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Densities, Viscosities, Refractive Indexes, and Surface Tensions for Mixtures of Ethanol, Benzyl Acetate, and Benzyl Alcohol

Kai-Di Chen, Yi-Feng Lin, and Chein-Hsiun Tu*

Department of Applied Chemistry, Providence University, Shalu, Taichung 433, Republic of China, Taiwan

ABSTRACT: Densities, viscosities, refractive indexes, and surface tensions of the ternary system (ethanol + benzyl acetate + benzyl alcohol) at T = 303.15 K and its constituent binary systems (ethanol + benzyl acetate, ethanol + benzyl alcohol, and benzyl acetate + benzyl alcohol) at T = (293.15, 303.15, 313.15, and 323.15) K were measured under atmospheric pressure. Densities were determined using a vibrating-tube densimeter. Viscosities were measured with an automatic microviscometer based on the rolling-ball principle. Refractive indexes were measured using a digital Abbe-type refractometer. Surface tensions were determined by the Wilhelmy-plate method. From these data, excess molar volumes, deviations in viscosity, deviations in refractive index, and deviations in surface tension were derived. The results for the binary and ternary systems were fitted to the Redlich–Kister equation and the Cilbuka equation, respectively. The excess molar volumes and deviations in viscosity are used to study the nature of mixing behaviors between mixture components.



The flavor compounds are vitally interrelated to our daily lives. This paper is concerned with the measurement of the mixing properties for two kinds of flavor compounds, such as benzyl acetate and benzyl alcohol, mixed with ethanol. Benzyl alcohol was chosen for the present study because, except for its usage in perfumery and oral cavity sanitation as an antimicrobial agent, it is widely used in microscopy as the embedding material.¹ Benzyl alcohol is also important as a solvent for gelatin, cellulose acetate, and shellac.² Benzyl acetate has found its usage in artificial essences and as a base solvent for some flavor compounds. Ethanol is a versatile solvent with protic and self-associated properties, which can be used to study hydrophobic effects.

In this work, the effects of composition and temperature upon densities (ρ), viscosities (η), refractive indexes (n_D), and surface tensions (σ) for the systems formed by ethanol, benzyl acetate, and benzyl alcohol have been analyzed. More specifically, smooth representations of the excess molar volumes (V^E) are described. This kind of study is important toward the understanding of the molecular interaction between mixture components. In our previous papers, experimental densities, viscosities, refractive indexes, and surface tensions for ethanol + benzyl acetate were reported at T = (288.15, 298.15, 308.15, and 318.15) K.^{3,4} However, we are not aware of any literature data regarding the properties for the mixtures presented in this study.

EXPERIMENTAL SECTION

Materials. The chemicals used were of analytical grade and supplied by Merck (Germany). The pure components were stored over 0.3 nm molecular sieve to prevent water absorption. They were used without any further purification. The amount of water in each pure sample was monitored along the time it



took to carry out the present study with a Karl Fischer V20 moisture meter, Mettler. The purity of all chemicals was checked using a Perkin-Elmer Autosystem gas chromatograph (GC). The sources, purities, and analysis methods of the chemicals are shown in Table 1. The densities, viscosities, refractive indices,

 Table 1. Chemical Sources, Purities, and Analysis Methods

 for Pure Components

chemical name	source	initial mass fraction purity	purification method	final mass fraction purity	analysis method
ethanol	Merck	>0.999	molecular sieve	0.999	GC, ^{<i>a</i>} Karl Fischer ^{<i>b</i>}
benzyl acetate	Merck	>0.99	molecular sieve	0.997	GC, Karl Fischer
benzyl alcohol	Merck	>0.995	molecular sieve	0.999	GC, Karl Fischer
^a Gas-liou	uid chro	matography. ^b	'Karl Fische	r moisture met	ter.

and surface tensions at T = 298.15 K for the pure components are in good agreement with the accepted literature values (Table 2).^{5–18}

Apparatus and Procedure. The detailed experimental procedure and calibration have been described in our earlier papers,^{16,19} so only a brief description of the measurement is presented here. Densities ρ were measured with an Anton Paar DMA-5000 vibrating-tube densimeter (Anton-Paar, Graz, Austria) with an uncertainty of $\pm 8 \cdot 10^{-5}$ g·cm⁻³. Viscosities, η , were determined with an automatic microviscometer (Anton Paar type AMVn), which uses the rolling-ball principle. Triplicate measurements of

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Table 2. Comparison of Measured Densities (ρ), Viscosities (η), Refractive Indices (n_D), and Surface Tensions (σ) of Pure Components with Literature Values at $T = 298.15 \text{ K}^a$

	$ ho/{ m g}$	cm ⁻³	η/1	nPa∙s	n _D		σ/m	nN·m ^{−1}
component	expt.	lit.	expt.	lit.	expt.	lit.	expt.	lit.
ethanol	0.78507	0.78500 ^b	1.090	1.105 ^b	1.35934	1.35941 ^b	21.9	22.3 ^b
		0.78509 ^c		1.0826 ^{<i>f</i>}		1.35920 ^e		21.8 ^j
		0.78515 ^d		1.092 ^g		1.35922 ^h		
		0.78522 ^e				1.35950 ⁱ		
benzyl acetate	1.05113	1.05075 ^b	2.049	2.056 ^b	1.50007	1.49982 ^b	36.2	36.4 ^b
		1.0515 ^f						
benzyl alcohol	1.04134	1.0414^{k}	5.376	5.555 ^m	1.53848	1.5383 ^d	38.5	38.58^{k}
		1.04127 ^{<i>f</i>}		5.313 ⁿ		1.53837 ^{<i>f</i>}		38.63 ^m
		1.0413 ¹				1.53840 ¹		38.54°
						1.53843^{m}		

