791
0.5500	1.04263	−0.242	79.623	−0.294	105.091	−0.214	79.478	104.768
0.6001	1.06209	−0.224	79.673	−0.243	105.023	−0.282	79.544	104.745
0.6500	1.08203	−0.203	79.722	−0.194	104.941	−0.364	79.604	104.724
0.7000	1.10250	−0.178	79.769	−0.148	104.844	−0.461	79.662	104.710
0.7500	1.12360	−0.157	79.812	−0.105	104.732	−0.573	79.708	104.679
0.8000	1.14515	−0.121	79.848	−0.068	104.605	−0.699	79.766	104.701
0.8500	1.16757	−0.102	79.878	−0.039	104.466	−0.839	79.796	104.623
0.9000	1.19051	−0.073	79.899	−0.017	104.314	−0.991	79.835	104.571
0.9250	1.20214	−0.052	79.907	−0.010	104.235	−1.070	79.860	104.608
0.9750	1.22618	−0.026	79.916	−0.001	104.072	−1.233	79.890	104.278
				T/K = 308.15				
0.0251	0.85787	−0.042	79.583	−0.810	105.993	−0.001	78.720	105.951
0.0500	0.86542	−0.070	79.639	−0.754	105.991	−0.003	78.990	105.920
0.0501	0.86547	−0.071	79.639	−0.754	105.991	−0.003	78.981	105.919
0.0750	0.87310	−0.096	79.682	−0.711	105.988	−0.006	79.111	105.890
0.1000	0.88082	−0.117	79.716	−0.678	105.985	−0.009	79.224	105.864
0.1552	0.89832	−0.173	79.765	−0.628	105.978	−0.016	79.281	105.789
0.2001	0.91279	−0.203	79.791	−0.603	105.972	−0.022	79.379	105.740
0.2501	0.92928	−0.233	79.815	−0.578	105.965	−0.029	79.462	105.683
0.3002	0.94616	−0.254	79.841	−0.552	105.955	−0.039	79.547	105.631
0.3500	0.96329	−0.267	79.875	−0.518	105.939	−0.055	79.631	105.583
0.4001	0.98093	−0.274	79.918	−0.476	105.913	−0.081	79.709	105.537
0.4500	0.99892	−0.272	79.970	−0.424	105.874	−0.119	79.788	105.498
0.5000	1.01736	−0.267	80.029	−0.364	105.820	−0.174	79.860	105.460
0.5001	1.01745	−0.272	80.029	−0.364	105.820	−0.174	79.849	105.449
0.5500	1.03629	−0.256	80.094	−0.299	105.748	−0.245	79.928	105.424
0.6001	1.05567	−0.239	80.160	−0.234	105.659	−0.334	79.995	105.396
0.6500	1.07550	−0.216	80.223	−0.170	105.554	−0.440	80.061	105.376
0.7000	1.09588	−0.191	80.279	−0.114	105.436	−0.558	80.120	105.357
0.7500	1.11688	−0.168	80.326	−0.067	105.312	−0.681	80.169	105.322
0.8000	1.13831	−0.130	80.361	−0.032	105.193	−0.801	80.231	105.344
0.8500	1.16061	−0.109	80.383	−0.010	105.090	−0.904	80.265	105.265
0.9000	1.18344	−0.079	80.393	0.000	105.022	−0.972	80.305	105.203
0.9250	1.19500	−0.056	80.395	0.002	105.007	−0.987	80.332	105.245
0.9750	1.21890	−0.027	80.394	0.001	105.033	−0.961	80.366	104.932
				T/K = 313.15				
0.0251	0.85225	−0.041	80.058	−0.820	106.692	0.000	79.239	106.650
0.0500	0.85977	−0.071	80.089	−0.790	106.691	−0.002	79.463	106.618
0.0501	0.85982	−0.071	80.089	−0.789	106.691	−0.002	79.454	106.617

Table 3. Continued

x_1	ρ / g·cm^{-3}	V^E / cm^3·mol^{-1}	V_1 / cm^3·mol^{-1}	V_1^E / cm^3·mol^{-1}	V_2 / cm^3·mol^{-1}	V_2^E / cm^3·mol^{-1}	V_{ϕ_1} / cm^3·mol^{-1}	V_{ϕ_2} / cm^3·mol^{-1}
0.0750	0.86742	−0.098	80.116	−0.762	106.689	−0.003	79.568	106.586
0.1000	0.87511	−0.120	80.140	−0.738	106.687	−0.006	79.675	106.559
0.1552	0.89254	−0.179	80.189	−0.690	106.680	−0.013	79.726	106.481
0.2001	0.90696	−0.212	80.225	−0.653	106.672	−0.021	79.819	106.428
0.2501	0.92337	−0.242	80.265	−0.613	106.660	−0.032	79.909	106.369
0.3002	0.94018	−0.265	80.306	−0.572	106.644	−0.048	79.996	106.314
0.3500	0.95724	−0.279	80.351	−0.527	106.623	−0.070	80.081	106.263
0.4001	0.97480	−0.287	80.399	−0.479	106.594	−0.098	80.161	106.215
0.4500	0.99271	−0.286	80.450	−0.428	106.556	−0.136	80.243	106.173
0.5000	1.01106	−0.280	80.504	−0.374	106.507	−0.185	80.319	106.134
0.5001	1.01116	−0.286	80.504	−0.374	106.507	−0.185	80.306	106.120
0.5500	1.02991	−0.270	80.559	−0.319	106.446	−0.247	80.388	106.093
0.6001	1.04920	−0.252	80.615	−0.263	106.371	−0.322	80.458	106.063
0.6500	1.06894	−0.229	80.669	−0.209	106.280	−0.412	80.526	106.039
0.7000	1.08921	−0.202	80.720	−0.158	106.175	−0.518	80.590	106.020
0.7500	1.11011	−0.178	80.766	−0.112	106.053	−0.639	80.641	105.980
0.8000	1.13144	−0.139	80.805	−0.073	105.917	−0.776	80.704	105.997
0.8500	1.15362	−0.116	80.837	−0.041	105.767	−0.926	80.741	105.916
0.9000	1.17632	−0.084	80.860	−0.018	105.606	−1.087	80.785	105.856
0.9250	1.18782	−0.060	80.868	−0.010	105.522	−1.170	80.813	105.894
0.9750	1.21159	−0.028	80.877	−0.001	105.351	−1.342	80.849	105.570
				T/K = 318.15				
0.0251	0.84659	−0.043	80.505	−0.866	107.408	0.000	79.667	107.365
0.0500	0.85409	−0.075	80.534	−0.837	107.407	−0.002	79.871	107.330
0.0501	0.85413	−0.074	80.534	−0.837	107.407	−0.002	79.885	107.330
0.0750	0.86170	−0.103	80.561	−0.810	107.405	−0.003	80.002	107.297
0.1000	0.86935	−0.125	80.586	−0.785	107.403	−0.006	80.121	107.270
0.1552	0.88671	−0.186	80.637	−0.734	107.395	−0.013	80.172	107.188
0.2001	0.90108	−0.222	80.677	−0.694	107.387	−0.022	80.261	107.131
0.2501	0.91742	−0.254	80.721	−0.650	107.374	−0.035	80.355	107.070
0.3002	0.93415	−0.277	80.768	−0.603	107.356	−0.053	80.448	107.013
0.3500	0.95114	−0.292	80.817	−0.554	107.332	−0.076	80.535	106.959
0.4001	0.96862	−0.300	80.870	−0.501	107.300	−0.108	80.620	106.908
0.4500	0.98646	−0.301	80.925	−0.446	107.260	−0.149	80.703	106.862
0.5000	1.00473	−0.295	80.982	−0.389	107.208	−0.201	80.781	106.819
0.5001	1.00483	−0.302	80.982	−0.388	107.207	−0.201	80.768	106.805
0.5500	1.02349	−0.284	81.041	−0.330	107.143	−0.266	80.854	106.777
0.6001	1.04269	−0.266	81.099	−0.272	107.064	−0.344	80.927	106.743
0.6500	1.06234	−0.242	81.155	−0.216	106.971	−0.438	80.998	106.716
0.7000	1.08251	−0.214	81.207	−0.164	106.862	−0.547	81.065	106.694
0.7500	1.10331	−0.190	81.254	−0.116	106.737	−0.671	81.118	106.650
0.8000	1.12452	−0.148	81.295	−0.076	106.597	−0.812	81.186	106.669
0.8500	1.14658	−0.123	81.328	−0.043	106.442	−0.967	81.226	106.588
0.9000	1.16916	−0.088	81.352	−0.019	106.275	−1.134	81.273	106.526
0.9250	1.18061	−0.064	81.360	−0.011	106.187	−1.221	81.302	106.555
0.9750	1.20425	−0.030	81.370	−0.001	106.006	−1.402	81.340	106.221
				T/K = 323.15				
0.0251	0.84089	−0.046	80.945	−0.928	108.140	0.000	80.052	108.094
0.0500	0.84836	−0.079	80.979	−0.894	108.139	−0.002	80.284	108.057
0.0501	0.84839	−0.078	80.979	−0.894	108.139	−0.002	80.324	108.059
0.0750	0.85593	−0.107	81.010	−0.864	108.137	−0.004	80.442	108.025
0.1000	0.86355	−0.131	81.038	−0.835	108.134	−0.007	80.564	107.995

dx.doi.org/10.1021/je101361u |*J. Chem. Eng. Data* 2011, 56, 1629–1657

Table 3. Continued

x_1	ρ / g·cm^{-3}	V^E / cm^3·mol^{-1}	V_1 / cm^3·mol^{-1}	V_1^E / cm^3·mol^{-1}	V_2 / cm^3·mol^{-1}	V_2^E / cm^3·mol^{-1}	V_{ϕ_1} / cm^3·mol^{-1}	V_{ϕ_2} / cm^3·mol^{-1}
0.1552	0.88084	−0.195	81.096	−0.777	108.126	−0.015	80.618	107.910
0.2001	0.89515	−0.233	81.140	−0.733	108.116	−0.025	80.711	107.850
0.2501	0.91142	−0.266	81.189	−0.684	108.102	−0.039	80.809	107.786
0.3002	0.92808	−0.290	81.240	−0.633	108.082	−0.058	80.906	107.725
0.3500	0.94500	−0.307	81.293	−0.580	108.057	−0.084	80.995	107.668
0.4001	0.96241	−0.317	81.349	−0.524	108.023	−0.117	81.082	107.613
0.4500	0.98016	−0.316	81.407	−0.466	107.980	−0.160	81.170	107.565
0.5000	0.99835	−0.311	81.467	−0.406	107.925	−0.215	81.252	107.519
0.5001	0.99845	−0.317	81.467	−0.406	107.925	−0.215	81.238	107.506
0.5500	1.01703	−0.300	81.529	−0.345	107.858	−0.283	81.327	107.473
0.6001	1.03613	−0.281	81.589	−0.284	107.775	−0.365	81.405	107.438
0.6500	1.05568	−0.256	81.648	−0.225	107.678	−0.463	81.479	107.409
0.7000	1.07576	−0.227	81.702	−0.171	107.564	−0.577	81.548	107.383
0.7500	1.09645	−0.201	81.752	−0.121	107.434	−0.707	81.606	107.338
0.8000	1.11756	−0.158	81.794	−0.079	107.287	−0.853	81.676	107.352
0.8500	1.13951	−0.131	81.828	−0.045	107.126	−1.014	81.718	107.264
0.9000	1.16197	−0.094	81.853	−0.020	106.952	−1.189	81.768	107.197
0.9250	1.17335	−0.068	81.862	−0.011	106.861	−1.280	81.799	107.230
0.9750	1.19686	−0.031	81.872	−0.001	106.672	−1.468	81.841	106.885
				T/K = 328.15				
0.0251	0.83513	−0.047	81.401	−0.982	108.889	−0.001	80.494	108.841
0.0500	0.84255	−0.080	81.437	−0.946	108.887	−0.002	80.781	108.805
0.0501	0.84260	−0.081	81.438	−0.946	108.887	−0.002	80.770	108.804
0.0750	0.85011	−0.112	81.471	−0.913	108.885	−0.004	80.890	108.768
0.1000	0.85770	−0.137	81.501	−0.882	108.882	−0.007	81.013	108.737
0.1552	0.87492	−0.204	81.564	−0.820	108.873	−0.016	81.071	108.648
0.2001	0.88917	−0.243	81.611	−0.772	108.863	−0.026	81.168	108.585
0.2501	0.90537	−0.278	81.664	−0.720	108.848	−0.042	81.271	108.518
0.3002	0.92197	−0.305	81.718	−0.666	108.827	−0.062	81.367	108.453
0.3500	0.93881	−0.322	81.774	−0.609	108.800	−0.089	81.463	108.393
0.4001	0.95614	−0.332	81.834	−0.550	108.764	−0.125	81.554	108.336
0.4500	0.97382	−0.333	81.896	−0.488	108.718	−0.171	81.644	108.284
0.5000	0.99193	−0.327	81.959	−0.424	108.660	−0.229	81.729	108.235
0.5001	0.99202	−0.333	81.960	−0.424	108.660	−0.229	81.717	108.223
0.5500	1.01051	−0.316	82.024	−0.359	108.588	−0.301	81.810	108.188
0.6001	1.02953	−0.296	82.088	−0.296	108.502	−0.387	81.890	108.149
0.6500	1.04898	−0.270	82.150	−0.234	108.399	−0.490	81.969	108.119
0.7000	1.06897	−0.241	82.207	−0.177	108.280	−0.609	82.040	108.087
0.7500	1.08955	−0.212	82.258	−0.125	108.144	−0.745	82.101	108.042
0.8000	1.11055	−0.167	82.303	−0.081	107.992	−0.897	82.175	108.054
0.8500	1.13239	−0.139	82.338	−0.046	107.825	−1.064	82.220	107.963
0.9000	1.15473	−0.099	82.363	−0.020	107.646	−1.243	82.273	107.895
0.9250	1.16605	−0.072	82.372	−0.011	107.553	−1.336	82.306	107.926
0.9750	1.18943	−0.033	82.382	−0.001	107.362	−1.527	82.350	107.588
				T/K = 333.15				
0.0251	0.82932	−0.048	81.854	−1.050	109.653	−0.001	80.995	109.605
0.0500	0.83672	−0.083	81.896	−1.009	109.652	−0.002	81.234	109.566
0.0501	0.83676	−0.083	81.896	−1.008	109.651	−0.002	81.248	109.566
0.0750	0.84424	−0.116	81.934	−0.970	109.649	−0.005	81.362	109.529
0.1000	0.85180	−0.142	81.970	−0.935	109.646	−0.008	81.482	109.496
0.1552	0.86895	−0.212	82.040	−0.865	109.635	−0.018	81.538	109.403

dx.doi.org/10.1021/je101361u |*J. Chem. Eng. Data* 2011, 56, 1629–1657

Table 3. Continued

x_1	ρ / g·cm^{-3}	V^E / cm^3·mol^{-1}	V_1 / cm^3·mol^{-1}	V_1^E / cm^3·mol^{-1}	V_2 / cm^3·mol^{-1}	V_2^E / cm^3·mol^{-1}	V_{ϕ_1} / cm^3·mol^{-1}	V_{ϕ_2} / cm^3·mol^{-1}
0.2001	0.88315	−0.255	82.093	−0.811	109.624	−0.030	81.632	109.335
0.2501	0.89927	−0.290	82.151	−0.754	109.607	−0.047	81.745	109.267
0.3002	0.91579	−0.318	82.210	−0.695	109.585	−0.069	81.847	109.200
0.3500	0.93256	−0.336	82.270	−0.635	109.556	−0.098	81.944	109.137
0.4001	0.94982	−0.347	82.333	−0.572	109.518	−0.136	82.037	109.075
0.4500	0.96742	−0.348	82.398	−0.507	109.469	−0.184	82.130	109.020
0.5000	0.98545	−0.343	82.465	−0.440	109.409	−0.245	82.218	108.967
0.5001	0.98553	−0.348	82.465	−0.440	109.409	−0.245	82.208	108.957
0.5500	1.00394	−0.331	82.533	−0.372	109.334	−0.320	82.303	108.918
0.6001	1.02287	−0.311	82.599	−0.306	109.244	−0.410	82.386	108.876
0.6500	1.04224	−0.285	82.663	−0.242	109.137	−0.517	82.466	108.839
0.7000	1.06212	−0.254	82.723	−0.182	109.013	−0.640	82.542	108.808
0.7500	1.08261	−0.225	82.776	−0.129	108.872	−0.781	82.605	108.756
0.8000	1.10350	−0.178	82.821	−0.083	108.715	−0.938	82.683	108.766
0.8500	1.12522	−0.147	82.858	−0.047	108.544	−1.110	82.732	108.673
0.9000	1.14744	−0.105	82.884	−0.021	108.360	−1.294	82.788	108.601
0.9250	1.15870	−0.077	82.893	−0.012	108.265	−1.389	82.822	108.630
0.9750	1.18197	−0.036	82.903	−0.001	108.070	−1.583	82.868	108.224

