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Articles

Viscosity and Density Measurements of Diisopropyl Ether and Dibutyl Ether at Different Temperatures and Pressures[†]

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Experimental results of viscosity and density of diisopropyl ether and dibutyl ether are reported over the temperature range from (243.15 to 373.15) K. The measurements were performed at pressures from atmospheric pressure or above saturation up to the maximum pressure, which were approximately 21.7 MPa for diisopropyl ether and 21.1 MPa for dibutyl ether. The measurements were performed simultaneously using a vibrating-wire instrument operated in the forced mode of oscillation. The present results for both properties are compared with values from the literature when possible. The overall uncertainties of these results are ± 2.0 % in viscosity and ± 0.2 % in density. The measurements were correlated with the Tait-type equation for density and hard-sphere scheme for viscosity. For diisopropyl ether, the average absolute deviations of measurements from the correlations of viscosity and density are 0.39 % and 0.008 %, respectively. With regard to dibutyl ether, the average absolute deviations of the present results from the correlations are 0.21 % for viscosity and 0.009 % for density.

Introduction

Usages of oxygenated additives have been recognized as safe, efficient, and cost-effective way to reduce the levels of mainly soot and particulate emissions and to improve combustion. During the last two decades, various ethers have become important as gasoline additives.[1] Ethers, either alone or with other ethers or alcohols, are widely used to increase the amount of oxygen in fuel and enhance the octane rating, improving combustion and reducing emissions and the contaminant agents of automobile catalysts. Methyl *tert*-butyl ether, MTBE, has been used as a gasoline additive to increase the octane rating and reduce air pollution. The practice of adding MTBE to gasoline started in the late 1970s and increased dramatically in the 1990s in an effort to increase combustion efficiency and reduce air pollution. But, due to its high solubility in water, mobility, and low natural biodegradation potential in the subsurface environment, MTBE has become a significant groundwater contaminant and can create a hazard to public health and the environment. MTBE is classified as a potential human carcinogen by the U.S. Environmental Protection Agency. Alternative oxygenates to MTBE have been hardly studied yet. Diisopropyl ether was suggested as one of the alternatives, which is environmentally benign.

Thermodynamic and transport properties are very important to the application of oxygenated fuels or fuel additives. In recent years, various thermophysical properties of such oxygenated substances have been measured by our group.[2−6] In this work, continuing our previous research, we measured the viscosity and density of diisopropyl ether and dibutyl ether at temperatures from (243.15 to 373.15) K and at pressures up to about 22 MPa.

Experimental Section

Fluid Samples. Diisopropyl ether and dibutyl ether were purchased from Alfa Aesar, USA, with purities > 98 % and > 99 %, respectively. The fluid samples were introduced in the measuring cell without any further treatment through a reciprocating plunger pulsation-free pump (2PB05, Beijing Xingda Technology and Development Corporation, China).

Measurements. The viscosity and density measurements were performed simultaneously with a vibrating-wire viscometer, shown in Figure 1, which has been described previously.[7] Only the main features of the instrument are mentioned here. A tungsten wire with nominal diameter of 0.1 mm was used, one end of which is clamped in a stainless steel chuck that is supported from the pressure vessel lid. The lower end of the vertically suspended wire is attached to an aluminum weight. A pair of samarium−cobalt magnets was mounted onto a cage. The magnetic induction in the center of the gap between the magnetic poles, where the wire was located, was about 0.3 T. The electrical connections of the vibrating wire were made using four copper leads, two for each end of the wire.