^{*a*} The standard uncertainties *u* are u(T) = (0.01, 0.05, 0.03, and 0.05) K for ρ , η , n_D , and σ , respectively, and the combined expanded uncertainties U_c are $U_c(\rho) = 0.08$ kg·m⁻³, $U_c(\eta) = 0.008$ mPa·s, $U_c(n_D) = 0.00005$, and $U_c(\sigma) = 0.2$ mN·m⁻¹ (level of confidence = 0.95). ^{*b*} Sheu and Tu, 2006. ⁵ ^{*c*} Francesconi et al., 1997. ⁶ ^{*d*} Segade et al., 2003. ⁷ ^{*e*} Arce et al., 2000. ⁸ ^{*f*} Riddick et al., 1986. ⁹ ^{*g*} Phillips and Murphy, 1970. ¹⁰ ^{*h*} Tojo et al., 2001. ¹¹ ^{*i*} Chen et al., 2001. ¹² ^{*j*} Azizian and Bashavard, 2005. ¹³ ^{*k*} Azizian et al., 2006. ¹⁴ ^{*l*} Singh and Sinha, 1986. ¹⁵ ^{*m*} Yeh and Tu, 2007. ¹⁶ ^{*n*} Aralaguppi et al., 2003. ¹⁷ ^{*o*} Lange, 1985. ¹⁸

flow times were reproducible within \pm 0.1 %. The uncertainty of the viscosity measurement was estimated to be better than \pm 0.008 mPa·s.

Refractive indices, $n_{\rm D}$, were measured with an automatic Anton Paar RXA-156 refractometer, which runs with the wavelength of 589 nm corresponding to the D-ray of sodium with an uncertainty of \pm 0.00005. Surface tensions, σ , were measured with an automatic tensionmeter model CBVP-A3 (Kyowa, Japan), which works by the Wilhelmy-plate method. A glass cover with a hole for the thermometer and a short cut for the Wilhelmy-plate was used to cover the vessel for minimizing the errors caused by evaporation losses. The uncertainty of surface tension measurement was estimated at \pm 0.2 mN·m⁻¹.

All samples were prepared by mass in a 50 cm³ Erlenmeyer flask provided with a joint stopper, using a Mettler AB204 balance with a precision of \pm 0.1 mg. The possible error of composition in mole fraction was estimated to be $\pm 1 \cdot 10^{-4}$. For reducing the time to reach the measuring temperatures, the sample mixtures in airtight stoppered bottles were preheated in a temperature-controlled water bath before being poured into the measuring cell. The bottles were almost completely filled with the liquid mixtures to keep the vapor space above the liquid as small as possible. All liquids were thermostatically controlled under atmospheric pressure (100.8 \pm 0.4) kPa to within \pm 0.01 K for ρ , \pm 0.05 K for η , \pm 0.03 K for $n_{\rm D}$, and \pm 0.05 K for σ .

RESULTS AND DISCUSSION

The experimental data of density, ρ , viscosity, η , refractive index, n_D , and surface tension, σ , for the binary systems (ethanol + benzyl acetate, ethanol + benzyl alcohol, and benzyl acetate + benzyl alcohol) at *T* = (293.15, 303.15, 313.15, and 323.15) K are presented in Tables 3 to 5. Increasing temperatures from (293.15 to 323.15) K decreases the values of ρ , η , $n_{\rm D}$, and σ . The experimental ρ , η , $n_{\rm D}$, and σ data for the ternary system (ethanol + benzyl acetate + benzyl alcohol) at T = 303.15 K are listed in Table 6. Although the properties (ρ , η , n_D , and σ) of ethanol + benzyl acetate have been measured previously at T =(298.15, 308.15, 318.15, and 328.15) K, the system is repeated mainly because of the designation to have new experimental data at new investigated temperatures to complete this study. The agreement between our present measurements and previous results on this system is generally satisfactory except for viscosity. A fair agreement observed for the viscosity may

not be solely due to the present experimental method, which uses the rolling-ball principle instead of the previous Ubbelohde capillary viscometry, since the experimental data may more or less deviate from the true values depending upon the experimental apparatus, procedure, and compounds used.

The experimental ρ , η , n_D , or σ data of pure components at T = (293.15, 303.15, 313.15, and 323.15) K were correlated with temperature by the following equation:

$$Q = B_0 + B_1 T + B_2 T^2 \tag{1}$$

where Q refers to the $\rho/g \cdot \text{cm}^{-3}$, $\eta/\text{mPa} \cdot \text{s}$, n_D , and $\sigma/\text{mN} \cdot \text{m}^{-1}$, and T is the temperature in K. The values of the coefficient B_k together with the standard deviation (δ) are presented in Table 7. The standard deviation is calculated by:

$$\delta = \left[\sum_{i=1}^{n} \frac{(Q_i^{\text{ calc}} - Q_i^{\text{ expt}})^2}{n-p}\right]^{1/2}$$
(2)

where *n* is the number of data points and *p* is the number of coefficients used in fitting the data. The standard deviations of ρ , η , $n_{\rm D}$, and σ are less than 0.00009 g·cm⁻³, 0.004 mPa·s, 0.00003, and 0.2 mN·m⁻¹, respectively.