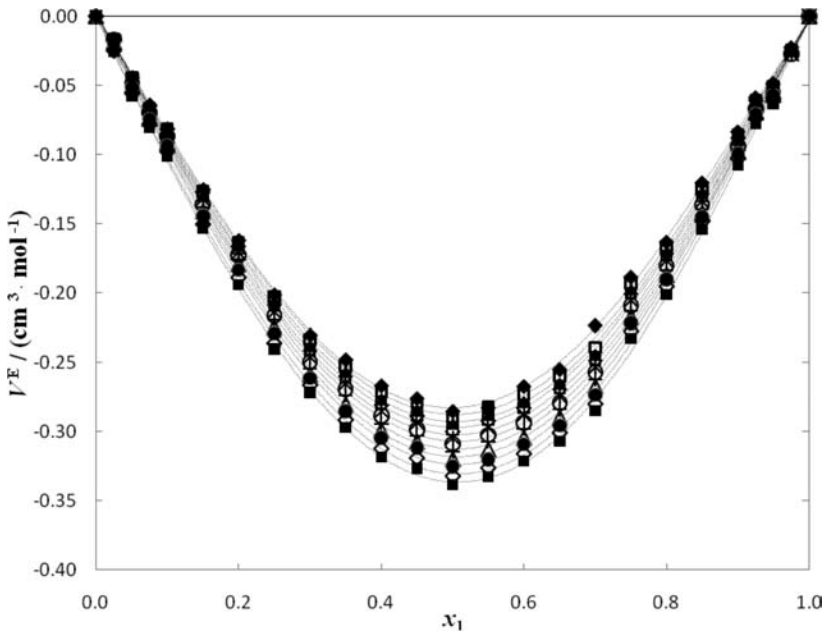

Figure 2. Plot of excess molar volume, V^E, for the system 1,2-DCE (1) + DEGDME (2), against the mole fraction, x_1, at different temperatures. Symbols: experimental values (◆, 283.15 K; □, 288.15 K; ▲, 293.15 K; □, 298.15 K; ∗, 303.15 K; ○, 308.15 K; +, 313.15 K; △, 318.15 K; ●, 323.15 K; ◇, 328.15 K; ■, 333.15 K). Dashed lines: Redlich−Kister correlation.

The empirical parameters A_i in eq 2 are listed in Table 6 along with the standard deviations, σ, defined as:

$$\sigma = \left[\frac{\sum_{i=1}^{i=N} \left(V^E_{(\mathrm{expt}),i} - V^E_{(\mathrm{calc}),i}\right)^2}{N-n}\right]^{1/2} \quad (3)$$

where N is the number of experiments and n the number of adjusted parameters A_i.

Figures 1 to 3 show the experimental values of excess molar volume, V^E, as a function of 1,2-DCE mole fraction, x_1, along with fitted curves calculated by eq 2, at selected temperatures ranging from (283.15 to 333.15) K, for the systems 1,2-DCE + EGDME, 1,2-DCE + DEGDME, and 1,2-DCE + DEGDEE, respectively. As it can be seen, the V^E values are negative over the whole mole fraction and temperature ranges, for all of the mixtures, symmetrical for both the systems 1,2-DCE + DEGDME and 1,2-DCE + DEGDEE, and slightly skewed

Table 4. Experimental Densities, ρ, Excess Molar Volumes, V^E, Partial Molar Volumes, V_i, Partial Molar Excess Volumes, V_i^E, and Apparent Molar Volumes, $V_{\phi i}$, for the 1,2-DCE + DEGDME Binary System

	ρ	V^E	V_1	V_1^E	V_2	V_2^E	V_{ϕ_1}	V_{ϕ_2}
x_1	g·cm^{-3}	cm^3·mol^{-1}	cm^3·mol^{-1}	cm^3·mol^{-1}	cm^3·mol^{-1}	cm^3·mol^{-1}	cm^3·mol^{-1}	cm^3·mol^{-1}
				T/K = 283.15				
0.0252	0.95822	−0.017	77.269	−0.812	140.695	0.000	77.403	140.677
0.0508	0.96301	−0.044	77.257	−0.825	140.696	0.001	77.214	140.648
0.0751	0.96764	−0.064	77.253	−0.829	140.696	0.001	77.232	140.626
0.1000	0.97247	−0.081	77.257	−0.825	140.695	0.001	77.269	140.605
0.1502	0.98262	−0.125	77.285	−0.796	140.691	−0.004	77.249	140.548
0.1999	0.99312	−0.162	77.335	−0.747	140.681	−0.014	77.272	140.493
0.2500	1.00425	−0.201	77.400	−0.682	140.662	−0.033	77.277	140.427
0.3002	1.01591	−0.230	77.476	−0.606	140.633	−0.062	77.315	140.366
0.3501	1.02801	−0.248	77.557	−0.525	140.594	−0.101	77.374	140.314
0.4000	1.04079	−0.266	77.639	−0.442	140.544	−0.151	77.416	140.251
0.4500	1.05420	−0.276	77.720	−0.362	140.484	−0.211	77.469	140.194
0.5003	1.06849	−0.285	77.797	−0.285	140.415	−0.280	77.512	140.125
0.5499	1.08331	−0.282	77.865	−0.217	140.339	−0.356	77.568	140.068
0.5999	1.09898	−0.267	77.925	−0.156	140.258	−0.437	77.637	140.028
0.6501	1.11577	−0.255	77.976	−0.106	140.173	−0.521	77.690	139.967
0.7000	1.13330	−0.223	78.016	−0.066	140.091	−0.604	77.763	139.951
0.7500	1.15198	−0.188	78.046	−0.036	140.013	−0.682	77.831	139.941
0.8000	1.17208	−0.163	78.065	−0.016	139.945	−0.750	77.878	139.879
0.8499	1.19331	−0.120	78.077	−0.005	139.892	−0.803	77.940	139.893
0.9000	1.21625	−0.083	78.082	0.000	139.859	−0.836	77.989	139.861
0.9250	1.22827	−0.059	78.082	0.001	139.852	−0.843	78.018	139.913
0.9494	1.24066	−0.048	78.082	0.001	139.853	−0.842	78.031	139.739
0.9750	1.25389	−0.022	78.082	0.000	139.862	−0.832	78.059	139.796
0.0000	0.94872	0.000	77.689	−0.841	141.427	0.000	77.843	141.410
				T/K = 288.15				
0.0252	0.95325	−0.017	77.673	−0.857	141.428	0.000	77.649	141.380
0.0508	0.95801	−0.045	77.667	−0.863	141.428	0.000	77.648	141.356
0.0751	0.96262	−0.066	77.669	−0.862	141.428	0.000	77.717	141.337
0.1000	0.96740	−0.081	77.677	−0.853	141.427	−0.001	77.688	141.278
0.1502	0.97749	−0.127	77.714	−0.817	141.421	−0.006	77.711	141.223
0.1999	0.98792	−0.164	77.769	−0.761	141.410	−0.018	77.718	141.157
0.2500	0.99897	−0.203	77.839	−0.691	141.389	−0.038	77.753	141.094
0.3002	1.01056	−0.233	77.919	−0.612	141.359	−0.068	77.809	141.039
0.3501	1.02259	−0.253	78.002	−0.528	141.319	−0.109	77.852	140.975
0.4000	1.03528	−0.271	78.086	−0.444	141.268	−0.159	77.910	140.920
0.4500	1.04858	−0.279	78.168	−0.362	141.208	−0.220	77.952	140.848
0.5003	1.06278	−0.289	78.245	−0.285	141.138	−0.290	78.017	140.800
0.5499	1.07745	−0.282	78.314	−0.216	141.062	−0.366	78.075	140.745
0.5999	1.09307	−0.273	78.374	−0.156	140.980	−0.447	78.131	140.685
0.6501	1.10973	−0.260	78.425	−0.106	140.896	−0.531	78.189	140.630
0.7000	1.12726	−0.239	78.464	−0.066	140.814	−0.614	78.272	140.653
0.7500	1.14568	−0.194	78.494	−0.036	140.736	−0.691	78.322	140.595
0.8000	1.16561	−0.167	78.514	−0.017	140.668	−0.759	78.384	140.600
0.8499	1.18669	−0.124	78.525	−0.005	140.615	−0.812	78.435	140.568
0.9000	1.20944	−0.086	78.530	0.000	140.582	−0.846	78.465	140.620
0.9250	1.22136	−0.061	78.531	0.001	140.575	−0.853	78.477	140.428
0.9494	1.23366	−0.051	78.531	0.001	140.575	−0.853	78.505	140.437
0.9750	1.24679	−0.025	78.531	0.000	140.583	−0.844	77.843	141.410

Table 4. Continued

x_1	ρ / g·cm^{-3}	V^E / cm^3·mol^{-1}	V_1 / cm^3·mol^{-1}	V_1^E / cm^3·mol^{-1}	V_2 / cm^3·mol^{-1}	V_2^E / cm^3·mol^{-1}	V_{ϕ_1} / cm^3·mol^{-1}	V_{ϕ_2} / cm^3·mol^{-1}
				T/K = 293.15				
0.0252	0.94826	−0.018	78.106	−0.879	142.171	0.000	78.289	142.153
0.0508	0.95299	−0.045	78.101	−0.884	142.171	0.000	78.090	142.123
0.0751	0.95757	−0.067	78.104	−0.881	142.171	0.000	78.089	142.098
0.1000	0.96233	−0.084	78.114	−0.871	142.170	−0.001	78.143	142.077
0.1502	0.97235	−0.130	78.153	−0.832	142.164	−0.007	78.123	142.018
0.1999	0.98270	−0.166	78.211	−0.775	142.152	−0.019	78.156	141.963
0.2500	0.99369	−0.207	78.283	−0.703	142.131	−0.040	78.156	141.894
0.3002	1.00520	−0.238	78.364	−0.622	142.100	−0.071	78.193	141.831
0.3501	1.01714	−0.257	78.449	−0.537	142.059	−0.112	78.253	141.776
0.4000	1.02975	−0.276	78.534	−0.451	142.007	−0.163	78.294	141.710
0.4500	1.04296	−0.284	78.617	−0.368	141.946	−0.225	78.353	141.654
0.5003	1.05705	−0.294	78.696	−0.290	141.875	−0.295	78.398	141.582
0.5499	1.07162	−0.287	78.765	−0.220	141.798	−0.372	78.463	141.532
0.5999	1.08713	−0.278	78.826	−0.159	141.716	−0.455	78.521	141.475
0.6501	1.10367	−0.265	78.877	−0.108	141.631	−0.540	78.578	141.413
0.7000	1.12107	−0.244	78.918	−0.068	141.547	−0.624	78.636	141.356
0.7500	1.13934	−0.197	78.948	−0.038	141.468	−0.703	78.722	141.381
0.8000	1.15912	−0.170	78.968	−0.017	141.399	−0.772	78.773	141.320
0.8499	1.18004	−0.127	78.980	−0.006	141.344	−0.827	78.835	141.321
0.9000	1.20260	−0.088	78.985	0.000	141.309	−0.862	78.888	141.292
0.9250	1.21442	−0.062	78.986	0.000	141.301	−0.870	78.919	141.346
0.9494	1.22662	−0.051	78.986	0.000	141.300	−0.871	78.931	141.152
0.9750	1.23964	−0.025	78.986	0.000	141.308	−0.863	78.960	141.165
				T/K = 298.15				
0.0252	0.94326	−0.016	78.550	−0.897	142.922	0.000	78.800	142.905
0.0508	0.94797	−0.046	78.546	−0.901	142.922	0.000	78.536	142.873
0.0751	0.95252	−0.068	78.550	−0.897	142.922	0.000	78.536	142.848
0.1000	0.95724	−0.084	78.561	−0.886	142.921	−0.001	78.602	142.828
0.1502	0.96719	−0.130	78.602	−0.845	142.915	−0.007	78.581	142.769
0.1999	0.97748	−0.168	78.661	−0.786	142.902	−0.020	78.605	142.711
0.2500	0.98839	−0.210	78.735	−0.712	142.881	−0.041	78.609	142.642
0.3002	0.99983	−0.242	78.817	−0.630	142.849	−0.073	78.642	142.576
0.3501	1.01169	−0.261	78.904	−0.543	142.807	−0.114	78.702	142.520
0.4000	1.02420	−0.280	78.991	−0.456	142.755	−0.167	78.748	142.455
0.4500	1.03732	−0.288	79.075	−0.372	142.693	−0.229	78.806	142.397
0.5003	1.05131	−0.298	79.154	−0.293	142.621	−0.301	78.851	142.325
0.5499	1.06577	−0.291	79.225	−0.222	142.543	−0.379	78.917	142.275
0.5999	1.08117	−0.283	79.287	−0.160	142.460	−0.462	78.976	142.216
0.6501	1.09758	−0.269	79.338	−0.109	142.373	−0.548	79.034	142.154
0.7000	1.11485	−0.248	79.379	−0.068	142.289	−0.633	79.093	142.096
0.7500	1.13298	−0.200	79.409	−0.038	142.209	−0.712	79.180	142.120
0.8000	1.15261	−0.173	79.430	−0.017	142.140	−0.782	79.231	142.057
0.8499	1.17337	−0.130	79.442	−0.005	142.084	−0.837	79.294	142.053
0.9000	1.19574	−0.090	79.447	0.000	142.050	−0.872	79.348	142.026
0.9250	1.20747	−0.064	79.447	0.000	142.042	−0.880	79.378	142.073
0.9494	1.21957	−0.053	79.448	0.000	142.041	−0.880	79.391	141.874
0.9750	1.23247	−0.025	79.447	0.000	142.049	−0.872	79.421	141.903
				T/K = 303.15				
0.0252	0.93826	−0.018	78.992	−0.924	143.684	0.000	79.198	143.665
0.0508	0.94293	−0.047	78.991	−0.926	143.684	0.000	78.988	143.634
0.0751	0.94745	−0.070	78.997	−0.920	143.684	0.000	78.988	143.609