A sinusoidal voltage generated by a function generator (Agilent 33220A) is passed through a resistance of about 2 kΩ and the tungsten wire. The voltage was varied between (10 and 1000) mV to maintain the amplitude of the wire motion. A driving current of 5 μA was used for the wire in a vacuum, and the maximum current was 0.3 mA when immersed in these two liquid alkyl ethers. The electromotive force induced at the wire forced to perform transverse oscillations in a magnetic field is proportional to the velocity of the oscillations. The amplitude and phase of the induced signal were detected with the lock-in amplifier (Stanford SR830) over a frequency range of about $f_r \pm 5g$, where g is half the resonance line width and f_r is the fundamental transverse resonance frequency. A schematic

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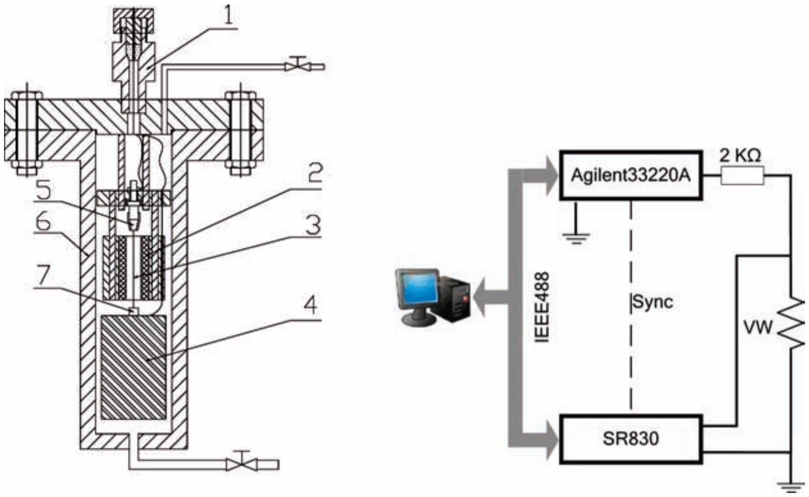

Figure 1. Diagram of the vibrating-wire apparatus and the measurement circuit. 1, Feedthrough; 2, Magnets; 3, Tungsten wire; 4, Weight; 5, Upper clamp; 6, Pressure vessel; 7, Bottom clamp.

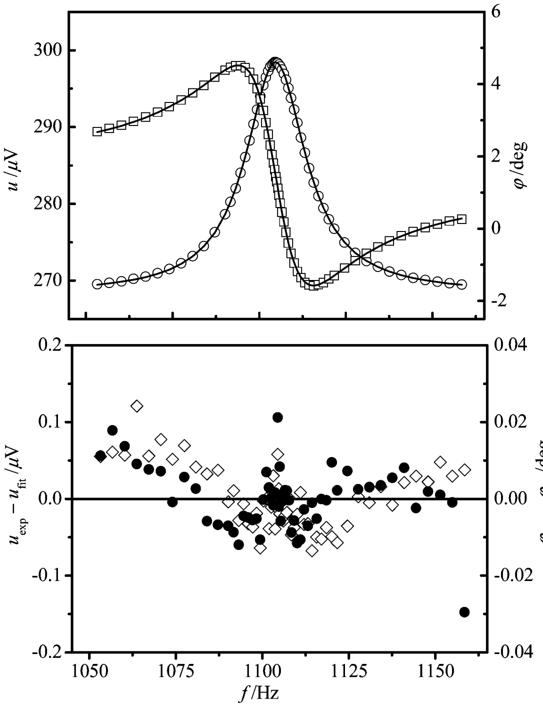

Figure 2. Experimental and theoretical resonance curves of amplitude and phase for diisopropyl ether at 293.15 K and 0.1 MPa. u and φ are the amplitude and phase of the induced signal, respectively, and the subscripts, (exp) and (fit), represent values of experiment and theoretical fit: solid line, theory; ○, experimental amplitude; □, experimental phase; ◇, amplitude deviation; ●, phase deviation.

diagram of the measurement circuit is also shown in Figure 1. The density and viscosity of the fluid were determined by a directly simultaneous fitting of the working equations to the entire curves of amplitude and phase.[8] Such a fitting for diisopropyl ether at 293.15 K and 0.1 MPa was shown in Figure 2 together with the deviations of the experimental signal from the theoretical curves. As illustrated in Figure 2, the typical deviations between the acquired and theoretical resonance curves are within ± 0.2 μV for amplitude and ± 0.03° for phase.