These new experimental data were used to calculate excess molar volumes $(V^{\rm E})$, deviations in viscosity $(\Delta \eta)$, deviations in refractive index $(\Delta n_{\rm D})$, and deviations in surface tension $(\Delta \sigma)$. The molar excess volumes, $V^{\rm E}$, were obtained from the experimental density according to the following equation:

$$V^{\rm E} = \sum_{i=1}^{N} x_i M_i \left(\frac{1}{\rho} - \frac{1}{\rho_i} \right) \tag{3}$$

where x_i , M_{i_i} and ρ_i are the mole fraction, molecular weight, and density of pure component *i*, respectively. ρ is the density of the mixture, and N is the number of components in the mixture. The uncertainty of $V^{\rm E}$ was estimated to be within $\pm 6 \cdot 10^{-3}$ cm³·mol⁻¹. The deviations in the viscosity, $\Delta \eta$, were determined from the viscosity of pure component *i*, η_{ν} and the viscosity of the mixture, η , as eq 4:

$$\Delta \eta = \eta - \sum_{i=1}^{N} x_i \eta_i \tag{4}$$

Table 3. Experimental Densities (ρ), Viscosities (η), Refractive Indices (n_D), Surface Tensions (σ), Excess Molar Volumes (V^E), and Deviations in Viscosities ($\Delta \eta$) for Ethanol (1) + Benzyl Acetate (2) at T = (293.15, 303.15, 313.15, and 323.15) K^a

	ρ	η		σ	VE	$\Delta \eta$		ρ	η		σ	VE	$\Delta \eta$
x_1	g·cm ^{−3}	mPa·s	$n_{\rm D}$	$mN \cdot m^{-1}$	cm ³ ·mol ⁻¹	mPa∙s	x_1	g·cm ^{−3}	mPa∙s	$n_{\rm D}$	$mN \cdot m^{-1}$	cm ³ ·mol ⁻¹	mPa∙s
						T/K =	293.15						
0.0000	1.05581	2.324	1.50245	37.3	0.000	0.000	0.5499	0.96973	1.439	1.45652	27.9	-0.296	-0.258
0.0502	1.05061	2.180	1.49958	36.3	-0.060	-0.087	0.6000	0.95731	1.392	1.44996	27.2	-0.301	-0.247
0.1000	1.04489	2.063	1.49646	35.4	-0.090	-0.147	0.6500	0.94377	1.347	1.44279	26.7	-0.307	-0.235
0.1498	1.03877	1.962	1.49316	34.4	-0.117	-0.191	0.7000	0.92869	1.305	1.43481	26.2	-0.301	-0.220
0.1998	1.03215	1.879	1.48968	33.4	-0.138	-0.217	0.7499	0.91206	1.267	1.42603	25.8	-0.297	-0.201
0.2499	1.02514	1.808	1.48589	32.5	-0.167	-0.231	0.7999	0.89344	1.232	1.41623	25.2	-0.280	-0.179
0.2998	1.01751	1.736	1.48190	31.6	-0.181	-0.246	0.8500	0.87242	1.202	1.40518	24.5	-0.255	-0.152
0.3500	1.00927	1.672	1.47760	30.8	-0.193	-0.253	0.9000	0.84854	1.188	1.39263	23.8	-0.207	-0.109
0.4000	1.00055	1.613	1.47289	30.0	-0.223	-0.255	0.9500	0.82138	1.178	1.37820	23.1	-0.148	-0.062
0.4501	0.99115	1.551	1.46787	29.3	-0.254	-0.259	1.0000	0.78910	1.183	1.36137	22.3	0.000	0.000
0.5000	0.98094	1.490	1.46245	28.6	-0.281	-0.264							
						T/K =	303.15						
0.0000	1.04674	1.836	1.49776	35.6	0.000	0.000	0.5499	0.95994	1.194	1.45179	27.1	-0.217	-0.171
0.0502	1.04118	1.750	1.49479	34.8	-0.013	-0.043	0.6000	0.94761	1.151	1.44531	26.4	-0.231	-0.171
0.1000	1.03533	1.663	1.49168	34.0	-0.027	-0.087	0.6500	0.93397	1.115	1.43815	25.8	-0.227	-0.165
0.1498	1.02909	1.595	1.48838	33.2	-0.040	-0.113	0.7000	0.91903	1.077	1.43018	25.2	-0.233	-0.160
0.1998	1.02242	1.534	1.48491	32.4	-0.056	-0.131	0.7499	0.90250	1.038	1.42142	24.7	-0.235	-0.156
0.2499	1.01530	1.477	1.48118	31.6	-0.074	-0.145	0.7999	0.88390	1.009	1.41163	24.2	-0.218	-0.142
0.2998	1.00778	1.420	1.47715	30.8	-0.103	-0.159	0.8500	0.86307	0.989	1.40062	23.6	-0.204	-0.119
0.3500	0.99968	1.375	1.47284	30.0	-0.132	-0.161	0.9000	0.83936	0.982	1.38811	22.9	-0.163	-0.084
0.4000	0.99086	1.327	1.46818	29.2	-0.150	-0.167	0.9500	0.81221	0.975	1.37384	22.2	-0.098	-0.048
0.4501	0.98138	1.281	1.46316	28.5	-0.175	-0.170	1.0000	0.78076	0.980	1.35712	21.4	0.000	0.000
0.5000	0.97111	1.233	1.45772	27.8	-0.196	-0.175							
						T/K =	313.15						
0.0000	1.03742	1.474	1.49309	34.3	0.000	0.000	0.5499	0.95019	0.999	1.44703	26.4	-0.173	-0.116
0.0502	1.03185	1.413	1.49006	33.6	-0.012	-0.028	0.6000	0.93783	0.964	1.44052	25.8	-0.184	-0.119
0.1000	1.02596	1.362	1.48693	32.8	-0.022	-0.047	0.6500	0.92436	0.930	1.43339	25.2	-0.196	-0.120
0.1498	1.01970	1.308	1.48362	32.0	-0.033	-0.068	0.7000	0.90951	0.891	1.42552	24.6	-0.208	-0.127
0.1998	1.01298	1.265	1.48007	31.3	-0.042	-0.079	0.7499	0.89304	0.867	1.41682	24.0	-0.214	-0.118
0.2499	1.00582	1.226	1.47629	30.5	-0.057	-0.085	0.7999	0.87460	0.841	1.40711	23.4	-0.207	-0.111
0.2998	0.99820	1.181	1.47228	29.8	-0.072	-0.098	0.8500	0.85375	0.823	1.39617	22.8	-0.186	-0.097
0.3500	0.98997	1.143	1.46794	29.1	-0.089	-0.103	0.9000	0.83017	0.812	1.38375	22.1	-0.151	-0.075
0.4000	0.98120	1.101	1.46327	28.4	-0.114	-0.112	0.9500	0.80327	0.808	1.36951	21.4	-0.097	-0.047
0.4501	0.97170	1.067	1.45826	27.7	-0.137	-0.114	1.0000	0.77199	0.822	1.35292	20.6	0.000	0.000
0.5000	0.96142	1.029	1.45286	27.0	-0.158	-0.119							
						T/K =	323.15						
0.0000	1.02751	1.256	1.48834	33.2	0.000	0.000	0.5499	0.94031	0.882	1.44215	25.3	-0.159	-0.067
0.0502	1.02188	1.220	1.48521	32.5	-0.002	-0.008	0.6000	0.92798	0.853	1.43561	24.7	-0.169	-0.068
0.1000	1.01597	1.187	1.48205	31.8	-0.009	-0.013	0.6500	0.91458	0.825	1.42851	24.1	-0.185	-0.068
0.1498	1.00969	1.154	1.47874	31.1	-0.016	-0.018	0.7000	0.89972	0.795	1.42067	23.5	-0.193	-0.070
0.1998	1.00294	1.120	1.47517	30.4	-0.020	-0.025	0.7499	0.88326	0.770	1.41198	22.9	-0.194	-0.068
0.2499	0.99585	1.086	1.47143	29.6	-0.043	-0.031	0.7999	0.86486	0.743	1.40231	22.3	-0.185	-0.067
0.2998	0.98826	1.050	1.46739	28.9	-0.062	-0.039	0.8500	0.84415	0.723	1.39132	21.7	-0.170	-0.059
0.3500	0.98003	1.015	1.46309	28.2	-0.076	-0.046	0.9000	0.82071	0.704	1.37895	21.0	-0.137	-0.050
0.4000	0.97124	0.979	1.45847	27.5	-0.097	-0.054	0.9500	0.79402	0.692	1.36489	20.3	-0.088	-0.034
0.4501	0.96172	0.943	1.45346	26.7	-0.116	-0.062	1.0000	0.76303	0.698	1.34873	19.4	0.000	0.000
0.5000	0.95149	0.911	1.44807	26.0	-0.141	-0.066							
^a The star	ndard uncer	tainties <i>u</i>	are $u(T) =$	(001.00	5.003 and (0.05) K for	r_0 $n_{\rm n_{\rm p}}$	and σ respe	ctively, an	d the com	bined expa	nded uncert	ainties U