dx.doi.org/10.1021/je101361u |*J. Chem. Eng. Data* 2011, 56, 1629–1657

Table 4. Continued

x_1	ρ / g·cm^{-3}	V^E / cm^3·mol^{-1}	V_1 / cm^3·mol^{-1}	V_1^E / cm^3·mol^{-1}	V_2 / cm^3·mol^{-1}	V_2^E / cm^3·mol^{-1}	V_{ϕ_1} / cm^3·mol^{-1}	V_{ϕ_2} / cm^3·mol^{-1}
0.1000	0.95214	−0.086	79.010	−0.907	143.682	−0.002	79.053	143.588
0.1502	0.96202	−0.132	79.054	−0.863	143.676	−0.008	79.037	143.528
0.1999	0.97224	−0.171	79.116	−0.800	143.663	−0.021	79.061	143.470
0.2500	0.98308	−0.213	79.193	−0.724	143.640	−0.044	79.063	143.399
0.3002	0.99444	−0.246	79.277	−0.639	143.608	−0.076	79.097	143.333
0.3501	1.00621	−0.265	79.366	−0.551	143.566	−0.119	79.160	143.276
0.4000	1.01864	−0.285	79.454	−0.462	143.512	−0.172	79.204	143.209
0.4500	1.03166	−0.293	79.540	−0.377	143.449	−0.235	79.265	143.151
0.5003	1.04556	−0.304	79.620	−0.297	143.376	−0.308	79.308	143.075
0.5499	1.05991	−0.297	79.691	−0.225	143.298	−0.386	79.377	143.024
0.5999	1.07519	−0.288	79.754	−0.163	143.213	−0.471	79.437	142.965
0.6501	1.09148	−0.274	79.806	−0.110	143.126	−0.558	79.495	142.901
0.7000	1.10862	−0.253	79.847	−0.069	143.040	−0.644	79.555	142.841
0.7500	1.12661	−0.205	79.878	−0.039	142.960	−0.724	79.643	142.863
0.8000	1.14607	−0.176	79.899	−0.018	142.889	−0.795	79.696	142.802
0.8499	1.16667	−0.134	79.911	−0.006	142.833	−0.851	79.759	142.793
0.9000	1.18886	−0.092	79.916	0.000	142.796	−0.888	79.814	142.759
0.9250	1.20048	−0.065	79.917	0.000	142.788	−0.896	79.846	142.813
0.9494	1.21248	−0.054	79.917	0.000	142.787	−0.897	79.859	142.608
0.9750	1.22528	−0.027	79.917	0.000	142.794	−0.890	79.889	142.602
				T/K = 308.15				
0.0252	0.93323	−0.017	79.449	−0.944	144.456	0.000	79.723	144.439
0.0508	0.93788	−0.048	79.448	−0.945	144.456	0.000	79.446	144.405
0.0751	0.94236	−0.070	79.455	−0.938	144.456	0.000	79.466	144.381
0.1000	0.94702	−0.087	79.469	−0.925	144.454	−0.002	79.525	144.359
0.1502	0.95685	−0.136	79.515	−0.879	144.448	−0.008	79.489	144.296
0.1999	0.96698	−0.173	79.579	−0.814	144.434	−0.022	79.530	144.240
0.2500	0.97775	−0.216	79.657	−0.736	144.411	−0.045	79.528	144.167
0.3002	0.98903	−0.249	79.744	−0.649	144.378	−0.078	79.563	144.100
0.3501	1.00072	−0.269	79.834	−0.559	144.334	−0.122	79.625	144.042
0.4000	1.01305	−0.288	79.924	−0.469	144.280	−0.176	79.673	143.976
0.4500	1.02599	−0.298	80.012	−0.382	144.216	−0.240	79.730	143.914
0.5003	1.03978	−0.309	80.093	−0.300	144.142	−0.314	79.776	143.838
0.5499	1.05403	−0.302	80.166	−0.227	144.062	−0.394	79.844	143.784
0.5999	1.06920	−0.293	80.229	−0.164	143.976	−0.480	79.904	143.723
0.6501	1.08536	−0.279	80.282	−0.111	143.888	−0.568	79.964	143.659
0.7000	1.10236	−0.257	80.324	−0.069	143.801	−0.655	80.026	143.599
0.7500	1.12021	−0.209	80.355	−0.038	143.720	−0.736	80.114	143.619
0.8000	1.13952	−0.180	80.376	−0.018	143.649	−0.807	80.168	143.554
0.8499	1.15994	−0.136	80.388	−0.006	143.592	−0.863	80.233	143.549
0.9000	1.18194	−0.094	80.393	0.000	143.557	−0.899	80.289	143.518
0.9250	1.19347	−0.067	80.394	0.000	143.549	−0.907	80.321	143.564
0.9494	1.20537	−0.056	80.394	0.001	143.549	−0.907	80.334	143.353
0.9750	1.21805	−0.027	80.393	0.000	143.557	−0.899	80.365	143.364
				T/K = 313.15				
0.0252	0.92820	−0.019	79.909	−0.969	145.239	0.000	80.132	145.220
0.0508	0.93281	−0.049	79.910	−0.968	145.239	0.000	79.910	145.188
0.0751	0.93726	−0.071	79.919	−0.959	145.239	−0.001	79.931	145.162
0.1000	0.94189	−0.089	79.934	−0.944	145.237	−0.002	79.988	145.140
0.1502	0.95165	−0.138	79.983	−0.895	145.230	−0.009	79.957	145.076
0.1999	0.96171	−0.176	80.050	−0.828	145.216	−0.024	79.999	145.020
0.2500	0.97240	−0.220	80.131	−0.747	145.192	−0.047	79.999	144.946

dx.doi.org/10.1021/je101361u |*J. Chem. Eng. Data* 2011, 56, 1629–1657

Table 4. Continued

x_1	ρ / g·cm^{-3}	V^E / cm^3·mol^{-1}	V_1 / cm^3·mol^{-1}	V_1^E / cm^3·mol^{-1}	V_2 / cm^3·mol^{-1}	V_2^E / cm^3·mol^{-1}	V_{ϕ_1} / cm^3·mol^{-1}	V_{ϕ_2} / cm^3·mol^{-1}
0.3002	0.98361	−0.254	80.219	−0.659	145.159	−0.081	80.031	144.876
0.3501	0.99521	−0.274	80.311	−0.567	145.114	−0.125	80.096	144.818
0.4000	1.00746	−0.294	80.402	−0.476	145.059	−0.180	80.142	144.749
0.4500	1.02029	−0.303	80.491	−0.388	144.994	−0.245	80.205	144.688
0.5003	1.03398	−0.314	80.573	−0.305	144.920	−0.320	80.250	144.611
0.5499	1.04812	−0.307	80.646	−0.232	144.838	−0.401	80.319	144.557
0.5999	1.06317	−0.298	80.711	−0.168	144.752	−0.487	80.381	144.495
0.6501	1.07921	−0.284	80.764	−0.114	144.662	−0.577	80.441	144.428
0.7000	1.09608	−0.262	80.807	−0.071	144.575	−0.665	80.503	144.365
0.7500	1.11378	−0.213	80.838	−0.040	144.492	−0.747	80.594	144.386
0.8000	1.13293	−0.184	80.859	−0.019	144.419	−0.820	80.648	144.320
0.8499	1.15319	−0.140	80.872	−0.006	144.361	−0.879	80.714	144.308
0.9000	1.17500	−0.096	80.877	−0.001	144.323	−0.917	80.771	144.275
0.9250	1.18642	−0.068	80.878	0.000	144.313	−0.926	80.804	144.329
0.9494	1.19822	−0.057	80.879	0.000	144.312	−0.928	80.818	144.111
0.9750	1.21078	−0.027	80.878	0.000	144.318	−0.921	80.850	144.139
				T/K = 318.15				
0.0252	0.92314	−0.019	80.384	−0.987	146.035	0.000	80.609	146.015
0.0508	0.92772	−0.050	80.385	−0.986	146.034	0.000	80.381	145.982
0.0751	0.93215	−0.074	80.394	−0.976	146.034	−0.001	80.382	145.954
0.1000	0.93674	−0.091	80.410	−0.960	146.032	−0.002	80.458	145.933
0.1502	0.94643	−0.141	80.461	−0.910	146.025	−0.010	80.431	145.868
0.1999	0.95642	−0.179	80.529	−0.842	146.010	−0.024	80.474	145.810
0.2500	0.96704	−0.225	80.611	−0.760	145.987	−0.048	80.472	145.735
0.3002	0.97816	−0.259	80.701	−0.670	145.952	−0.082	80.509	145.665
0.3501	0.98969	−0.280	80.794	−0.577	145.907	−0.127	80.571	145.603
0.4000	1.00183	−0.299	80.886	−0.484	145.852	−0.183	80.624	145.536
0.4500	1.01456	−0.307	80.976	−0.395	145.786	−0.249	80.688	145.476
0.5003	1.02816	−0.320	81.060	−0.311	145.710	−0.325	80.732	145.394
0.5499	1.04219	−0.313	81.134	−0.237	145.627	−0.407	80.802	145.339
0.5999	1.05713	−0.304	81.199	−0.172	145.539	−0.495	80.864	145.274
0.6501	1.07304	−0.290	81.254	−0.117	145.448	−0.586	80.925	145.206
0.7000	1.08977	−0.267	81.297	−0.074	145.359	−0.676	80.989	145.144
0.7500	1.10732	−0.217	81.329	−0.042	145.274	−0.760	81.081	145.165
0.8000	1.12631	−0.187	81.351	−0.020	145.199	−0.835	81.137	145.099
0.8499	1.14640	−0.143	81.364	−0.007	145.139	−0.896	81.203	145.085
0.9000	1.16802	−0.098	81.370	−0.001	145.099	−0.936	81.262	145.052
0.9250	1.17934	−0.070	81.371	0.000	145.089	−0.946	81.296	145.106
0.9494	1.19102	−0.057	81.371	0.000	145.086	−0.949	81.311	144.910
				T/K = 323.15				
0.0252	0.91807	−0.020	80.866	−1.007	146.840	0.000	81.092	146.820
0.0508	0.92262	−0.051	80.869	−1.005	146.840	0.000	80.859	146.786
0.0751	0.92701	−0.075	80.878	−0.995	146.839	−0.001	80.880	146.759
0.1000	0.93158	−0.094	80.895	−0.978	146.838	−0.002	80.935	146.736
0.1502	0.94120	−0.144	80.947	−0.927	146.830	−0.010	80.912	146.670
0.1999	0.95112	−0.183	81.016	−0.857	146.815	−0.025	80.956	146.611
0.2500	0.96166	−0.229	81.100	−0.773	146.791	−0.049	80.957	146.535
0.3002	0.97268	−0.261	81.191	−0.682	146.756	−0.084	81.003	146.467
0.3501	0.98414	−0.285	81.286	−0.587	146.710	−0.130	81.058	146.401
0.4000	0.99619	−0.304	81.380	−0.493	146.654	−0.186	81.112	146.333
0.4500	1.00881	−0.311	81.471	−0.402	146.586	−0.254	81.181	146.274
0.5003	1.02231	−0.325	81.557	−0.317	146.509	−0.331	81.224	146.190

dx.doi.org/10.1021/je101361u |*J. Chem. Eng. Data* 2011, 56, 1629–1657

Table 4. Continued

x_1	ρ / g·cm^{-3}	V^E / cm^3·mol^{-1}	V_1 / cm^3·mol^{-1}	V_1^E / cm^3·mol^{-1}	V_2 / cm^3·mol^{-1}	V_2^E / cm^3·mol^{-1}	V_{ϕ_1} / cm^3·mol^{-1}	V_{ϕ_2} / cm^3·mol^{-1}
0.5499	1.03625	−0.320	81.632	−0.241	146.425	−0.415	81.291	146.129
0.5999	1.05105	−0.309	81.699	−0.175	146.336	−0.504	81.358	146.067
0.6501	1.06684	−0.295	81.754	−0.119	146.243	−0.597	81.419	145.996
0.7000	1.08344	−0.273	81.798	−0.075	146.152	−0.687	81.483	145.929
0.7500	1.10083	−0.222	81.831	−0.042	146.066	−0.773	81.578	145.954
0.8000	1.11965	−0.190	81.853	−0.020	145.990	−0.850	81.635	145.889
0.8499	1.13957	−0.145	81.866	−0.007	145.929	−0.911	81.702	145.872
0.9000	1.16099	−0.100	81.872	−0.001	145.888	−0.952	81.762	145.845
0.9250	1.17221	−0.071	81.873	0.000	145.877	−0.963	81.797	145.899
0.9494	1.18378	−0.057	81.873	0.000	145.874	−0.966	81.813	145.711
				T/K = 328.15				
0.0252	0.91299	−0.025	81.337	−1.047	147.661	0.000	81.393	147.635
0.0508	0.91750	−0.056	81.345	−1.039	147.661	0.000	81.282	147.602
0.0751	0.92185	−0.078	81.359	−1.024	147.660	−0.001	81.345	147.577
0.1000	0.92639	−0.098	81.380	−1.003	147.658	−0.003	81.404	147.552
0.1502	0.93595	−0.151	81.439	−0.945	147.649	−0.012	81.382	147.484
0.1999	0.94579	−0.189	81.513	−0.871	147.633	−0.028	81.438	147.425
0.2500	0.95626	−0.236	81.599	−0.785	147.608	−0.053	81.439	147.346
0.3002	0.96718	−0.266	81.692	−0.691	147.572	−0.088	81.497	147.280
0.3501	0.97856	−0.291	81.788	−0.596	147.526	−0.134	81.551	147.212
0.4000	0.99053	−0.312	81.883	−0.501	147.470	−0.191	81.603	147.140
0.4500	1.00305	−0.319	81.974	−0.410	147.402	−0.259	81.674	147.081
0.5003	1.01644	−0.332	82.059	−0.325	147.325	−0.336	81.720	146.996
0.5499	1.03026	−0.326	82.134	−0.249	147.241	−0.419	81.791	146.936
0.5999	1.04495	−0.316	82.201	−0.183	147.152	−0.509	81.857	146.871
0.6501	1.06060	−0.301	82.257	−0.126	147.058	−0.603	81.921	146.801
0.7000	1.07708	−0.280	82.302	−0.082	146.965	−0.695	81.984	146.728
0.7500	1.09432	−0.227	82.336	−0.048	146.876	−0.785	82.081	146.752
0.8000	1.11298	−0.195	82.359	−0.024	146.795	−0.866	82.139	146.684
0.8499	1.13271	−0.148	82.374	−0.010	146.727	−0.934	82.209	146.672
0.9000	1.15395	−0.103	82.381	−0.002	146.677	−0.984	82.270	146.635
0.9250	1.16508	−0.074	82.383	−0.001	146.660	−1.001	82.304	146.675
0.9494	1.17654	−0.060	82.384	0.000	146.650	−1.011	82.321	146.482
				T/K = 333.15				
0.0252	0.90788	−0.026	81.810	−1.095	148.491	0.000	81.888	148.465
0.0508	0.91236	−0.057	81.825	−1.080	148.490	−0.001	81.772	148.430
0.0751	0.91668	−0.080	81.845	−1.059	148.489	−0.002	81.837	148.404
0.1000	0.92119	−0.101	81.872	−1.033	148.486	−0.005	81.893	148.379
0.1502	0.93067	−0.153	81.939	−0.966	148.477	−0.014	81.886	148.311
0.1999	0.94045	−0.194	82.020	−0.885	148.459	−0.032	81.934	148.248
0.2500	0.95083	−0.240	82.110	−0.794	148.433	−0.058	81.944	148.171
0.3002	0.96167	−0.271	82.207	−0.698	148.396	−0.095	82.001	148.103
0.3501	0.97296	−0.297	82.304	−0.601	148.349	−0.142	82.057	148.034
0.4000	0.98484	−0.318	82.399	−0.505	148.292	−0.199	82.109	147.960
0.4500	0.99727	−0.326	82.491	−0.414	148.225	−0.266	82.179	147.898
0.5003	1.01054	−0.338	82.576	−0.329	148.147	−0.344	82.229	147.814
0.5499	1.02425	−0.332	82.652	−0.253	148.064	−0.427	82.300	147.752
0.5999	1.03881	−0.321	82.718	−0.187	147.974	−0.517	82.369	147.688
0.6501	1.05434	−0.307	82.774	−0.130	147.880	−0.611	82.432	147.614
0.7000	1.07067	−0.285	82.819	−0.085	147.787	−0.704	82.498	147.541
0.7500	1.08777	−0.233	82.854	−0.051	147.697	−0.794	82.594	147.560
0.8000	1.10628	−0.201	82.878	−0.027	147.613	−0.878	82.653	147.484