The calibration and test of the vibrating wire instrument was performed in our previous work.[7] The complete set of parameters describing the present vibrating-wire sensor is given in Table 1. The uncertainties of the measurements are ± 2.0 % in viscosity and ± 0.2 % in density, which were estimated elsewhere.[7]

Table 1. Parameters of the Cell

			source
vibrating wire (tungsten)			
half-length	L/m	$24.55 \cdot 10^{-3}$	measured
radius	R/m	$49.693 \cdot 10^{-6}$	calibrated
density	ρ_s/kg·m^{-3}	$19.230 \cdot 10^{3}$	literature
Young's modulus	E/GPa	406	literature
internal damping	Δ_0	$1.3082 \cdot 10^{-5}$	measured
aluminum mass			
mass	M_w/kg	0.23244	measured
density	ρ_w/kg·m^{-3}	2731.43	calibrated

The thermostatic system was essentially identical to the one described previously.[7] The temperature stability and uniformity of the bath were better than ± 2 mK. The total uncertainty of temperature was less than ± 10 mK. Pressure was measured with a transducer (Micro Sensor Co., Ltd., China, model MPM480, with a maximum operating pressure of 40 MPa). The accuracy of the transducer was ± 0.25 % FS, and the uncertainty of the pressure was ± 0.1 MPa.

Results and Correlation

The viscosity and density of diisopropyl ether and dibutyl ether were measured along 14 isotherms at temperatures between (243.15 and 373.15) K. The measurements were performed at pressures from atmospheric pressure or above saturation up to the maximum pressure, which were approximately 21.7 MPa for diisopropyl ether and 21.1 MPa for dibutyl ether. At each temperature and pressure, the experiment is measured three times, and the repeatability of the results is better than ± 0.02 % for density and ± 0.5 % for viscosity. The results are shown in Table 2 for diisopropyl ether and in Table 3 for dibutyl ether. All the experimental results of density were correlated with a Tait-type equation, and a hard-sphere scheme was used for viscosity. The average absolute deviation (AAD), maximum deviation (DM), and average deviation (Bias) are introduced to assess the performances of correlations, which are defined by

$$\mathrm{AAD}/\% = \frac{100}{N}\sum_{i}^{N}\left|\frac{\rho_{\mathrm{exptl},i}}{\rho_{\mathrm{calcd},i}} - 1\right| \qquad (1)$$

$$\mathrm{DM}/\% = 100\mathrm{MAX}\left(\left|\frac{\rho_{\mathrm{exptl},i}}{\rho_{\mathrm{calcd},i}} - 1\right|\right) \qquad (2)$$

Table 2. Experimental Density ρ and Viscosity η of Diisopropyl Ether Determined with the Vibrating-Wire Sensor as a Function of Temperature T and Pressure p