The standard uncertainties u are u(T) = (0.01, 0.05, 0.03, and 0.05) K for ρ , η , n_D , and σ , respectively, and the combined expanded uncertainties U_c are $U_c(\rho) = 0.08 \text{ kg}\cdot\text{m}^{-3}$, $U_c(\eta) = 0.008 \text{ mPa}\cdot\text{s}$, $U_c(n_D) = 0.00005$, $U_c(\sigma) = 0.2 \text{ mN}\cdot\text{m}^{-1}$, and $U_c(V^E) = 0.006 \text{ cm}^3\cdot\text{mol}^{-1}$ (level of confidence = 0.95).

The deviation in the refractive index, Δn_D , was calculated on a volume fraction basis in which case it has simple theoretical significance as reflecting changes in free volume, as stated by Brocos et al.,²⁰ and is given by: where n_D is the refractive index of the mixture. n_{Di} and ϕ_i are the refractive index and the volume fraction of pure component *i*, respectively. The volume fraction, ϕ_i is defined by:

$$\Delta n_{\rm D} = n_{\rm D} - \sum_{i=1}^{N} \phi_i n_{\rm Di}$$
⁽⁵⁾

$$\phi_i = \frac{x_i(M_i/\rho_i)}{\sum_{j=1}^N x_j(M_j/\rho_j)} \tag{6}$$

Table 4. Experimental Densities (ρ), Viscosities (η), Refractive Indices (n_D), Surface Tensions (σ), Excess Molar Volumes (V^E), and Deviations in Viscosity ($\Delta \eta$) for Ethanol (1) + Benzyl Alcohol (3) at T = (293.15, 303.15, 313.15, and 323.15) K^a