dx.doi.org/10.1021/je101361u |*J. Chem. Eng. Data* 2011, 56, 1629–1657

Table 4. Continued

	ρ	V^E	V_1	V_1^E	V_2	V_2^E	V_{ϕ_1}	V_{ϕ_2}
x_1	g·cm^{-3}	cm^3·mol^{-1}	cm^3·mol^{-1}	cm^3·mol^{-1}	cm^3·mol^{-1}	cm^3·mol^{-1}	cm^3·mol^{-1}	cm^3·mol^{-1}
0.8499	1.12584	−0.154	82.893	−0.011	147.541	−0.950	82.723	147.463
0.9000	1.14689	−0.108	82.901	−0.003	147.485	−1.006	82.785	147.412
0.9250	1.15790	−0.077	82.903	−0.001	147.465	−1.026	82.821	147.458
0.9494	1.16926	−0.063	82.904	0.000	147.451	−1.040	82.838	147.240

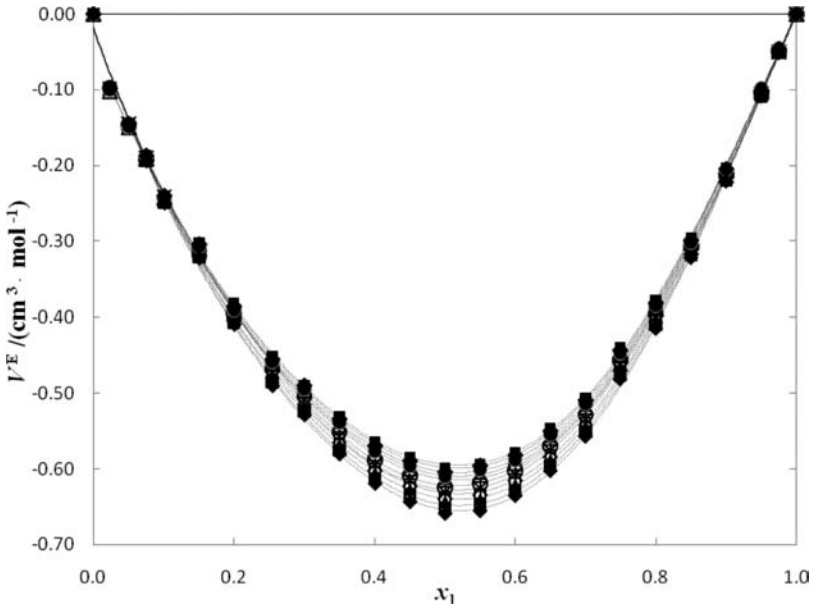

Figure 3. Plot of excess molar volume, V^E, for the system 1,2-DCE (1) + DEGDEE (2), against the mole fraction, x_1, at different temperatures. Symbols: experimental values (◆, 333.15 K; □, 328.15 K; ▲, 323.15 K; □, 318.15 K; ∗, 313.15 K; ○, 308.15 K; +, 303.15 K; △, 298.15 K; ●, 293.15 K; ◇, 288.15 K; ■, 283.15 K). Dashed lines: Redlich−Kister correlation.

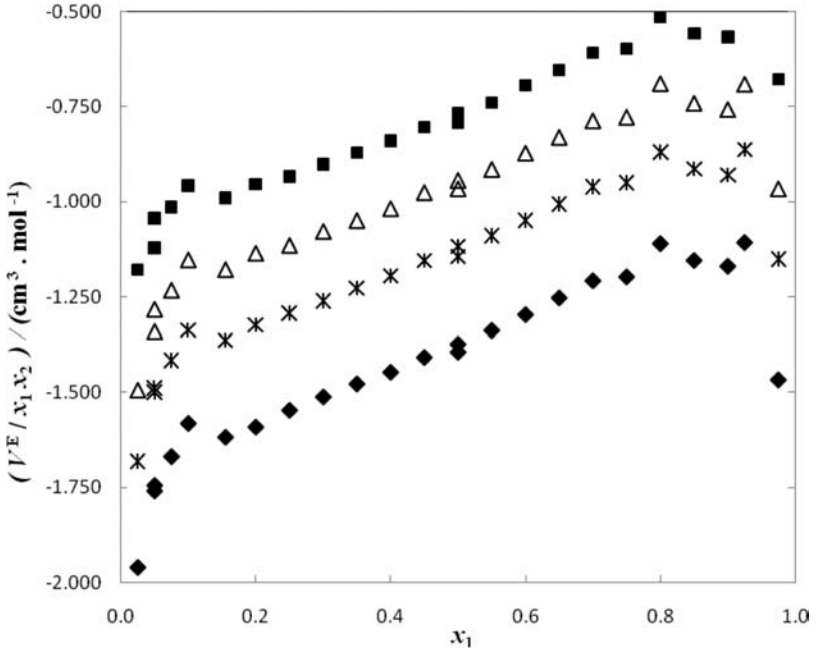

Figure 4. Plot of V^E/x_1x_2 for the system 1,2-DCE (1) + EGDME (2) against the mole fraction, x_1, at selected temperatures. ■, 283.15 K; △, 298.15 K; ∗, 313.15 K; ◆, 333.15 K.

dx.doi.org/10.1021/je101361u |J. Chem. Eng. Data 2011, 56, 1629–1657

Table 5. Experimental Densities, ρ, Excess Molar Volumes, V^E, Partial Molar Volumes, V_i, Partial Molar Excess Volumes, V_i^E, and Apparent Molar Volumes, $V_{\phi i}$, for the 1,2-DCE + DEGDEE Binary System

x_1	ρ / g·cm^{-3}	V^E / cm^3·mol^{-1}	V_1 / cm^3·mol^{-1}	V_1^E / cm^3·mol^{-1}	V_2 / cm^3·mol^{-1}	V_2^E / cm^3·mol^{-1}	V_{ϕ_1} / cm^3·mol^{-1}	V_{ϕ_2} / cm^3·mol^{-1}
				T/K = 283.15				
0.0234	0.92054	−0.097	75.812	−2.270	177.037	−0.001	73.942	176.938
0.0504	0.92519	−0.148	75.888	−2.194	177.034	−0.004	75.144	176.881
0.0751	0.92956	−0.194	75.953	−2.129	177.029	−0.008	75.502	176.828
0.1009	0.93431	−0.249	76.020	−2.062	177.023	−0.015	75.611	176.760
0.1504	0.94366	−0.322	76.158	−1.923	177.003	−0.035	75.940	176.658
0.2000	0.95371	−0.409	76.319	−1.763	176.968	−0.069	76.038	176.526
0.2546	0.96543	−0.490	76.523	−1.559	176.908	−0.129	76.158	176.380
0.2999	0.97565	−0.528	76.708	−1.374	176.837	−0.200	76.320	176.283
0.3500	0.98775	−0.580	76.919	−1.162	176.735	−0.302	76.425	176.145
0.4006	1.00078	−0.619	77.129	−0.953	176.609	−0.428	76.537	176.005
0.4502	1.01442	−0.643	77.319	−0.763	176.468	−0.569	76.653	175.868
0.5002	1.02916	−0.658	77.486	−0.595	176.317	−0.720	76.765	175.720
0.5499	1.04487	−0.655	77.624	−0.458	176.165	−0.872	76.891	175.582
0.6000	1.06187	−0.635	77.732	−0.350	176.020	−1.017	77.024	175.450
0.6500	1.08019	−0.602	77.811	−0.271	175.889	−1.149	77.156	175.317
0.6999	1.10005	−0.557	77.867	−0.215	175.772	−1.266	77.286	175.182
0.7492	1.12114	−0.481	77.909	−0.173	175.663	−1.375	77.440	175.120
0.8000	1.14522	−0.414	77.946	−0.136	175.535	−1.502	77.564	174.967
0.8500	1.17112	−0.321	77.983	−0.099	175.357	−1.681	77.704	174.895
0.9000	1.19976	−0.221	78.024	−0.058	175.066	−1.971	77.837	174.832
0.9500	1.23156	−0.108	78.062	−0.019	174.576	−2.462	77.968	174.876
0.9750	1.24890	−0.051	78.076	−0.006	174.219	−2.819	78.029	174.992
				T/K = 288.15				
0.0234	0.91570	−0.100	76.259	−2.271	177.974	−0.001	74.235	177.873
0.0504	0.92030	−0.148	76.349	−2.182	177.971	−0.004	75.592	177.819
0.0751	0.92464	−0.194	76.421	−2.109	177.966	−0.009	75.952	177.766
0.1009	0.92936	−0.250	76.493	−2.038	177.959	−0.016	76.057	177.698
0.1504	0.93864	−0.321	76.634	−1.897	177.939	−0.037	76.395	177.597
0.2000	0.94862	−0.407	76.792	−1.738	177.905	−0.070	76.494	177.466
0.2546	0.96024	−0.485	76.991	−1.540	177.846	−0.129	76.624	177.325
0.2999	0.97039	−0.524	77.172	−1.359	177.777	−0.199	76.784	177.227
0.3500	0.98241	−0.576	77.379	−1.151	177.677	−0.299	76.885	177.090
0.4006	0.99534	−0.613	77.586	−0.945	177.552	−0.423	76.999	176.952
0.4502	1.00887	−0.635	77.774	−0.756	177.413	−0.562	77.119	176.820
0.5002	1.02352	−0.653	77.940	−0.590	177.263	−0.712	77.226	176.670
0.5499	1.03911	−0.648	78.076	−0.454	177.113	−0.863	77.352	176.536
0.6000	1.05600	−0.629	78.182	−0.348	176.969	−1.006	77.482	176.403
0.6500	1.07419	−0.596	78.260	−0.270	176.841	−1.135	77.614	176.273
0.6999	1.09392	−0.551	78.315	−0.216	176.727	−1.248	77.743	176.138
0.7492	1.11487	−0.476	78.355	−0.175	176.622	−1.354	77.895	176.077
0.8000	1.13879	−0.410	78.391	−0.139	176.497	−1.478	78.017	175.924
0.8500	1.16452	−0.319	78.428	−0.102	176.319	−1.657	78.156	175.852
0.9000	1.19298	−0.219	78.470	−0.060	176.022	−1.954	78.287	175.782
0.9500	1.22458	−0.109	78.510	−0.020	175.513	−2.463	78.416	175.805
0.9750	1.24180	−0.052	78.525	−0.006	175.140	−2.836	78.477	175.908
				T/K = 293.15				
0.0234	0.91083	−0.096	76.745	−2.240	178.921	−0.001	74.861	178.823
0.0504	0.91541	−0.146	76.830	−2.156	178.917	−0.004	76.083	178.767
0.0751	0.91972	−0.192	76.900	−2.086	178.913	−0.009	76.432	178.714