T/K	p/MPa	ρ/kg·m^{-3}	η/mPa·s
243.15	0.10	772.385	0.6191
	4.66	776.195	0.6466
	10.07	780.420	0.6826
	15.37	784.377	0.7177
	20.86	788.392	0.7529
253.15	0.10	762.804	0.5343
	4.72	766.842	0.5601
	9.99	771.350	0.5898
	15.40	775.704	0.6187
	20.74	779.692	0.6500
263.15	0.10	753.037	0.4687
	4.47	757.298	0.4896
	9.49	761.805	0.5141
	14.49	766.126	0.5388
	19.64	770.142	0.5638
273.15	0.10	743.309	0.4142
	4.69	748.026	0.4344
	10.01	753.179	0.4579
	15.29	757.990	0.4815
	20.42	762.359	0.5042
283.15	0.10	733.393	0.3689
	4.70	738.525	0.3877
	10.10	744.147	0.4088
	15.46	749.321	0.4306
	21.36	754.612	0.4560
293.15	0.10	723.318	0.3311
	4.47	728.638	0.3474
	9.59	734.393	0.3671
	14.75	739.779	0.3855
	20.45	745.301	0.4079
303.15	0.10	713.113	0.2990
	4.44	718.817	0.3124
	9.50	725.014	0.3310
	14.65	730.787	0.3496
	19.65	735.942	0.3668
313.15	0.10	702.804	0.2703
	4.84	709.502	0.2869
	10.14	716.438	0.3038
	15.55	722.843	0.3213
	21.49	729.298	0.3414
323.15	0.10	692.225	0.2468
	4.76	699.461	0.2615
	10.37	707.408	0.2776
	15.48	713.832	0.2946
	20.78	720.040	0.3110
333.15	0.10	681.435	0.2254
	4.75	689.427	0.2389
	10.36	697.963	0.2554
	15.67	705.137	0.2716
	20.89	711.630	0.2848
343.15	0.13	670.401	0.2064
	4.39	678.519	0.2183
	9.53	687.069	0.2335
	14.74	694.891	0.2471
	21.23	703.496	0.2649
353.15	0.20	659.151	0.1889
	4.83	668.720	0.2030
	10.32	678.629	0.2176
	15.76	687.163	0.2324
	21.10	694.710	0.2466
363.15	0.23	647.498	0.1736
	4.73	657.763	0.1871
	10.17	668.510	0.2014
	15.83	678.192	0.2152
	20.86	685.734	0.2294
373.15	0.31	635.452	0.1602
	4.73	646.883	0.1721
	9.63	657.520	0.1854
	15.60	668.559	0.2008
	21.68	678.358	0.2152

$$\mathrm{Bias}/\% = \frac{100}{N}\sum_{i}^{N}\left(\frac{\rho_{\mathrm{exptl},i}}{\rho_{\mathrm{calcd},i}} - 1\right) \qquad (3)$$

where $\rho_{\mathrm{exptl},i}$ ($\eta_{\mathrm{exptl},i}$ for viscosity) is the ith density experimental datum; $\rho_{\mathrm{calcd},i}$ ($\eta_{\mathrm{calcd},i}$ for viscosity) is the ith value calculated by means of the correlations; and N is the number of experimental data in the set of measurements used to define the correlation equation.

A Tait-type equation was employed to correlate the density results, which represents the density as a function of pressure along each isotherm by two parameters, B and C.

Table 3. Experimental Density ρ and Viscosity η of Dibutyl Ether Determined with the Vibrating-Wire Sensor as a Function of Temperature T and Pressure p

T/K	p/MPa	ρ/kg·m^{-3}	η/mPa·s
243.15	0.10	809.772	1.7336
	4.80	812.717	1.8358
	10.29	816.304	1.9540
	15.70	819.465	2.0834
	21.12	822.606	2.2209
253.15	0.10	801.370	1.3786
	4.55	804.548	1.4481
	9.65	807.789	1.5396
	14.76	811.186	1.6238
	19.76	814.140	1.7160
263.15	0.10	793.117	1.1256
	4.65	796.489	1.1828
	10.00	800.232	1.2560
	15.29	803.649	1.3321
	20.52	807.105	1.4037
273.15	0.10	784.503	0.9420
	4.81	788.298	0.9913
	10.20	792.324	1.0492
	15.57	796.106	1.1091
	20.87	799.664	1.1706
283.15	0.10	776.314	0.8032
	4.78	780.133	0.8437
	10.15	784.429	0.8898
	15.58	788.422	0.9423
	20.83	792.172	0.9923
293.15	0.10	767.938	0.6906
	4.75	772.058	0.7263
	10.18	776.552	0.7684
	15.47	780.608	0.8120
	20.76	784.626	0.8546
303.15	0.10	759.934	0.6080
	4.50	763.973	0.6386
	9.57	768.455	0.6735
	14.53	772.612	0.7081
	19.67	776.718	0.7436
313.15	0.10	751.438	0.5388
	4.51	755.825	0.5648
	9.60	760.621	0.5966
	14.65	765.058	0.6282
	19.64	769.315	0.6571
323.15	0.10	743.119	0.4805
	4.51	747.707	0.5061
	9.57	752.915	0.5306
	14.63	757.591	0.5608
	19.60	761.898	0.5900
333.15	0.10	734.484	0.4326
	4.49	739.443	0.4553
	9.58	744.884	0.4806
	14.63	749.942	0.5061
	19.62	754.541	0.5317
343.15	0.10	725.879	0.3914
	4.64	731.433	0.4120
	9.64	737.137	0.4352
	14.73	742.477	0.4581
	19.73	747.369	0.4822
353.15	0.10	717.116	0.3538
	4.51	722.869	0.3738
	9.57	729.120	0.3945
	14.64	734.754	0.4166
	19.63	740.012	0.4373
363.15	0.10	708.168	0.3236
	4.51	714.412	0.3413
	9.72	721.185	0.3622
	15.30	727.703	0.3835
	21.10	733.972	0.4070
373.15	0.10	699.123	0.2954
	4.90	706.359	0.3145
	10.17	713.653	0.3337
	15.63	720.422	0.3536
	20.59	726.094	0.3733