	ρ	η		σ	VE	$\Delta \eta$		ρ	η		σ	VE	$\Delta \eta$
x_1	g·cm ^{−3}	mPa∙s	$n_{\rm D}$	$mN \cdot m^{-1}$	cm ³ ·mol ⁻¹	mPa∙s	x_1	g·cm ^{−3}	mPa∙s	$n_{\rm D}$	$mN \cdot m^{-1}$	cm ³ ·mol ⁻¹	mPa∙s
						T/K =	293.15						
0.0000	1.04544	6.287	1.54049	39.2	0.000	0.000	0.5500	0.94823	2.857	1.47074	30.9	-0.617	-0.623
0.0500	1.03893	5.903	1.53607	38.7	-0.086	-0.129	0.5999	0.93557	2.623	1.46176	29.9	-0.623	-0.602
0.1000	1.03201	5.548	1.53119	38.1	-0.162	-0.229	0.6500	0.92193	2.392	1.45220	28.9	-0.617	-0.577
0.1504	1.02472	5.197	1.52584	37.5	-0.242	-0.322	0.6997	0.90734	2.169	1.44199	28.0	-0.596	-0.547
0.1999	1.01709	4.871	1.52041	36.8	-0.309	-0.396	0.7500	0.89149	1.971	1.43095	27.1	-0.563	-0.488
0.2502	1.00895	4.550	1.51444	36.1	-0.377	-0.460	0.7999	0.87442	1.782	1.41922	26.1	-0.509	-0.422
0.3003	1.00031	4.236	1.50804	35.3	-0.435	-0.518	0.8496	0.85594	1.611	1.40661	25.2	-0.435	-0.340
0.3499	0.99124	3.940	1.50154	34.5	-0.489	-0.561	0.8998	0.83544	1.454	1.39275	24.3	-0.307	-0.240
0.3998	0.98152	3.655	1.49454	33.6	-0.533	-0.591	0.9500	0.81326	1.305	1.37776	23.3	-0.171	-0.133
0.4500	0.97112	3.377	1.48707	32.7	-0.570	-0.613	1.0000	0.78910	1.183	1.36137	22.3	0.000	0.000
0.5001	0.96001	3.107	1.47910	31.8	-0.597	-0.627							
						T/K =	303.15						
0.0000	1.03745	4.579	1.53635	38.1	0.000	0.000	0.5500	0.93995	2.206	1.46632	29.8	-0.629	-0.394
0.0500	1.03091	4.276	1.53175	37.5	-0.087	-0.123	0.5999	0.92733	2.030	1.45731	28.8	-0.624	-0.390
0.1000	1.02402	4.006	1.52681	36.9	-0.168	-0.213	0.6500	0.91364	1.873	1.44770	27.8	-0.621	-0.367
0.1504	1.01676	3.761	1.52150	36.2	-0.248	-0.277	0.6997	0.89899	1.716	1.43754	26.9	-0.598	-0.345
0.1999	1.00906	3.529	1.51591	35.5	-0.311	-0.331	0.7500	0.88314	1.568	1.42651	26.0	-0.567	-0.312
0.2502	1.00090	3.321	1.51002	34.8	-0.390	-0.358	0.7999	0.86599	1.423	1.41479	25.1	-0.508	-0.277
0.3003	0.99229	3.117	1.50367	34.1	-0.447	-0.381	0.8496	0.84751	1.292	1.40202	24.2	-0.437	-0.229
0.3499	0.98316	2.924	1.49716	33.3	-0.496	-0.396	0.8998	0.82713	1.173	1.38825	23.3	-0.312	-0.168
0.3998	0.97334	2.735	1.49014	32.5	-0.548	-0.405	0.9500	0.80504	1.060	1.37331	22.3	-0.183	-0.100
0.4500	0.96291	2.542	1.48260	31.6	-0.599	-0.414	1.0000	0.78076	0.980	1.35712	21.4	0.000	0.000
0.5001	0.95176	2.368	1.47469	30.7	-0.607	-0.411							
						T/K =	313.15						
0.0000	1.02961	3.335	1.53215	37.2	0.000	0.000	0.5500	0.93178	1.684	1.46191	28.9	-0.638	-0.269
0.0500	1.02304	3.171	1.52743	36.6	-0.089	-0.038	0.5999	0.91904	1.561	1.45296	27.9	-0.642	-0.266
0.1000	1.01621	3.002	1.52250	35.9	-0.170	-0.082	0.6500	0.90541	1.441	1.44333	26.9	-0.637	-0.261
0.1504	1.00886	2.841	1.51718	35.3	-0.256	-0.116	0.6997	0.89069	1.332	1.43309	26.0	-0.608	-0.245
0.1999	1.00116	2.688	1.51156	34.6	-0.328	-0.145	0.7500	0.87475	1.236	1.42212	25.1	-0.583	-0.214
0.2502	0.99296	2.539	1.50560	33.9	-0.392	-0.167	0.7999	0.85751	1.146	1.41040	24.2	-0.523	-0.179
0.3003	0.98428	2.389	1.49935	33.2	-0.470	-0.191	0.8496	0.83883	1.048	1.39761	23.3	-0.430	-0.152
0.3499	0.97505	2.244	1.49265	32.4	-0.496	-0.212	0.8998	0.81848	0.972	1.38389	22.4	-0.326	-0.102
0.3998	0.96524	2.101	1.48568	31.6	-0.551	-0.229	0.9500	0.79632	0.899	1.36905	21.5	-0.219	-0.049
0.4500	0.95484	1.955	1.47818	30.7	-0.591	-0.249	1.0000	0.77199	0.822	1.35292	20.6	0.000	0.000
0.5001	0.94367	1.819	1.47030	29.8	-0.618	-0.259							
						T/K =	323.15						
0.0000	1.02150	2.545	1.52796	36.3	0.000	0.000	0.5500	0.92328	1.462	1.45755	27.8	-0.698	-0.067
0.0500	1.01486	2.439	1.52308	35.6	-0.091	-0.014	0.5999	0.91048	1.368	1.44855	26.8	-0.695	-0.069
0.1000	1.00798	2.337	1.51807	34.9	-0.189	-0.023	0.6500	0.89661	1.279	1.43892	25.8	-0.685	-0.065
0.1504	1.00057	2.238	1.51273	34.2	-0.275	-0.029	0.6997	0.88189	1.189	1.42870	24.8	-0.658	-0.064
0.1999	0.99289	2.142	1.50721	33.5	-0.353	-0.034	0.7500	0.86588	1.105	1.41775	23.9	-0.622	-0.055
0.2502	0.98467	2.041	1.50123	32.8	-0.431	-0.042	0.7999	0.84864	1.022	1.40607	23.0	-0.557	-0.046
0.3003	0.97599	1.941	1.49494	32.1	-0.515	-0.049	0.8496	0.83007	0.937	1.39329	22.1	-0.461	-0.039
0.3499	0.96671	1.844	1.48825	31.3	-0.541	-0.055	0.8998	0.80962	0.854	1.37963	21.2	-0.350	-0.029
0.3998	0.95684	1.746	1.48127	30.5	-0.598	-0.061	0.9500	0.78741	0.774	1.36475	20.3	-0.232	-0.016
0.4500	0.94637	1.649	1.47378	29.6	-0.636	-0.065	1.0000	0.76303	0.698	1.34873	19.4	0.000	0.000
0.5001	0.93523	1.556	1.46589	28.7	-0.682	-0.065							