dx.doi.org/10.1021/je101361u |J. Chem. Eng. Data 2011, 56, 1629–1657

Table 5. Continued

x_1	ρ / g·cm^{-3}	V^E / cm^3·mol^{-1}	V_1 / cm^3·mol^{-1}	V_1^E / cm^3·mol^{-1}	V_2 / cm^3·mol^{-1}	V_2^E / cm^3·mol^{-1}	V_{ϕ_1} / cm^3·mol^{-1}	V_{ϕ_2} / cm^3·mol^{-1}
0.1009	0.92439	−0.245	76.970	−2.016	178.906	−0.016	76.562	178.650
0.1504	0.93361	−0.317	77.110	−1.875	178.886	−0.036	76.879	178.549
0.2000	0.94352	−0.403	77.268	−1.717	178.852	−0.070	76.971	178.418
0.2546	0.95505	−0.479	77.466	−1.519	178.793	−0.128	77.103	178.279
0.2999	0.96513	−0.518	77.646	−1.340	178.724	−0.197	77.259	178.182
0.3500	0.97705	−0.568	77.851	−1.134	178.625	−0.296	77.363	178.048
0.4006	0.98989	−0.606	78.054	−0.931	178.503	−0.418	77.474	177.911
0.4502	1.00332	−0.627	78.239	−0.746	178.366	−0.555	77.592	177.781
0.5002	1.01786	−0.644	78.402	−0.584	178.219	−0.702	77.699	177.634
0.5499	1.03335	−0.640	78.536	−0.450	178.071	−0.850	77.821	177.499
0.6000	1.05012	−0.621	78.640	−0.345	177.930	−0.991	77.950	177.368
0.6500	1.06818	−0.588	78.717	−0.268	177.803	−1.119	78.080	177.241
0.6999	1.08777	−0.544	78.772	−0.213	177.689	−1.233	78.208	177.108
0.7492	1.10858	−0.470	78.813	−0.173	177.583	−1.339	78.358	177.048
0.8000	1.13234	−0.405	78.849	−0.136	177.457	−1.464	78.479	176.895
0.8500	1.15790	−0.315	78.886	−0.099	177.280	−1.642	78.615	176.823
0.9000	1.18617	−0.217	78.927	−0.058	176.988	−1.933	78.745	176.754
0.9500	1.21756	−0.107	78.966	−0.019	176.495	−2.427	78.872	176.776
0.9750	1.23466	−0.051	78.980	−0.006	176.135	−2.787	78.933	176.889
				T/K = 298.15				
0.0234	0.90598	−0.098	77.227	−2.220	179.879	−0.001	75.246	179.779
0.0504	0.91052	−0.146	77.313	−2.134	179.876	−0.004	76.543	179.726
0.0751	0.91480	−0.192	77.383	−2.064	179.871	−0.009	76.893	179.672
0.1009	0.91944	−0.245	77.454	−1.993	179.864	−0.016	77.019	179.607
0.1504	0.92858	−0.314	77.592	−1.855	179.844	−0.036	77.357	179.510
0.2000	0.93842	−0.400	77.748	−1.699	179.811	−0.069	77.446	179.379
0.2546	0.94986	−0.475	77.944	−1.503	179.753	−0.127	77.581	179.242
0.2999	0.95986	−0.512	78.122	−1.325	179.684	−0.195	77.739	179.148
0.3500	0.97169	−0.561	78.325	−1.122	179.586	−0.293	77.843	179.016
0.4006	0.98444	−0.599	78.527	−0.920	179.465	−0.415	77.951	178.880
0.4502	0.99777	−0.620	78.710	−0.737	179.330	−0.550	78.069	178.751
0.5002	1.01221	−0.637	78.871	−0.576	179.184	−0.696	78.173	178.605
0.5499	1.02758	−0.633	79.003	−0.444	179.038	−0.842	78.296	178.474
0.6000	1.04423	−0.614	79.106	−0.341	178.900	−0.980	78.424	178.344
0.6500	1.06216	−0.581	79.180	−0.267	178.776	−1.104	78.553	178.219
0.6999	1.08163	−0.539	79.233	−0.214	178.666	−1.213	78.677	178.083
0.7492	1.10229	−0.465	79.272	−0.175	178.564	−1.316	78.826	178.025
0.8000	1.12589	−0.402	79.308	−0.139	178.441	−1.439	78.945	177.872
0.8500	1.15127	−0.312	79.345	−0.102	178.264	−1.616	79.080	177.803
0.9000	1.17935	−0.215	79.387	−0.060	177.966	−1.914	79.208	177.732
0.9500	1.21052	−0.106	79.427	−0.020	177.457	−2.423	79.335	177.760
0.9750	1.22750	−0.050	79.441	−0.006	177.084	−2.796	79.396	177.886
				T/K = 303.15				
0.0234	0.90112	−0.098	77.709	−2.208	180.847	−0.001	75.719	180.748
0.0504	0.90562	−0.145	77.797	−2.119	180.844	−0.004	77.046	180.696
0.0751	0.90987	−0.190	77.869	−2.047	180.839	−0.009	77.385	180.643
0.1009	0.91447	−0.242	77.941	−1.975	180.832	−0.016	77.518	180.579
0.1504	0.92355	−0.312	78.082	−1.835	180.812	−0.036	77.842	180.481
0.2000	0.93331	−0.396	78.238	−1.679	180.779	−0.070	77.935	180.353
0.2546	0.94467	−0.472	78.432	−1.484	180.721	−0.127	78.065	180.216
0.2999	0.95459	−0.507	78.608	−1.309	180.654	−0.195	78.226	180.124
0.3500	0.96634	−0.557	78.808	−1.109	180.557	−0.291	78.325	179.991

dx.doi.org/10.1021/je101361u |*J. Chem. Eng. Data* 2011, 56, 1629–1657

Table 5. Continued

x_1	ρ / g·cm^{-3}	V^E / cm^3·mol^{-1}	V_1 / cm^3·mol^{-1}	V_1^E / cm^3·mol^{-1}	V_2 / cm^3·mol^{-1}	V_2^E / cm^3·mol^{-1}	V_{ϕ_1} / cm^3·mol^{-1}	V_{ϕ_2} / cm^3·mol^{-1}
0.4006	0.97899	−0.594	79.006	−0.910	180.438	−0.410	78.434	179.858
0.4502	0.99222	−0.614	79.186	−0.730	180.305	−0.544	78.552	179.731
0.5002	1.00655	−0.631	79.345	−0.572	180.161	−0.687	78.655	179.586
0.5499	1.02180	−0.626	79.475	−0.442	180.018	−0.830	78.779	179.458
0.6000	1.03833	−0.607	79.576	−0.340	179.881	−0.967	78.905	179.330
0.6500	1.05614	−0.576	79.650	−0.266	179.758	−1.091	79.031	179.204
0.6999	1.07547	−0.534	79.704	−0.213	179.648	−1.201	79.154	179.069
0.7492	1.09599	−0.461	79.743	−0.174	179.544	−1.304	79.301	179.010
0.8000	1.11942	−0.398	79.779	−0.138	179.420	−1.428	79.419	178.858
0.8500	1.14462	−0.309	79.816	−0.100	179.243	−1.606	79.553	178.790
0.9000	1.17251	−0.214	79.857	−0.059	178.948	−1.900	79.679	178.713
0.9500	1.20345	−0.105	79.897	−0.020	178.448	−2.401	79.806	178.749
0.9750	1.22032	−0.050	79.911	−0.006	178.082	−2.766	79.865	178.846
				T/K = 308.15				
0.0234	0.89625	−0.098	78.207	−2.187	181.828	−0.001	76.198	181.729
0.0504	0.90073	−0.147	78.295	−2.098	181.825	−0.004	77.479	181.675
0.0751	0.90495	−0.192	78.366	−2.027	181.820	−0.009	77.833	181.621
0.1009	0.90951	−0.243	78.437	−1.957	181.813	−0.016	77.987	181.559
0.1504	0.91852	−0.312	78.574	−1.819	181.794	−0.036	78.321	181.462
0.2000	0.92820	−0.394	78.728	−1.665	181.761	−0.069	78.422	181.337
0.2546	0.93947	−0.468	78.920	−1.473	181.704	−0.126	78.555	181.202
0.2999	0.94932	−0.504	79.095	−1.298	181.637	−0.193	78.713	181.110
0.3500	0.96097	−0.552	79.294	−1.099	181.541	−0.289	78.817	180.981
0.4006	0.97353	−0.589	79.492	−0.901	181.422	−0.408	78.924	180.847
0.4502	0.98666	−0.609	79.671	−0.722	181.289	−0.540	79.041	180.722
0.5002	1.00088	−0.625	79.828	−0.565	181.147	−0.682	79.144	180.580
0.5499	1.01602	−0.620	79.957	−0.437	181.005	−0.824	79.266	180.453
0.6000	1.03244	−0.603	80.056	−0.337	180.872	−0.958	79.389	180.323
0.6500	1.05011	−0.570	80.128	−0.266	180.752	−1.077	79.516	180.200
0.6999	1.06930	−0.529	80.178	−0.215	180.647	−1.182	79.637	180.066
0.7492	1.08967	−0.457	80.216	−0.177	180.548	−1.281	79.784	180.009
0.8000	1.11294	−0.395	80.251	−0.142	180.428	−1.402	79.899	179.855
0.8500	1.13796	−0.306	80.288	−0.105	180.248	−1.581	80.033	179.787
0.9000	1.16564	−0.211	80.331	−0.062	179.944	−1.885	80.158	179.717
0.9500	1.19636	−0.104	80.372	−0.021	179.420	−2.409	80.284	179.753
0.9750	1.21310	−0.049	80.387	−0.006	179.035	−2.794	80.343	179.876
				T/K = 313.15				
0.0234	0.89138	−0.098	78.704	−2.174	182.820	−0.001	76.684	182.721
0.0504	0.89582	−0.145	78.793	−2.085	182.817	−0.004	77.995	182.668
0.0751	0.90001	−0.191	78.865	−2.013	182.812	−0.009	78.337	182.615
0.1009	0.90454	−0.242	78.937	−1.941	182.805	−0.016	78.481	182.552
0.1504	0.91347	−0.308	79.076	−1.802	182.785	−0.036	78.830	182.458
0.2000	0.92309	−0.393	79.231	−1.647	182.752	−0.069	78.916	182.330
0.2546	0.93427	−0.465	79.422	−1.456	182.695	−0.126	79.052	182.197
0.2999	0.94404	−0.500	79.595	−1.283	182.629	−0.192	79.212	182.107
0.3500	0.95560	−0.547	79.792	−1.086	182.534	−0.287	79.316	181.980
0.4006	0.96806	−0.583	79.986	−0.892	182.417	−0.404	79.423	181.849
0.4502	0.98110	−0.604	80.162	−0.716	182.287	−0.534	79.536	181.722
0.5002	0.99521	−0.620	80.317	−0.561	182.147	−0.674	79.639	181.582
0.5499	1.01023	−0.614	80.443	−0.435	182.008	−0.814	79.762	181.457
0.6000	1.02651	−0.595	80.541	−0.337	181.876	−0.946	79.887	181.334
0.6500	1.04407	−0.565	80.612	−0.266	181.757	−1.064	80.008	181.206

dx.doi.org/10.1021/je101361u |*J. Chem. Eng. Data* 2011, 56, 1629–1657

Table 5. Continued

x_1	ρ / g·cm^{-3}	V^E / cm^3·mol^{-1}	V_1 / cm^3·mol^{-1}	V_1^E / cm^3·mol^{-1}	V_2 / cm^3·mol^{-1}	V_2^E / cm^3·mol^{-1}	V_{ϕ_1} / cm^3·mol^{-1}	V_{ϕ_2} / cm^3·mol^{-1}
0.6999	1.06311	−0.524	80.663	−0.215	181.652	−1.169	80.130	181.075
0.7492	1.08334	−0.453	80.701	−0.177	181.552	−1.269	80.274	181.016
0.8000	1.10644	−0.392	80.736	−0.142	181.430	−1.391	80.388	180.861
0.8500	1.13128	−0.305	80.774	−0.104	181.250	−1.571	80.520	180.790
0.9000	1.15875	−0.210	80.817	−0.061	180.947	−1.875	80.645	180.724
0.9500	1.18924	−0.103	80.858	−0.020	180.428	−2.393	80.770	180.762
0.9750	1.20585	−0.048	80.872	−0.006	180.049	−2.772	80.829	180.897
				T/K = 318.15				
0.0234	0.88651	−0.102	79.221	−2.150	183.827	−0.001	77.002	183.723
0.0504	0.89092	−0.150	79.308	−2.063	183.824	−0.004	78.399	183.670
0.0751	0.89506	−0.191	79.378	−1.993	183.819	−0.009	78.823	183.621
0.1009	0.89956	−0.243	79.447	−1.924	183.812	−0.016	78.963	183.558
0.1504	0.90843	−0.310	79.582	−1.789	183.793	−0.035	79.309	183.463
0.2000	0.91797	−0.393	79.733	−1.638	183.761	−0.067	79.407	183.337
0.2546	0.92905	−0.462	79.922	−1.449	183.705	−0.123	79.556	183.208
0.2999	0.93875	−0.497	80.094	−1.277	183.638	−0.190	79.713	183.118
0.3500	0.95021	−0.542	80.291	−1.080	183.544	−0.284	79.822	182.994
0.4006	0.96259	−0.580	80.485	−0.886	183.427	−0.401	79.922	182.860
0.4502	0.97552	−0.600	80.661	−0.710	183.296	−0.532	80.039	182.737
0.5002	0.98952	−0.615	80.815	−0.556	183.157	−0.671	80.142	182.598
0.5499	1.00442	−0.608	80.940	−0.431	183.020	−0.808	80.265	182.476
0.6000	1.02060	−0.592	81.036	−0.335	182.891	−0.937	80.384	182.347
0.6500	1.03800	−0.560	81.104	−0.267	182.777	−1.051	80.510	182.229
0.6999	1.05690	−0.519	81.152	−0.218	182.677	−1.151	80.629	182.098
0.7492	1.07700	−0.451	81.189	−0.182	182.582	−1.246	80.769	182.032
0.8000	1.09991	−0.389	81.223	−0.148	182.463	−1.365	80.885	181.884
0.8500	1.12457	−0.303	81.261	−0.109	182.279	−1.549	81.015	181.811
0.9000	1.15182	−0.207	81.306	−0.065	181.963	−1.865	81.141	181.755
0.9500	1.18208	−0.101	81.349	−0.022	181.413	−2.415	81.264	181.801
0.9750	1.19856	−0.047	81.365	−0.006	181.010	−2.818	81.323	181.964
0.0000	0.87766	0.000	79.666	−2.207	184.844	0.000	77.586	184.741
				T/K = 323.15				
0.0234	0.88162	−0.100	79.747	−2.126	184.843	−0.001	78.928	184.687
0.0504	0.88600	−0.149	79.828	−2.045	184.840	−0.004	79.367	184.640
0.0751	0.89010	−0.188	79.894	−1.979	184.835	−0.008	79.469	184.574
0.1009	0.89458	−0.243	79.962	−1.911	184.829	−0.015	79.832	184.482
0.1504	0.90337	−0.307	80.096	−1.777	184.809	−0.034	79.923	184.356
0.2000	0.91284	−0.390	80.248	−1.625	184.777	−0.067	80.072	184.229
0.2546	0.92383	−0.459	80.438	−1.436	184.721	−0.123	80.226	184.138
0.2999	0.93346	−0.494	80.609	−1.264	184.655	−0.189	80.334	184.015
0.3500	0.94483	−0.539	80.804	−1.069	184.561	−0.283	80.435	183.883
0.4006	0.95711	−0.576	80.996	−0.877	184.446	−0.398	80.550	183.760
0.4502	0.96994	−0.596	81.169	−0.704	184.318	−0.526	80.653	183.622
0.5002	0.98383	−0.610	81.320	−0.553	184.181	−0.663	80.780	183.509
0.5499	0.99859	−0.601	81.442	−0.431	184.046	−0.798	80.892	183.373
0.6000	1.01467	−0.588	81.537	−0.336	183.918	−0.926	81.020	183.260
0.6500	1.03192	−0.554	81.606	−0.267	183.804	−1.039	81.139	183.132
0.6999	1.05067	−0.514	81.655	−0.218	183.703	−1.141	81.276	183.061
0.7492	1.07063	−0.447	81.692	−0.181	183.605	−1.239	81.391	182.915
0.8000	1.09336	−0.386	81.727	−0.146	183.482	−1.362	81.519	182.836
0.8500	1.11784	−0.301	81.766	−0.107	183.298	−1.546	81.644	182.785
0.9000	1.14487	−0.206	81.810	−0.063	182.985	−1.859	81.770	182.878