Table 4. Fitting Parameters of Equation 4

parameter	diisopropyl ether	dibutyl ether
A_0/kg·m^{-3}	1077.92	1109.8
A_1/kg·m^{-3}·K^{-1}	−1.84064	−1.86552
A_2/kg·m^{-3}·K^{-2}	3.61952·10^{-3}	3.62422·10^{-3}
A_3/kg·m^{-3}·K^{-3}	−5.00312·10^{-6}	−4.21953·10^{-6}
C	0.194	0.191
B_0/MPa	314.195	344.144
B_1/MPa·K^{-1}	−1.3298	−1.33004
B_2/MPa·K^{-2}	1.44493·10^{-3}	1.35405·10^{-3}
AAD/%	0.008	0.009
DM/%	0.047	0.027
Bias/%	−0.0003	−0.00004

Table 5. Characteristic Volumes V_0 of Diisopropyl Ether and Dibutyl Ether from T = (243.15 to 373.15) K

	10^6V_0/m^3·mol^{-1}	
T/K	diisopropyl ether	dibutyl ether
243.15	89.55	118.59
253.15	89.04	117.67
263.15	88.57	116.82
273.15	88.11	116.04
283.15	87.63	115.31
293.15	87.17	114.59
303.15	86.67	114.01
313.15	86.21	113.39
323.15	85.72	112.78
333.15	85.19	112.21
343.15	84.67	111.59
353.15	84.20	110.93
363.15	83.66	110.33
373.15	83.12	109.71

Table 6. Fitting Parameters of Equations 5 to 7

parameter	diisopropyl ether	dibutyl ether
a/m^3·mol^{-1}	105.772	190.279
b/m^3·mol^{-1}·K^{-1}	−0.0994354	−0.58901
c/m^3·mol^{-1}·K^{-2}	1.91522·10^{-4}	1.60297·10^{-3}
d/m^3·mol^{-1}·K^{-3}	−2.35109·10^{-7}	−1.61679·10^{-6}
R_η	1.197	1.296
AAD/%	0.39	0.21
DM/%	1.47	0.89
Bias/%	−0.017	−0.0067

$$\frac{\rho - \rho_0}{\rho} = C\log\left[\frac{B+p}{B+p_0}\right] \qquad (4)$$

where ρ_0, the density at the reference pressure (p_0 = 0.1 MPa), is given by $\rho_0 = A_0 + A_1T + A_2T^2 + A_3T^3$. The B is a quadratic function of temperature, with the form of $B = B_0 + B_1T + B_2T^2$, and the parameter C can usually be assumed to be constant. To determine the optimized value of constant C, the exhaustion method was used. The AAD, DM, and Bias, obtained from the Tait-type correlations for diisopropyl ether and dibutyl ether, are listed in Table 4, together with the values of the parameters.