^{*a*}The standard uncertainties *u* are u(T) = (0.01, 0.05, 0.03, and 0.05) K for ρ , η , n_D , and σ , respectively, and the combined expanded uncertainties U_c are $U_c(\rho) = 0.08 \text{ kg} \cdot \text{m}^{-3}$, $U_c(\eta) = 0.008 \text{ mPa} \cdot \text{s}$, $U_c(n_D) = 0.00005$, $U_c(\sigma) = 0.2 \text{ mN} \cdot \text{m}^{-1}$, and $U_c(V^E) = 0.006 \text{ cm}^3 \cdot \text{mol}^{-1}$ (level of confidence = 0.95).

where x_i , M_i and ρ_i are the mole fraction, molecular weight, and density of pure component *i*, respectively. The deviations in surface tension, $\Delta\sigma$, were evaluated from the following equation:

$$\Delta \sigma = \sigma - \sum_{i=1}^{N} x_i \sigma_i \tag{7}$$

where σ and σ_i are the surface tensions of the mixture and pure liquid *i*, respectively.

All of the binary quantities $(V^{\text{E}}, \Delta\eta, \Delta n_{\text{D}}, \text{and } \Delta\sigma)$ have been fitted to the Redlich–Kister equation²¹ by the method of least-squares, to derive the binary coefficients (a_k) and standard deviation (δ) :

$$\Delta Q_{ij} = x_i x_j \sum_{k=0}^{m} a_k (x_i - x_j)^k \tag{8}$$

Table 5. Experimental Densities (ρ), Viscosities (η), Refractive Indices (n_D), Surface Tensions (σ), Excess Molar Volumes (V^E), and Deviations in Viscosity ($\Delta \eta$) for Benzyl Acetate (2) + Benzyl Alcohol (3) at T = (293.15, 303.15, 313.15, and 323.15) K^{*a*}