dx.doi.org/10.1021/je101361u |*J. Chem. Eng. Data* 2011, 56, 1629–1657

Table 5. Continued

	ρ	V^E	V_1	V_1^E	V_2	V_2^E	V_{ϕ_1}	V_{ϕ_2}
x_1	g·cm^{-3}	cm^3·mol^{-1}	cm^3·mol^{-1}	cm^3·mol^{-1}	cm^3·mol^{-1}	cm^3·mol^{-1}	cm^3·mol^{-1}	cm^3·mol^{-1}
0.9500	1.17486	−0.098	81.852	−0.021	182.450	−2.393	81.826	183.025
0.9750	1.19123	−0.045	81.867	−0.006	182.061	−2.783	77.586	184.741
				T/K = 328.15				
0.0234	0.87673	−0.098	80.253	−2.131	185.870	−0.001	78.179	185.770
0.0504	0.88107	−0.145	80.344	−2.040	185.866	−0.005	79.504	185.718
0.0751	0.88515	−0.187	80.417	−1.966	185.861	−0.009	79.892	185.669
0.1009	0.88959	−0.240	80.490	−1.894	185.854	−0.016	80.002	185.604
0.1504	0.89831	−0.304	80.629	−1.755	185.834	−0.036	80.361	185.513
0.2000	0.90770	−0.386	80.781	−1.603	185.802	−0.069	80.453	185.388
0.2546	0.91861	−0.455	80.968	−1.416	185.747	−0.124	80.595	185.260
0.2999	0.92816	−0.490	81.136	−1.248	185.682	−0.189	80.750	185.171
0.3500	0.93944	−0.534	81.327	−1.057	185.590	−0.281	80.857	185.049
0.4006	0.95161	−0.570	81.515	−0.869	185.477	−0.394	80.962	184.921
0.4502	0.96434	−0.589	81.685	−0.699	185.351	−0.520	81.074	184.799
0.5002	0.97812	−0.604	81.834	−0.550	185.216	−0.655	81.175	184.662
0.5499	0.99277	−0.596	81.955	−0.428	185.082	−0.789	81.300	184.547
0.6000	1.00871	−0.582	82.049	−0.334	184.955	−0.915	81.414	184.416
0.6500	1.02584	−0.550	82.118	−0.266	184.842	−1.029	81.537	184.299
0.6999	1.04444	−0.510	82.167	−0.216	184.740	−1.131	81.656	184.173
0.7492	1.06424	−0.443	82.205	−0.179	184.642	−1.229	81.792	184.103
0.8000	1.08678	−0.382	82.240	−0.144	184.519	−1.352	81.907	183.963
0.8500	1.11108	−0.299	82.278	−0.105	184.336	−1.535	82.032	183.878
0.9000	1.13790	−0.205	82.321	−0.062	184.028	−1.843	82.156	183.823
0.9500	1.16769	−0.101	82.363	−0.021	183.503	−2.368	82.277	183.853
0.9750	1.18390	−0.046	82.378	−0.006	183.119	−2.751	82.336	184.017
				T/K = 333.15				
0.0234	0.87183	−0.099	80.771	−2.133	186.913	−0.001	78.692	186.813
0.0504	0.87613	−0.144	80.874	−2.031	186.909	−0.005	80.049	186.762
0.0751	0.88018	−0.186	80.954	−1.951	186.903	−0.010	80.424	186.712
0.1009	0.88459	−0.240	81.030	−1.875	186.896	−0.018	80.522	186.646
0.1504	0.89323	−0.302	81.170	−1.735	186.876	−0.038	80.898	186.559
0.2000	0.90254	−0.383	81.318	−1.586	186.844	−0.070	80.992	186.436
0.2546	0.91336	−0.451	81.500	−1.404	186.790	−0.123	81.133	186.309
0.2999	0.92286	−0.490	81.665	−1.240	186.727	−0.187	81.271	186.214
0.3500	0.93403	−0.531	81.852	−1.052	186.637	−0.277	81.388	186.097
0.4006	0.94609	−0.564	82.039	−0.866	186.525	−0.389	81.496	185.972
0.4502	0.95872	−0.584	82.209	−0.696	186.399	−0.515	81.606	185.851
0.5002	0.97239	−0.600	82.358	−0.547	186.264	−0.650	81.706	185.714
0.5499	0.98694	−0.593	82.480	−0.425	186.130	−0.784	81.826	185.595
0.6000	1.00274	−0.578	82.574	−0.331	186.003	−0.911	81.941	185.468
0.6500	1.01973	−0.546	82.642	−0.263	185.889	−1.025	82.064	185.353
0.6999	1.03818	−0.506	82.691	−0.214	185.789	−1.125	82.181	185.226
0.7492	1.05781	−0.439	82.727	−0.178	185.693	−1.220	82.318	185.162
0.8000	1.08017	−0.379	82.761	−0.143	185.575	−1.339	82.431	185.021
0.8500	1.10427	−0.296	82.799	−0.106	185.395	−1.518	82.556	184.939
0.9000	1.13088	−0.204	82.842	−0.063	185.088	−1.826	82.678	184.877
0.9500	1.16044	−0.102	82.884	−0.021	184.558	−2.356	82.798	184.880
0.9750	1.17653	−0.048	82.899	−0.006	184.169	−2.745	82.855	184.974

toward the region of low mole fraction of 1,2-DCE, for the mixtures containing EGDME. The V^E magnitudes, for both mixtures of 1,2-DCE with EGDME and DEGDME, are close and increase slightly as the temperature increases, whereas the V^E magnitude, for the mixture with DEGDEE, decreases as the temperature increases and is more important. Furthermore, the

dx.doi.org/10.1021/je101361u |J. Chem. Eng. Data 2011, 56, 1629–1657

Table 6. Parameters A_i of Equation 2 and Standard Deviations, σ, at Different Temperatures, for the 1,2-DCE + Polyether (EGDME, DEGDME, or DEGDEE) Binary Systems

T/K	A_1	A_2	A_3	A_4	A_5	σ/(cm^3·mol^{-1})
			1,2-DCE (1) + EGDME (2)			
283.15	−0.7691	0.3743	0.0169	−0.1097		0.003
288.15	−0.8305	0.3689	−0.0161	−0.0886		0.004
293.15	−0.8881	0.3700	−0.0115	−0.0909		0.004
298.15	−0.9431	0.3707	−0.0165	−0.0906		0.004
303.15	−1.0039	0.3704	−0.0224	−0.0814		0.004
308.15	−1.0752	0.3808	0.1782	−0.3649		0.003
313.15	−1.1191	0.3783	−0.0220	−0.0914		0.004
318.15	−1.1788	0.3752	−0.0179	−0.0774		0.004
323.15	−1.2418	0.3812	−0.0229	−0.0814		0.004
328.15	−1.3065	0.3901	−0.0164	−0.0897		0.004
333.15	−1.3694	0.3896	−0.0196	−0.0974		0.004
			1,2-DCE (1) + DEGDME (2)			
283.15	−1.1301	0.0118	0.3283			0.003
288.15	−1.1496	−0.0075	0.3159			0.004
293.15	−1.1704	−0.0093	0.3146			0.004
298.15	−1.1870	−0.0142	0.3177			0.004
303.15	−1.2085	−0.0200	0.3149			0.004
308.15	−1.2282	−0.0265	0.3207			0.004
313.15	−1.2495	−0.0279	0.3163			0.004
318.15	−1.2721	−0.0256	0.3181			0.004
323.15	−1.2946	−0.0268	0.3218			0.004
328.15	−1.3211	−0.0198	0.2943			0.005
333.15	−1.3447	−0.0280	0.2701			0.004
			1,2-DCE (1) + DEGDEE (2)			
283.15	−2.6315	−0.2479	0.4389	0.7124	−0.6167	0.008
288.15	−2.6057	−0.2417	0.4383	0.7168	−0.6704	0.009
293.15	−2.5720	−0.2359	0.4157	0.6964	−0.6296	0.008
298.15	−2.5438	−0.2382	0.4078	0.7207	−0.6545	0.009
303.15	−2.5178	−0.2281	0.3870	0.6950	−0.6339	0.009
308.15	−2.4947	−0.2332	0.3801	0.7372	−0.6668	0.009
313.15	−2.4708	−0.2244	0.3563	0.7193	−0.6463	0.009
318.15	−2.4527	−0.2279	0.3513	0.7747	−0.6863	0.009
323.15	−2.4319	−0.2170	0.3219	0.7529	−0.6329	0.009
328.15	−2.4085	−0.2077	0.3137	0.7153	−0.6369	0.009
333.15	−2.3933	−0.2039	0.3357	0.7046	−0.6846	0.009

temperature effect on V^E decreases in the sequence EGDME < DEGDME < DEGDEE. Over the entire temperature range investigated, the absolute maximum V^E/(cm^3·mol^{-1}) value for the systems 1,2-DCE + EGDME and 1,2-DCE + DEGDME increases from 0.202 to 0.347 and from 0.285 to 0.338, respectively, while it decreases from 0.658 to 0.600 for 1,2-DCE + DEGDEE. So, when the alkyl chain end length of the polyether is fixed, a small increase in the magnitude V^E is observed with the addition of an OC_2H_4 group at the middle of the ether molecule. Contrarily, when the number of OC_2H_4 group is fixed, the V^E is more negative when the alkyl chain end length increases. To the best of our knowledge, there is no V^E data reported for the binary systems investigated, except for 1,2-DCE + EGDME.[12] A comparison of our experimental results with these literature data[12] does not agree. In fact, V^E literature data[12] exhibit an S-shape curve. It should be pointed out that no S-shape curve was found for the excess molar enthalpies.[26]

Knowledge of partial molar properties at infinite dilution provides useful information about solute−solvent interactions since, at the infinite dilution, solute−solute interactions disappear. This information is of particular interest because it is independent of the composition of the mixture. In this work, we are also interested in focusing on the partial molar volume of 1,2-DCE at infinite dilution ($x_1 = 0$) in a polyether (EGDME, DEGDME, or DEGDEE) and partial molar volume of the polyether at infinite dilution ($x_2 = 0$) in 1,2-DCE.

The partial molar volumes, V_1 and V_2, for 1,2-DCE (1) and polyether (2), respectively, were evaluated over the whole composition according to the following equations

$$V_1 = V^E + V_1^0 + (1 - x_1)(\partial V^E/\partial x_1)_{P,T} \quad (4)$$

$$V_2 = V^E + V_2^0 - x_1(\partial V^E/\partial x_1)_{P,T} \quad (5)$$

where V_1^0 and V_2^0 are the molar volumes of pure liquid compounds 1 and 2, respectively.

Differentiation of V^E from eq 2 with respect to x_1 and substitution of the results in eqs 4 and 5 lead to the following eqs 6 and 7 for the partial molar volumes V_1 and V_2

$$V_1 = V_1^0 + (1 - x_1)^2 \sum_{i=0}^{i=n} A_i(1 - 2x_1)^i - 2x_1(1 - x_1)^2 \sum_{i=0}^{i=n} A_i(i)(1 - 2x_1)^{i-1} \quad (6)$$

$$V_2 = V_2^0 + x_1^2 \sum_{i=0}^{i=n} A_i(1 - 2x_1)^i + 2x_1^2(1 - x_1) \sum_{i=0}^{i=n} A_i(i)(1 - 2x_1)^{i-1} \quad (7)$$

Setting $x_1 = 0$ in eq 6 and $x_2 = 0$ in eq 7 leads to eqs 8 and 9, for the partial molar volume of 1,2-DCE at infinite dilution, V_1^∞, in the polyether and the partial molar volume of the polyether at infinite dilution, V_2^∞, in 1,2-DCE

$$V_1^\infty = V_1^0 + \sum_{i=0}^{i=n} A_i \quad (8)$$

$$V_2^\infty = V_2^0 + \sum_{i=0}^{i=n} A_i(i)^{-1} \quad (9)$$

Rearrangement of eqs 8 and 9 leads to eqs 10 and 11, for the partial excess molar volume of 1,2-DCE at infinite dilution,-$(V_1^E)^\infty$, in the polyether, and the partial molar volume of the polyether at infinite dilution, $(V_2^E)^\infty$, in 1,2-DCE, respectively,

$$(V_1^E)^\infty = \sum_{i=0}^{i=n} A_i \quad (10)$$

$$(V_2^E)^\infty = \sum_{i=0}^{i=n} A_i(i)^{-1} \quad (11)$$

Table 7. Partial Molar Volume at Infinite Dilution, V_1^{∞}, and Partial Molar Excess Volume at Infinite Dilution, $V^{E}{}_1^{\infty}$, of 1,2-DCE in Polyether as a Function of Temperature

	$V_1^{\infty}/(cm^3 \cdot mol^{-1})$		$(V_1^{E})^{\infty}/(cm^3 \cdot mol^{-1})$	
T/K	calculated using the Redlich−Kister equation	calculated using eqs 15 and 16	calculated using the Redlich−Kister equation	calculated using eqs 15 and 16
		1,2-DCE (1) + EGDME (2)		
283.15	77.594	76.866	−0.488	−1.216
288.15	77.964	77.117	−0.566	−1.413
293.15	78.365	77.513	−0.621	−1.472
298.15	78.768	77.907	−0.680	−1.540
303.15	79.179	78.250	−0.737	−1.667
308.15	79.512	78.622	−0.881	−1.771
313.15	80.024	79.154	−0.854	−1.724
318.15	80.472	79.569	−0.899	−1.802
323.15	80.908	79.948	−0.965	−1.925
328.15	81.361	80.407	−1.022	−1.977
333.15	81.808	80.906	−1.097	−1.999
		1,2-DCE (1) + DEGDME (2)		
283.15	77.292	77.217	−0.790	−0.865
288.15	77.689	77.639	−0.841	−0.891
293.15	78.120	78.084	−0.865	−0.901
298.15	78.564	78.539	−0.883	−0.908
303.15	79.003	78.991	−0.914	−0.926
308.15	79.459	79.433	−0.934	−0.960
313.15	79.917	79.894	−0.961	−0.984
318.15	80.391	80.370	−0.980	−1.001
323.15	80.873	80.841	−1.000	−1.032
328.15	81.337	81.269	−1.047	−1.115
333.15	81.802	81.770	−1.103	−1.135
		1,2-DCE (1) + DEGDEE (2)		
283.15	75.737	73.211	−2.345	−4.871
288.15	76.168	73.449	−2.363	−5.081
293.15	76.660	74.121	−2.325	−4.864
298.15	77.139	74.478	−2.308	−4.969
303.15	77.619	74.944	−2.298	−4.973
308.15	78.116	75.421	−2.277	−4.972
313.15	78.612	75.905	−2.266	−4.973
318.15	79.130	76.143	−2.241	−5.228
323.15	79.666	76.752	−2.207	−5.121
328.15	80.159	77.383	−2.224	−5.001
333.15	80.663	77.893	−2.242	−5.012

Partial molar volumes, V_i, partial molar volumes at infinite dilution, V_i^{∞}, and partial molar excess volumes at infinite dilution, $(V_i^{E})^{\infty}$, were calculated at several temperatures ranging from (283.15 to 333.15) K, using the parameters A_i listed in Table 6. Values of V_i are listed in Tables 3 to 5 and those of V_i^{∞} and $(V_i^{E})^{\infty}$ are reported in Tables 7 and 8, respectively.