The viscosities of diisopropyl ether and dibutyl ether were correlated with the hard-sphere model proposed by Assael and Dymond.[9,10] The model defined a reduced dimensionless viscosity, η^*, which, using base SI units, is given by

$$\eta^* = 6.035\cdot10^8\left[\frac{1}{MRT}\right]^{1/2}\frac{\eta V^{2/3}}{R_\eta} \qquad (5)$$

where η is the viscosity; M is the molar mass; T is the temperature; V is the molar volume; and R is the gas constant. The proportionality factor, R_η, accounts for molecular roughness and departure from molecular sphericity, independent of pressure and temperature. The reduced viscosity should be a function of the ratio of the molar volume to a temperature-dependent characteristic volume, V_0, only. This characteristic volume generally decreases linearly with increasing temperature. A universal curve of reduced viscosity as a function of density and characteristic volume has been established for a large number of substances

$$\log(\eta^*) = \sum_{i=0}^{7} a_i\left(\frac{V_0}{V}\right)^i \qquad (6)$$

We have, therefore, correlated our results of viscosity by superimposing the isotherms on this universal curve using the values for the coefficients a_i given by Assael and Dymond,[9,10] and the obtained values of V_0 for each temperature were listed in Table 5. The best-fit values of R_η for diisopropyl ether and dibutyl ether obtained by the exhaustion method are 1.197 and 1.296, respectively. The values of V_0 in Table 5 were represented by the empirical relation

$$V_0\cdot10^6/(\mathrm{m^3\cdot mol^{-1}}) = a + b(T/\mathrm{K}) + c(T/\mathrm{K})^2 + d(T/\mathrm{K})^3 \qquad (7)$$

The obtained parameters and the results for the hard-sphere scheme are presented in Table 6.

Comparison with Literature

Diisopropyl Ether. In Figure 3, the density relative deviations of diisopropyl ether between experimental values and the correla-

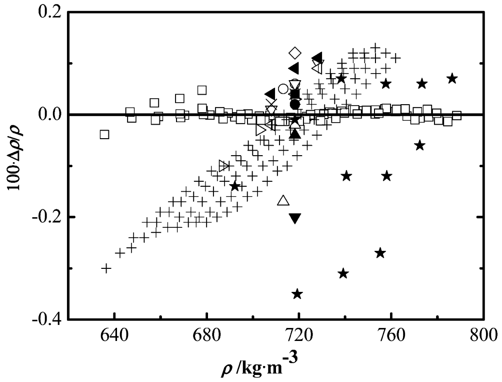

Figure 3. Relative deviation $\Delta\rho/\rho = (\rho_{\mathrm{exptl}} - \rho_{\mathrm{calcd}})/\rho_{\mathrm{calcd}}$ of the experimentally determined density ρ_{exptl} from the value obtained from eq 4, ρ_{calcd}, for diisopropyl ether as a function of density. □, this work; ★, Ulbig et al.;[11] +, Ihmels and Gmehling;[12] ○, Hwang et al.;[13] Δ, Reddy et al.;[14] ▽, Chen and Tu;[15] ◇, Atik and Lourddani;[16] open triangle pointing left, Ye and Tu;[17] open triangle pointing right, Venkatesu et al.;[18] ☆, Ouyang et al.;[19] ■, Peralta et al.;[20] ×, George and Sastry;[21] |, Peng and Tu;[22] ●, Domanska et al.;[23] ▲, Pineiro et al.;[24] ▼, Rezanova et al.;[25] —, Arce et al.;[26] solid triangle pointing left, Obama et al.[27]