	ρ	η		σ	VE	Δη		ρ	η		σ	VE	$\Delta \eta$
x_2	g·cm ^{−3}	mPa·s	$n_{\rm D}$	$mN \cdot m^{-1}$	cm ³ ·mol ⁻¹	mPa·s	x_2	g·cm ^{−3}	mPa·s	$n_{\rm D}$	$mN \cdot m^{-1}$	cm ³ ·mol ⁻¹	mPa·s
						T/K =	= 293.15						
0.0000	1.04544	6.287	1.54049	39.2	0.000	0.000	0.5501	1.05226	2.930	1.51710		-0.038	-1.177
0.0500	1.04629	5.782	1.53821		-0.015	-0.307	0.6001	1.05274	2.795	1.51530	38.4	-0.038	-1.114
0.1001	1.04703	5.319	1.53584	39.2	-0.022	-0.571	0.6500	1.05319	2.684	1.51352		-0.037	-1.027
0.1502	1.04773	4.905	1.53352		-0.028	-0.787	0.6999	1.05364	2.589	1.51182	38.1	-0.036	-0.924
0.2001	1.04838	4.536	1.53127	39.2	-0.030	-0.958	0.7502	1.05403	2.505	1.51014		-0.031	-0.809
0.2500	1.04899	4.214	1.52907		-0.031	-1.082	0.8000	1.05442	2.428	1.50852	37.8	-0.027	-0.689
0.3000	1.04958	3.927	1.52689	39.1	-0.032	-1.171	0.8500	1.05477	2.376	1.50696		-0.019	-0.542
0.3498	1.05015	3.678	1.52480		-0.033	-1.223	0.9000	1.05511	2.343	1.50544	37.5	-0.010	-0.377
0.4001	1.05071	3.454	1.52279	39.0	-0.035	-1.247	0.9500	1.05546	2.326	1.50396		-0.004	-0.196
0.4500	1.05124	3.252	1.52083		-0.036	-1.252	1.0000	1.05581	2.324	1.50245	37.3	0.000	0.000
0.5000	1.05177	3.087	1.51893	38.7	-0.038	-1.219							
						T/K =	= 303.15						
0.0000	1.03745	4.579	1.53635	38.1	0.000	0.000	0.5501	1.04343	2.332	1.51239		-0.019	-0.738
0.0500	1.03818	4.210	1.53390		-0.010	-0.232	0.6001	1.04384	2.234	1.51057	36.7	-0.016	-0.699
0.1001	1.03883	3.894	1.53143	38.0	-0.015	-0.410	0.6500	1.04424	2.171	1.50881		-0.014	-0.625
0.1502	1.03944	3.623	1.52903		-0.018	-0.544	0.6999	1.04462	2.091	1.50711	36.3	-0.011	-0.568
0.2001	1.04001	3.378	1.52673	37.9	-0.020	-0.652	0.7502	1.04499	2.035	1.50545		-0.008	-0.486
0.2500	1.04058	3.165	1.52449		-0.023	-0.728	0.8000	1.04535	1.985	1.50383	36.0	-0.005	-0.400
0.3000	1.04111	2.972	1.52231	37.8	-0.024	-0.784	0.8500	1.04570	1.941	1.50227		-0.002	-0.306
0.3498	1.04161	2.806	1.52022		-0.024	-0.813	0.9000	1.04605	1.902	1.50075	35.8	-0.001	-0.208
0.4001	1.04210	2.662	1.51819	37.5	-0.024	-0.820	0.9500	1.04640	1.867	1.49926		-0.001	-0.106
0.4500	1.04257	2.535	1.51621		-0.023	-0.810	1.0000	1.04674	1.836	1.49776	35.6	0.000	0.000
0.5000	1.04301	2.432	1.51428	37.1	-0.021	-0.776							
						<i>T</i> /K =	313.15						
0.0000	1.02961	3.335	1.53215	37.2	0.000	0.000	0.5501	1.03460	1.903	1.50774		-0.008	-0.419
0.0500	1.03021	3.180	1.52962		-0.008	-0.062	0.6001	1.03494	1.832	1.50590	35.2	-0.006	-0.386
0.1001	1.03076	3.006	1.52715	37.0	-0.011	-0.143	0.6500	1.03527	1.774	1.50410		-0.003	-0.351
0.1502	1.03127	2.848	1.52471		-0.014	-0.207	0.6999	1.03557	1.728	1.50237	34.8	0.002	-0.304
0.2001	1.03172	2.687	1.52235	36.8	-0.016	-0.276	0.7502	1.03587	1.684	1.50070		0.006	-0.255
0.2500	1.03223	2.536	1.52007		-0.018	-0.334	0.8000	1.03618	1.646	1.49906	34.6	0.007	-0.200
0.3000	1.03267	2.396	1.51785	36.4	-0.018	-0.381	0.8500	1.03648	1.613	1.49748		0.008	-0.140
0.3498	1.03308	2.265	1.51571		-0.017	-0.419	0.9000	1.03679	1.572	1.49596	34.4	0.007	-0.088
0.4001	1.03348	2.154	1.51362	36.0	-0.015	-0.436	0.9500	1.03711	1.524	1.49450		0.004	-0.043
0.4500	1.03386	2.056	1.51160		-0.013	-0.442	1.0000	1.03742	1.474	1.49309	34.3	0.000	0.000
0.5000	1.03424	1.966	1.50964	35.6	-0.012	-0.439							
						T/K =	= 323.15						
0.0000	1.02150	2.545	1.52796	36.3	0.000	0.000	0.5501	1.02528	1.561	1.50314		-0.001	-0.275
0.0500	1.02194	2.450	1.52532		-0.004	-0.031	0.6001	1.02553	1.521	1.50128	33.9	0.003	-0.250
0.1001	1.02236	2.349	1.52278	36.0	-0.007	-0.067	0.6500	1.02579	1.482	1.49946		0.005	-0.225
0.1502	1.02275	2.232	1.52030		-0.008	-0.119	0.6999	1.02604	1.444	1.49771	33.5	0.007	-0.199
0.2001	1.02312	2.125	1.51791	35.7	-0.009	-0.162	0.7502	1.02628	1.410	1.49598		0.008	-0.168
0.2500	1.02348	2.021	1.51560		-0.009	-0.202	0.8000	1.02652	1.387	1.49434	33.4	0.009	-0.127
0.3000	1.02381	1.925	1.51335	35.2	-0.009	-0.233	0.8500	1.02677	1.361	1.49276		0.009	-0.088
0.3498	1.02413	1.838	1.51118		-0.008	-0.256	0.9000	1.02701	1.339	1.49124	33.3	0.008	-0.046
0.4001	1.02444	1.756	1.50908	34.8	-0.007	-0.273	0.9500	1.02726	1.308	1.48976		0.004	-0.012
0.4500	1.02473	1.683	1.50704		-0.005	-0.282	1.0000	1.02751	1.256	1.48834	33.2	0.000	0.000
0.5000	1.02502	1.620	1.50506	34.3	-0.004	-0.281							
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^{*a*}The standard uncertainties *u* are u(T) = (0.01, 0.05, 0.03, and 0.05) K for ρ , η , n_D , and σ , respectively, and the combined expanded uncertainties U_c are $U_c(\rho) = 0.08 \text{ kg} \cdot \text{m}^{-3}$, $U_c(\eta) = 0.008 \text{ mPa} \cdot \text{s}$, $U_c(n_D) = 0.00005$, $U_c(\sigma) = 0.2 \text{ mN} \cdot \text{m}^{-1}$, and $U_c(V^E) = 0.006 \text{ cm}^3 \cdot \text{mol}^{-1}$ (level of confidence = 0.95).