Following the suggestion of Desnoyers and Perron,[27] the quantity V^{E}/x_1x_2 was also calculated as it is more appropriate to give information on interactions at low concentrations. This thermodynamic quantity is equivalent to an apparent molar volume over the whole mole fraction range. In fact, $V^{E}/x_1x_2 = (V_{\phi 2} - V_2^0)/x_1 = (V_{\phi 1} - V_1^0)x_2$, where $V_{\phi i}$ is the apparent molar volume of i species and tends to the two excess standard partial molar volumes $(V_2 - V_2^0)$ and $(V_1 - V_1^0)$ as x_2 tends to 0 or 1. The trends of V^{E}/x_1x_2 with concentration will reflect the intermolecular interactions as in the case of apparent or partial molar volumes. The composition and temperature dependence of V^{E}/x_1x_2 for the binary mixtures investigated are reported in Figures 4 to 6. These plots show that the utilization of a polynomial expression like the one suggested by Redlich−Kister is not well-adapted for the representation of the excess volume. It shows that the three systems have different behaviors, particularly in their respective dilute regions. Such behaviors can be attributed to packing effect (due to the chain length of each chemical) or the effect of the additional C_2H_4O group of the

Table 8. Partial Molar Volume at Infinite Dilution, V_2^{∞}, and Partial Molar Excess Volume at Infinite Dilution, $(V_2^{E})^{\infty}$, of Polyether in 1,2-DCE as a Function of Temperature

	$V_1^{\infty}/(cm^3 \cdot mol^{-1})$		$(V_1^{E})^{\infty}/(cm^3 \cdot mol^{-1})$	
T/K	calculated using the Redlich−Kister equation	calculated using eqs 15 and 16	calculated using the Redlich−Kister equation	calculated using eqs 15 and 16
283.15	101.668	101.969	−1.017	−0.715
288.15	102.194	102.524	−1.127	−0.797
293.15	102.791	102.971	−1.179	−0.999
298.15	103.390	103.598	−1.240	−1.032
303.15	103.990	104.267	−1.315	−1.038
308.15	105.081	104.838	−0.913	−1.156
313.15	105.265	105.474	−1.428	−1.219
318.15	105.914	106.118	−1.495	−1.290
323.15	106.576	106.780	−1.565	−1.361
328.15	107.266	107.485	−1.623	−1.404
333.15	107.973	108.102	−1.681	−1.552
		1,2-DCE (1) + DEGDME (2)		
283.15	139.881	139.774	−0.814	−0.921
288.15	140.601	140.432	−0.826	−0.995
293.15	141.324	141.160	−0.846	−1.011
298.15	142.067	141.889	−0.855	−1.033
303.15	142.810	142.596	−0.874	−1.088
308.15	143.575	143.352	−0.881	−1.104
313.15	144.334	144.058	−0.905	−1.181
318.15	145.106	144.847	−0.928	−1.187
323.15	145.894	145.656	−0.946	−1.184
328.15	146.654	146.405	−1.007	−1.256
333.15	147.444	147.145	−1.047	−1.346
		1,2-DCE (1) + DEGDEE (2)		
283.15	173.764	175.096	−3.274	−1.941
288.15	174.663	175.990	−3.313	−1.985
293.15	175.675	176.975	−3.246	−1.947
298.15	176.607	177.980	−3.273	−1.900
303.15	177.617	178.935	−3.232	−1.913
308.15	178.544	179.977	−3.285	−1.852
313.15	179.565	181.007	−3.256	−1.814
318.15	180.493	182.091	−3.334	−1.737
323.15	181.565	183.184	−3.279	−1.660
328.15	182.632	184.136	−3.239	−1.735
333.15	183.671	185.045	−3.243	−1.869

DEGDEE which seems to increase the polarity and so the attractive interaction with 1,2-DCE.

Consequently, instead of using the equation of Redlich−Kister (eq 2), we have also considered another approach by calculating the partial molar volumes at infinite dilution, through apparent molar volumes, $V_{\phi i}$. The apparent molar volumes of 1,2-DCE in polyether, $V_{\phi 1}$, and the apparent molar volume of polyether in 1,2-DCE, $V_{\phi 2}$, are given by the following equations:

$$V_{\phi 1} = (V - x_2 V_2^0)/x_1 \quad (12)$$

$$V_{\phi 2} = (V - x_1 V_1^0)/x_2 \quad (13)$$

where the molar volume of the binary mixture, V, is defined by:

$$V = V^E + (x_1 V_1^0 + x_2 V_2^0) \quad (14)$$

The combination of eqs 12 to 14 leads to eqs 15 and 16, for the apparent molar volumes $V_{\phi 1}$ and $V_{\phi 2}$

$$V_{\phi 1} = V_1^0 + (V^E/x_1) \quad (15)$$

$$V_{\phi 2} = V_2^0 + (V^E/x_2) \quad (16)$$

The calculated apparent molar volumes, $V_{\phi i}$, are reported in Tables 3 to 5. Graphical or analytical extrapolation of $V_{\phi i}$ to $x_i = 0$ leads to the desired value of V_i^{∞}. Accordingly, partial molar excess volumes at infinite dilution, $(V_i^E)^{\infty}$, were then calculated.

dx.doi.org/10.1021/je101361u |J. Chem. Eng. Data 2011, 56, 1629–1657

Table 9. Values of the V^E Temperature Derivative, $(\partial V^E/\partial T)_{p,x}$, for the 1,2-DCE + Polyether (EGDME, DEGDME, or DEGDEE) Binary Systems

x_1	$(\partial V^E/\partial T)_{p,x}$ / $cm^3 \cdot mol^{-1} \cdot K^{-1}$	x_1	$(\partial V^E/\partial T)_{p,x}$ / $cm^3 \cdot mol^{-1} \cdot K^{-1}$	x_1	$(\partial V^E/\partial T)_{p,x}$ / $cm^3 \cdot mol^{-1} \cdot K^{-1}$
1,2-DCE (1) + EGDME (2)		1,2-DCE (1) + DEGDME (2)		1,2-DCE (1) + DEGDEE (2)	
0.0251	−0.0003569932	0.0252	−0.0001566699	0.0234	−0.0000348262
0.0500	−0.0006787719	0.0508	−0.0002549567	0.0504	0.0000335718
0.0501	−0.0005702628	0.0751	−0.0002977375	0.0751	0.0001347678
0.0750	−0.0008783532	0.1000	−0.0003841474	0.1009	0.0001672959
0.1000	−0.0010897142	0.1502	−0.0005606860	0.1504	0.0003836417
0.1552	−0.0016206023	0.1999	−0.0006212157	0.2000	0.0004978620
0.2001	−0.0020119846	0.2500	−0.0007798659	0.2546	0.0007424547
0.2501	−0.0022675896	0.3002	−0.0008201637	0.2999	0.0007913590
0.3002	−0.0025415354	0.3501	−0.0009710676	0.3500	0.0009973677
0.3500	−0.0027376623	0.4000	−0.0010074824	0.4006	0.0010632112
0.4001	−0.0028788402	0.4500	−0.0009863172	0.4502	0.0011322557
0.4500	−0.0029701624	0.5003	−0.0010586785	0.5002	0.0011695026
0.5000	−0.0029914932	0.5499	−0.0010502146	0.5499	0.0012625266
0.5001	−0.0029903228	0.5999	−0.0010719259	0.6000	0.0011365933
0.5500	−0.0029366337	0.6501	−0.0010331410	0.6500	0.0011197886
0.6001	−0.0028568936	0.7000	−0.0011036422	0.6999	0.0010186963
0.6500	−0.0026802513	0.7500	−0.0008566993	0.7492	0.0008077061
0.7000	−0.0024786383	0.8000	−0.0007327815	0.8000	0.0006961388
0.7500	−0.0022094021	0.8499	−0.0006364844	0.8500	0.0004855911
0.8000	−0.0018730333	0.9000	−0.0004470392	0.9000	0.0003518785
0.8500	−0.0014873654	0.9250	−0.0003429820	0.9500	0.0001830161
0.9000	−0.0010578774	0.9494	−0.0002512350	0.9750	0.0001074735
0.9250	−0.0008283219				
0.9750	−0.0003486463				

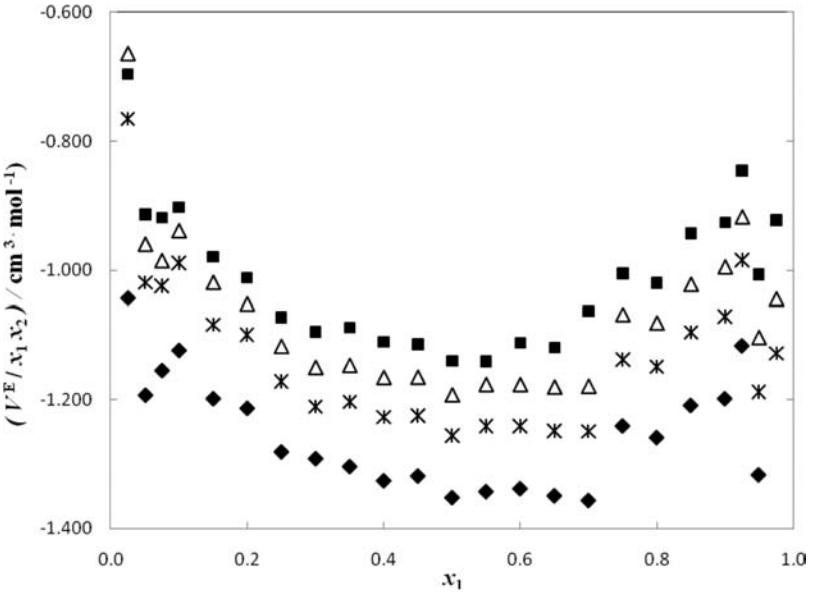

Figure 5. Plot of V^E/x_1x_2 for the system 1,2-DCE (1) + DEGDME (2) against the mole fraction, x_1, at selected temperatures. ■, 283.15 K; △, 298.15 K; ∗, 313.15 K; ◆, 333.15 K.

For comparison, the results were reported in Tables 7 and 8, along with results obtained using the Redlich−Kister equation. As it can be seen, the results obtained using both approaches do not always agree, as expected, and it is difficult to identify which

dx.doi.org/10.1021/je101361u |J. Chem. Eng. Data 2011, 56, 1629–1657

Table 10. Coefficients of Thermal Expansion of Pure Compounds, α_i, and Mixtures, α, and of Excess Thermal Expansion, α^E, at 298.15 K, for the 1,2-DCE + Polyether (EGDME, DEGDME, or DEGDEE) Binary Systems

x_1	$10^3\alpha/(K^{-1})$	$10^6\alpha^E/(K^{-1})$	x_1	$10^3\alpha/(K^{-1})$	$10^6\alpha^E/(K^{-1})$	x_1	$10^3\alpha/(K^{-1})$	$10^6\alpha^E/(K^{-1})$
	1,2-DCE + EGDME			1,2-DCE + DEGDME			1,2-DCE + DEGDEE	
0.0000	1.276	0.000	0.0000	1.059	0.000	0.0000	1.071	0.000
0.0251	1.271	−2.986	0.0252	1.060	−0.986	0.0234	1.072	0.398
0.0500	1.266	−5.821	0.0508	1.061	−1.474	0.0504	1.074	1.092
0.0501	1.267	−4.734	0.0751	1.063	−1.629	0.0751	1.076	1.980
0.0750	1.262	−7.498	0.1000	1.064	−2.155	0.1009	1.078	2.542
0.1000	1.259	−9.393	0.1502	1.066	−3.164	0.1504	1.083	4.393
0.1552	1.249	−14.173	0.1999	1.070	−3.388	0.2000	1.087	5.839
0.2001	1.241	−17.936	0.2500	1.073	−4.369	0.2546	1.092	8.175
0.2501	1.234	−20.434	0.3002	1.076	−4.521	0.2999	1.096	9.033
0.3002	1.227	−23.318	0.3501	1.079	−5.711	0.3500	1.101	11.163
0.3500	1.220	−25.530	0.4000	1.084	−5.992	0.4006	1.106	12.360
0.4001	1.214	−27.308	0.4500	1.088	−5.879	0.4502	1.111	13.526
0.4500	1.207	−28.708	0.5003	1.093	−6.591	0.5002	1.116	14.508
0.5000	1.201	−29.420	0.5499	1.098	−6.762	0.5499	1.122	15.825
0.5001	1.201	−29.336	0.5999	1.103	−7.252	0.6000	1.126	15.284
0.5500	1.196	−29.362	0.6501	1.109	−7.181	0.6500	1.132	15.511
0.6001	1.191	−29.127	0.7000	1.115	−7.501	0.6999	1.137	14.890
0.6500	1.187	−27.824	0.7500	1.123	−6.628	0.7492	1.141	12.790
0.7000	1.183	−26.240	0.8000	1.131	−5.830	0.8000	1.147	11.620
0.7500	1.179	−23.760	0.8499	1.139	−5.485	0.8500	1.152	8.934
0.8000	1.177	−20.632	0.9000	1.149	−4.012	0.9000	1.158	6.711
0.8500	1.174	−16.537	0.9250	1.154	−3.201	0.9500	1.164	3.628
0.9000	1.173	−11.930	0.9494	1.159	−2.296	0.9750	1.168	2.022
0.9250	1.172	−9.492	1.0000	1.171	0.000	1.0000	1.171	0.000
0.9750	1.171	−4.009						
1.0000	1.171	0.000						

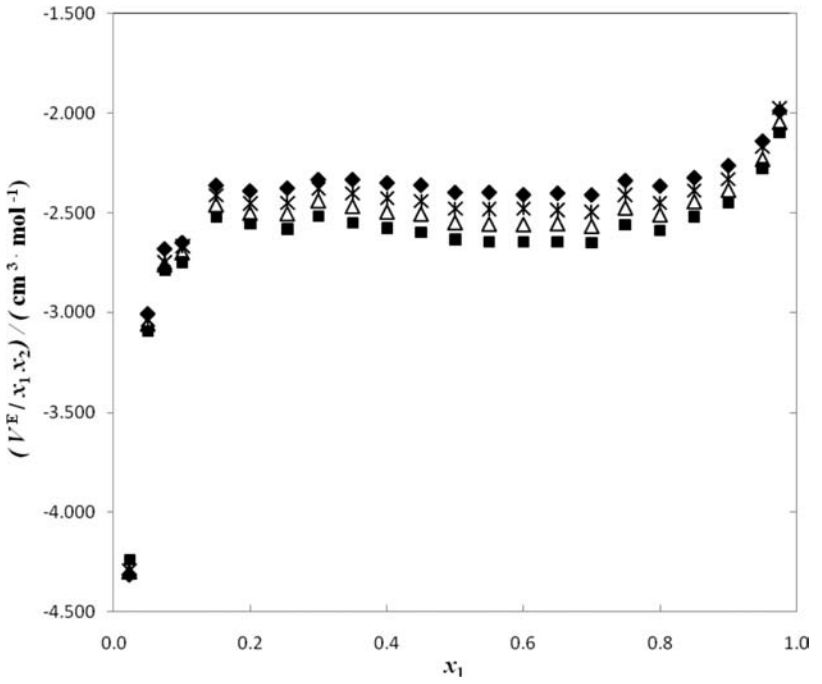

Figure 6. Plot of V^E/x_1x_2 for the system 1,2-DCE (1) + DEGDEE (2) against the mole fraction, x_1, at selected temperatures. ■, 283.15 K; △, 298.15 K; ∗, 313.15 K; ◆, 333.15 K.

dx.doi.org/10.1021/je101361u |*J. Chem. Eng. Data* 2011, 56, 1629–1657

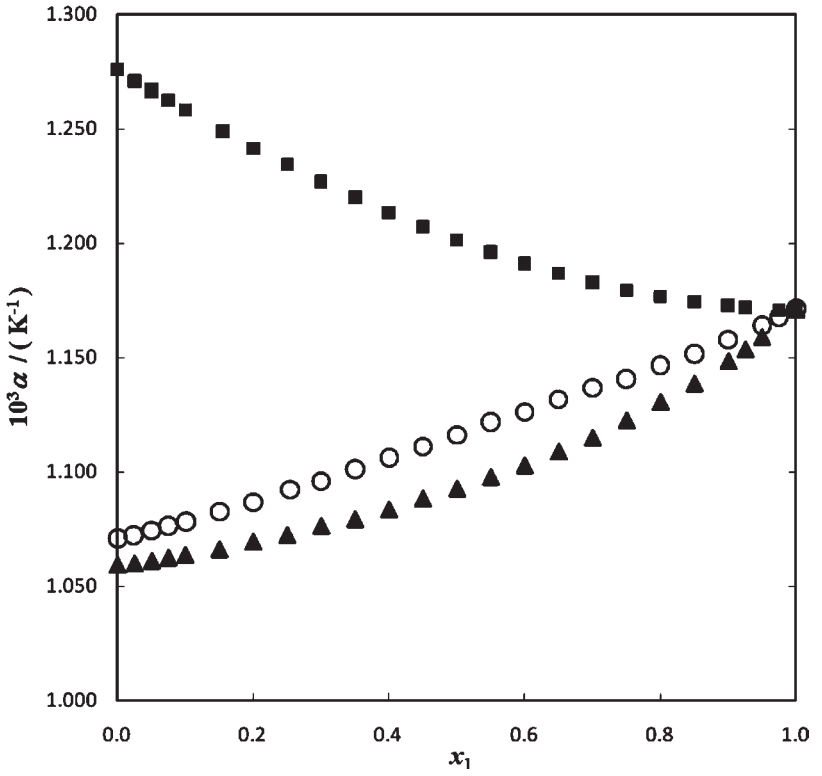

Figure 7. Plot of thermal expansivity, α, of the 1,2-DCE (1) + polyether (2) binary systems against the mole fraction, x_1, at 298.15 K. ■, EGDME; ○, DEGDME; ▲, DEGDEE.