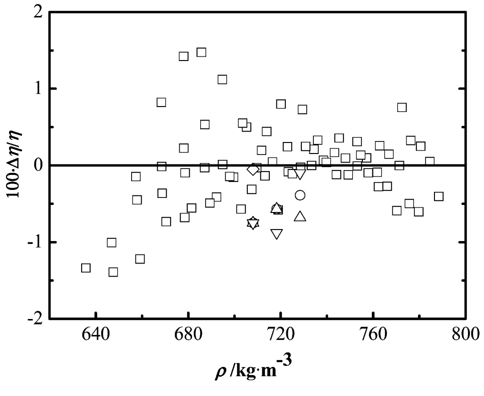

Figure 4. Relative deviation $\Delta\eta/\eta = (\eta_{\mathrm{exptl}} - \eta_{\mathrm{calcd}})/\eta_{\mathrm{calcd}}$ of the experimentally determined viscosity η_{exptl} from the value obtained from eqs 5 to 7, η_{calcd}, for diisopropyl ether as a function of density. □, this work; ○, Chen and Tu;[15] Δ, Ye and Tu;[17] ◇, George and Sastry;[21] ∇, Peng and Tu.[22]

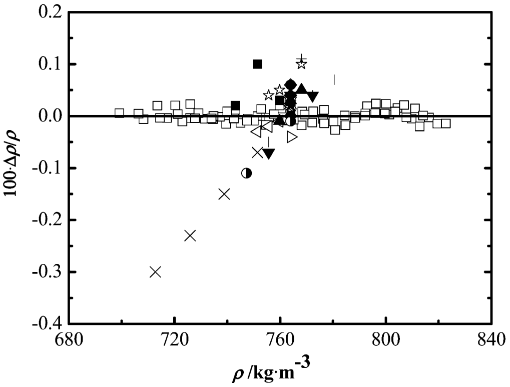

Figure 5. Relative deviation $\Delta\rho/\rho = (\rho_{\mathrm{exptl}} - \rho_{\mathrm{calcd}})/\rho_{\mathrm{calcd}}$ of the experimentally determined density ρ_{exptl} from the value obtained from eq 4, ρ_{calcd}, for dibutyl ether as a function of density. □, this work; ×, Venkatesu et al.;[18] ◇, Domanska et al.;[23] solid triangle pointing right, Rezanova et al.;[25] ▼, Obama et al.;[27] ○, Arce et al.;[28] Δ, Benito et al.;[29] ∇, Bernazzani et al.;[30] open triangle pointing left, George and Sastry;[31] open triangle pointing right, Han et al.;[32] ☆, Jimenez et al.;[33] +, Kirss et al.;[34] ■, Lee and Wei;[35] ●, Letcher and Goldon;[36] ▲, Mozo et al.;[37] ◆, Paul et al.;[38] solid triangle pointing right, Rilo et al.;[39] ★, Serna et al.;[40] —, Tanaka and Toyama;[41] |, Tovar et al.;[42] ◑, Villa et al.[43]

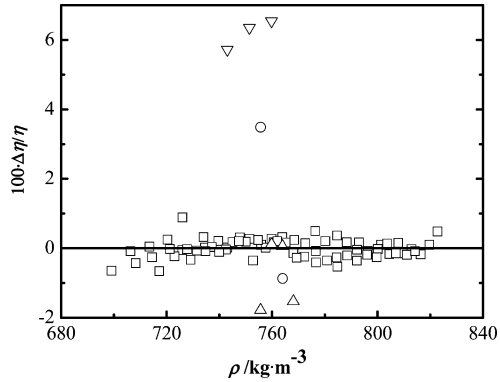

Figure 6. Relative deviation $\Delta\eta/\eta = (\eta_{\mathrm{exptl}} - \eta_{\mathrm{calcd}})/\eta_{\mathrm{calcd}}$ of the experimentally determined viscosity η_{exptl} from the value obtained from eqs 5 to 7, η_{calcd}, for dibutyl ether as a function of density. □, this work; ○, George and Sastry;[31] Δ, Jimenez et al.;[33] ∇, Lee and Wei.[35]

tion are shown. The AAD, DM, and Bias of the present results from the density correlation are 0.008 %, 0.047 %, and − 0.0003 %, respectively. Figure 3 also shows a comparison of the present measurements and the results of other authors. The figure makes evident that most of the data agree with the correlation eq 4 within ± 0.2 %. Extrapolation of the present data was made to enable comparison with the values of Ulbig et al.[11] up to 60 MPa, which are in good agreement with the correlation with an AAD of 0.14 %. The comparison with the data reported by Ihmels and Gmehling[12] with the vibrating-tube densimeter was limited to the pressures that overlap our range of $p < 21.7$ MPa. The results of Ihmels and Gmehling[12] also show an agreement with the correlation (AAD: 0.11 %), and the deviations vary from (0.13 to −0.3) % with rising temperature. The deviations of all the other published data from the correlation, measured at atmospheric pressure and at several scattered temperatures, were all within ± 0.2 %, and the AAD is 0.059 %.