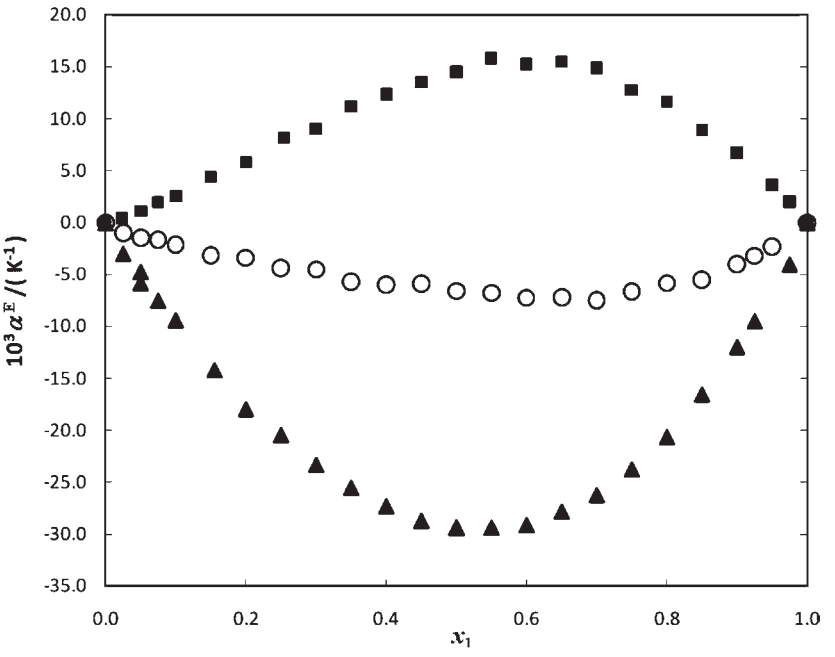

Figure 8. Plot of excess thermal expansivity, α^E, of the 1,2-DCE (1) + polyether (2) binary systems against the mole fraction, x_1, at 298.15 K. ■, EGDME; ○, DEGDME; ▲, DEGDEE.

one is the best. More information is needed in the very dilute region.

To understand the change in the solution structure during mixing, thermal expansivities were calculated from the density and V^E results. Thermal expansion coefficients, α_i and α, for pure compounds and mixtures, respectively, are defined by:

$$\alpha_i = (1/V_i^0)(\partial V_i^0/\partial T)_P \quad (17)$$

dx.doi.org/10.1021/je101361u |*J. Chem. Eng. Data* 2011, 56, 1629–1657

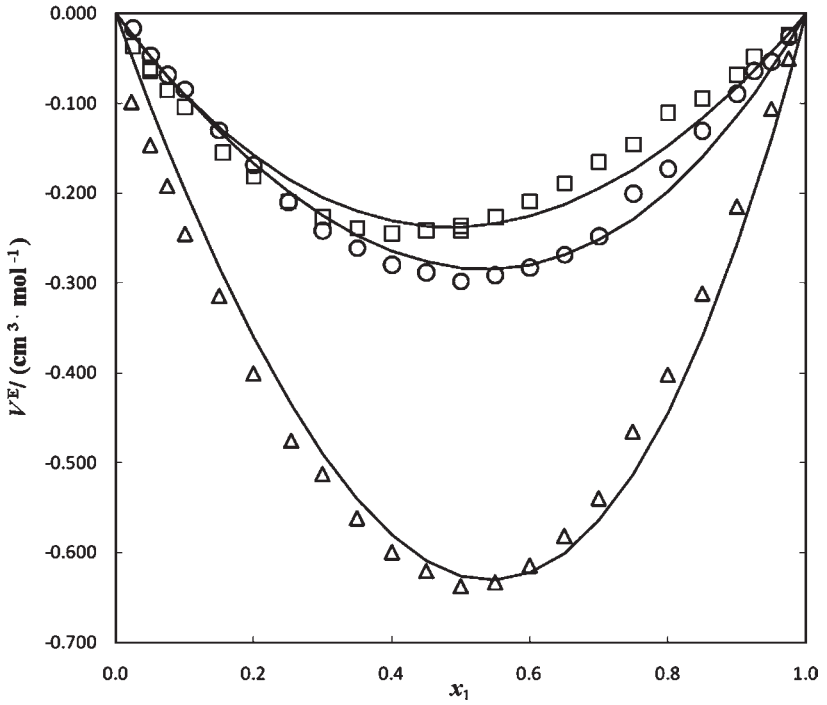

Figure 9. Plot of excess molar volume, V^E, of the 1,2-DCE (1) + polyether (2) binary systems against the mole fraction, x_1, at T = 298.15 K. Symbols, experimental results (■, EGDME; ○, DEGDME; ▲, DEGDE). Solid line, PFP model calculation.

Table 11. Physical Constants of Pure Compounds, at 298.15 K, used for Calculations of Excess Molar Volume, V^E, with PFP Model: V_i^0, Molar Volume; α_i, Coefficient of Thermal Expansion; κ_{Ti}, Isothermal Compressibility; Reduction Parameters of Volume, V_i^*, and Pressure, P_i^*

	V_i^0	$10^3\ \alpha_i$	$10^3\ \kappa_{Ti}$	V_i^*	P_i^*
compound	cm^3·mol^{-1}	K^{-1}	MPa^{-1}	cm^3·mol^{-1}	MPa
1,2-DCE	79.447	1.171[a]	7.620[c]	752.735	61.983
EDGME	104.630	1.276[a]	1.116[d]	577.608	80.380
DEGDME	142.922	1.059[a]	8.194[d]	611.740	113.459
DEGDEE	179.880	1.071[a]	0.900[b]	565.144	142.526

[a] This work. [b] Ref 15. [c] Ref 28. [d] Ref 29.

$$\alpha = (1/V)[(\partial V^E/\partial T)_{P,x} + \sum_{i=1}^{i=2} \alpha_i x_i V_i^0] \qquad (18)$$

Excess thermal expansions, α^E, were calculated using the following equation:

$$\alpha^E = \alpha - \sum_{i=1}^{i=2} \phi_i \alpha_i \qquad (19)$$

where ϕ_i is the volume fraction of the pure component i, defined as: $\phi_i = x_i V_i^0 / \sum_i x_i V_i^0$.

Values of the V^E temperature derivative, $(\partial V^E/\partial T)_{P,x}$, as a function of composition, for the binary mixtures investigated, are reported in Table 9. The values of the thermal expansivities α_i and α, and those of excess thermal expansivity, α^E, at 298.15 K, are reported in Table 10. Composition dependences of α and α^E are plotted in Figures 7 and 8, respectively. It can be shown that the behavior with EGDME is different because the size of this molecule is smaller than the others.

Application of the Prigogine–Flory–Patterson (PFP) Theory. PFP theory[1−9] has been used extensively to model excess thermodynamic functions of nonelectrolyte systems for different kinds of mixtures. Here, we have applied PFP's theory to predict excess molar volume, V^E, for the binary mixtures investigated, at 298.15 K and atmospheric pressure. By using this theory, quantitative estimation of different contributions to V^E values can be obtained.

According to PFP's theory, V^E is divided into three contributions: (i) interactional, which is proportional to χ_{12}, the so-called cross parameter; (ii) the free volume contribution, which arises from the dependence of the reduced volume upon the reduced temperature as a result of the difference between the degree of expansion of the two components; and (iii) the P^* contribution, which depends both on the differences of internal pressures and differences of reduced volumes of the components. PFP's theory leads to the following expression for V^E in terms of the three contributions:

$$\frac{V_m^E}{(x_1 V_1^* + x_2 V_2^*)} = \frac{(\tilde{V}^{1/3}-1)\tilde{V}^{2/3}}{[(4/3)\tilde{V}^{1/3}-1)]}\Psi_1\theta_2\left[\frac{\chi_{12}}{P_1^*}\right] \text{ (interactional contribution)}$$

$$-\frac{(\tilde{V}_1-\tilde{V}_2)^2[(14/9)\tilde{V}^{1/3}-1)]}{[(4/3)\tilde{V}^{1/3}-1)]}\Psi_1\Psi_2 \text{ (curvature contribution)}$$

$$+\frac{(\tilde{V}_1-\tilde{V}_2)^2-(P_1^*-P_2^*)}{P_1^*\Psi_2+P_2^*\Psi_1}\Psi_1\Psi_2 \text{ (internal pressure effect)} \qquad (20)$$

The reduced volume, $\tilde{V}$, of the solution is approximated in eq 21 by:

$$\tilde{V} = \Psi_1\tilde{V}_1 + \Psi_2\tilde{V}_2 \qquad (21)$$

dx.doi.org/10.1021/je101361u |J. Chem. Eng. Data 2011, 56, 1629–1657

Table 12. Values of the χ_{12} Interaction Parameter and Calculated Contributions to $V^E(x_1 = 0.5)$, at $T = 298.15$ K, for the 1, 2-DCE + Polyether (EGDME, DEGDME, or DEGDEE) Binary Systems

	χ_{12}	$V^E(x_1 = 0.5)/(cm^3 \cdot mol^{-1})$		calculated contributions to $V^E(x_1 = 0.5)/(cm^3 \cdot mol^{-1})$		
mixture	$J \cdot cm^{-3}$	exp.	calc.	interactional	free volume	P^* effect
1,2-DCE + EGDME	−11.033	−0.236	−0.237	−0.134	0.010	−0.093
1,2-DCE + DEGDME	−30.909	−0.298	−0.283	−0.362	0.015	0.094
1,2-DCE + DEGDEE	−55.819	−0.637	−0.626	−0.740	0.014	0.128

where Ψ represents the molecular contact energy fraction, given by:

$$\Psi_1 = 1 - \Psi_2 = \phi_1 P_1^* / (\phi_1 P_1^* + \phi_2 P_2^*) \quad (22)$$

With the hard-core volume fractions defined by:

$$\phi_1 = 1 - \phi_2 = x_1 V_1^* / (x_1 V_1^* + x_2 V_2^*) \quad (23)$$

The molecular surface fraction θ_2 is calculated by:

$$\theta_2 = \phi_2 / (\phi_1 (S_1/S_2) + \phi_2) \quad (24)$$

The ratios S_1/S_2 being approximated by $S_1/S_2 = (V_2^*/V_1^*)^{1/3}$, according to the original work of Abe and Flory,[4] where V_i^* is the pure component hard core volume.

The reduced volume is defined by the equation:

$$\tilde{V}_i = \left[\frac{1 + (4/3)\alpha_i T}{1 + \alpha_i T}\right]^3 \quad (25)$$

where the thermal expansion coefficient is $\alpha = (1V)(\partial V/\partial T)_p$.

The characteristic volume and pressure, V_i^* and P_i^*, respectively, are given by:

$$V_i^* = V_i/\tilde{V}_i \quad (26)$$

$$P_i^* = T\tilde{V}_i^2 \alpha_i / \kappa_{Ti} \quad (27)$$

with the isothermal compressibility $k_{Ti} = -(1/V)(\partial V/\partial P)_T$.

The characteristic parameters of pure components, V_i^* and P_i^*, were calculated from the corresponding thermal expansion coefficient, α_i, and isothermal compressibility, κ_{Ti}, using Flory's formalism. Values of α_i and κ_{Ti}, at 298.15 K, were obtained from our experimental density results and literature data,[15,28,29] respectively. Table 11 summarizes the values, at 298.15 K, of α_i, κ_{Ti}, V_i^*, and P_i^*.

The interaction parameter, χ_{12}, required for the calculation of V^E using PFP's theory was derived by fitting the V^E expression (eq 17) to the experimental V^E values, at 298.15 K. The calculated equimolar values of the three contributions to V^E are reported in Table 12, along with those of χ_{12}values. An analysis of each of the three contributions to the excess molar volume, V^E, for all of the mixtures, shows that the interactional contribution is predominant and always negative. Moreover, the magnitude of the interactional and the "free volume" contributions increases with the increase of size and dipole moment, μ_i/D of the polyether (1.71 for EGDME,[30] 1.97 for DEGDME,[30] and 1.92 for DEGDEE[15]), while the magnitude of the "free volume" contribution, the lowest, remains constant.

For comparison, Figure 9 shows the composition dependence of the excess molar volumes, at 298.15 K, deduced from experimental density data and calculated using PFP's theory, for the three binary mixtures investigated. It can be seen that the PFP model describes relatively well the excess molar volumes for these mixtures.

CONCLUSION

Densities of binary liquid mixtures of 1,2-DCE with polyethers such as EGDME, DEGDME, and DEGDEE were measured on the whole composition range at various temperatures ranging from (283.15 K to 333.15) K and at atmospheric pressure. The deduced excess molar volumes, V^E, for all of the binary mixtures investigated, are negative over the whole mole fraction range. The V^E magnitudes, for both mixtures of 1,2-DCE with EGDME and DEGDME, are close and increase slightly as the temperature increases, whereas the V^E magnitude for mixture with DEGDEE decreases with the temperature increase and is more important. The V^E magnitude increases slightly with the addition of an OC_2H_4 group at the middle of the ether molecule when the alkyl chain end length of the polyether is fixed (EGDME and DEGDME). The V^E is more negative when the alkyl chain end length increases if the number of OC_2H_4 group is fixed (DEGDME and DEGDEE). The dipole moments are similar; therefore, it seems that the difference in V^E magnitude is mainly due to the size effect.

The applicability of the PFP in predicting excess molar volume, V^E, at $T = 298.15$ K was relatively well tested, for the binary mixtures of 1,2-DCE with polyethers such as EGDME, DEGDME, and DEGDEE.

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