The viscosity deviations for diisopropyl ether between this work and the literature were shown in Figure 4. The AAD, DM, and Bias of the present results from the viscosity correlations are 0.39 %, 1.47 %, and −0.017 %, respectively. Chen and Tu,[15] Ye and Tu,[17] and Peng and Tu[22] reported the viscosity values at atmospheric pressure and at the same temperatures of 288.15 K, 298.15 K, and 308.15 K, shown in Figure 4 with the average absolute deviations of 0.57 %, 0.67 %, and 0.58 %, respectively. A large deviation is observed for the value of Reddy et al.[14] at 303.15 K and at atmospheric pressure with a suspended Ubbelohde-type viscometer, which is higher than the present value and other literature data with an amount of 16.9 %. To ensure the clarity of the deviation graph, the large deviation is not shown in Figure 4. The viscosity result of George and Sastry[21] at 308.15 K, using a suspended-type Ubbelohde viscometer, is in good agreement with the present measurement with a deviation of −0.05 %, but the deviation of the result at 298.15 K from the same author amounts to 20.72 % which does not appear in Figure 4. The result is also inconsistent with other researchers, and no particular information was available to estimate the reasons. No viscosity measurements at elevated pressures were found for diisopropyl ether.

Dibutyl Ether. The density deviations for dibutyl ether of the present measurements from the correlation eq 4 are shown in Figure 5. The AAD, DM, and Bias of the present results from the density correlation are 0.009 %, 0.027 %, and −0.00004 %, respectively. No experimental density and viscosity data have been found by the authors in the literature for dibutyl ether in the compressed liquid region. Therefore, the present results for this fluid can only be compared with literature data obtained at atmospheric pressure. The deviations of the literature data from the correlation eq 4 of the present results are also shown in Figure 5. These data are in good agreement with the correlation, with an average absolute deviation of 0.05 % in density. The differences encountered vary from (−0.11 to +0.11) % except for results published by Venkatesu et al.[18] with deviations from (−0.3 to +0.02) %.

The viscosity deviations for dibutyl ether between this work and results from other researchers are shown in Figure 6. The viscosity at 298.15 K and 0.1 MPa reported by George and Sastry[31] agrees with the present correlation with a relative deviation of −0.86 %, but the result at 308.15 K shows a deviation of 3.49 %. The results reported by Jimenez et al.[33] for this ether at temperatures from (293.15 to 308.15) K are in good agreement with this work. The deviations encountered vary from (−1.78 to 0.11) %, well within the uncertainty of the data. Lee and Wei[35] measured the viscosity of dibutyl ether at temperatures 303.15 K, 313.15 K, and 323.15 K with a falling-ball viscometer. All those data show positive deviations from the correlation of the present results, from (5.72 to 6.54) %, most of them outside the uncertainty of the measurements.

Conclusions

Measurements of viscosity and density of diisopropyl ether and dibutyl ether in the liquid phase along 14 isotherms between (243.15 and 373.15) K are presented. The maximum pressure was approximately 21.7 MPa for diisopropyl ether and 21.1 MPa for dibutyl ether. The overall uncertainties of the results obtained using the vibrating-wire instrument in viscosity and density are estimated not to exceed ± 2.0 % and ± 0.2 %, respectively. The experimental results of diisopropyl ether and dibutyl ether were fitted successfully with a Tait-type equation for density and a correlation scheme based on a hard-sphere model for viscosity. The deviations between the present results and most of the literature values are within the nominal uncertainty of the data.

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