where ΔQ_{ij} refers to the binary $V^{\text{E}}/\text{cm}^3 \cdot \text{mol}^{-1}$, $\Delta \eta/\text{mPa·s}$, Δn_{D} , or $\Delta \sigma/\text{mN·m}^{-1}$ for the i + j system and $x_j = 1 - x_i$. In each case, the optimum number of coefficients (a_k) was determined from an examination of the residuals as a function of composition and the variation of standard deviation (δ) as defined in eq 2. Estimated values of a_k and δ for V^{E} , $\Delta \eta$, Δn_{D} , and $\Delta \sigma$ are presented in Table 8. For the case of V^{E} , the δ values lie between $5 \cdot 10^{-4} \text{ cm}^3 \cdot \text{mol}^{-1}$ and $6 \cdot 10^{-3} \text{ cm}^3 \cdot \text{mol}^{-1}$, and the largest δ value corresponds to ethanol + benzyl acetate at T = 293.15 K.

The derived data, V^{E} , $\Delta \eta$, Δn_{D} , and $\Delta \sigma$, for the ternary system of ethanol (1) + benzyl acetate (2) + benzyl alcohol (3) at T = 303.15 K were correlated respectively using the equation:

$$\Delta Q_{123} = \Delta Q_{12} + \Delta Q_{13} + \Delta Q_{23} + x_1 x_2 x_3 \Delta_{123} \tag{9}$$

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m_{1} <	n_0 mNm ⁻¹ mVm ⁻¹ mV ⁻¹ mV ⁻¹ m		0	u	~	b	$V^{\rm E}$	Δn			o	и		b	$V^{\rm E}$	Δn
1 1	1 149634 3.50 -0013 0.03 0.1499 1.0035 3.13 0.026 0.026 0.033 1 1.9903 3.53 -00073 -0037 0.0308 0.3906 0.1903 0.99057 1.145 1.149730 3.13 -0.047 -0.033 1 1.5172 3.53 -00075 -0.037 0.3006 0.2306 0.3007 0.99073 1.147 3.14 -0.043 -0.043 1 1.5172 3.73 -0094 0.300 0.3001 0.99073 1.147 1.47595 3.14 -0.043 -0.043 1 1.5201 3.74 -0094 0.3301 0.93973 1.47597 3.15 -0.047 -0.033 1 1.5201 1.4901 0.3873 </th <th>$p - \frac{1}{2}$ mPa</th> <th>mPa</th> <th>,</th> <th>n.,</th> <th>¹⁻m·Nm</th> <th>cm³·mol⁻¹</th> <th>mPa-s</th> <th>.x.</th> <th>- *</th> <th>ه.cm⁻³</th> <th>mPa-s</th> <th>Ш</th> <th>mN·m⁻¹</th> <th>$cm^3 \cdot mol^{-1}$</th> <th>mPa-s</th>	$p - \frac{1}{2}$ mPa	mPa	,	n.,	¹⁻ m·Nm	cm ³ ·mol ⁻¹	mPa-s	.x.	- *	ه.cm ⁻³	mPa-s	Ш	mN·m ⁻¹	$cm^3 \cdot mol^{-1}$	mPa-s
	4 1.4993 35.2 -0.033 0.3010 0.4490 1.0035 1.4854 31.9 -0.326 -0.337 -0.0641 0 1.50055 3.55 -0.043 0.536 0.3008 0.3496 1.00133 21.5 1.48593 33.5 -0.047 -0.047 -0.058 0.3008 0.3496 1.0133 0.39951 1.48975 33.5 -0.047 -0.068 5 1.51972 3.65 -0.087 0.3006 0.0200 0.99975 1.4870 33.6 -0.447 -0.688 5 1.5172 3.74 -0.094 0.3010 0.9370 1.4871 1.47266 30.6 -0.032 -0.043 1 1.52073 3.74 -0.094 0.3010 0.3990 0.3301 0.99876 1.4757 30.6 -0.237 -0.043 1 1.52073 3.74 -0.094 0.331 0.99876 1.4757 30.6 -0.329 -0.247 -0.058 1 1.49910 3.12	g un g un g 1.04085 1.77	1.77	° 4	"D 1.49634	35.0	-0.015	-0.157	0.3011	0.5491	5 un 1.00517	1.576	ир 1.48187	31.5	-0.207	-0.413
	4 15026 355 -0043 -0.536 0.308 0.3496 110305 355 -0.037 -0.373 -0.668 0 15.9075 35.3 -00075 -0.568 0.300 0.9273 2.123 149705 3.31 -0.373 -0.668 5 15.977 -00075 -0087 0.3006 0.2300 0.99773 2.193 146775 3.05 -0.417 -0.663 5 15.152 37.4 -0008 -0.707 0.4011 0.4991 0.8999 0.5999 0.3996 0.3996 0.5999 0.3906 0.2906 0.1577 0.4017 0.4017 0.4017 0.4017 0.4017 0.4017 0.4017 0.4018 0.4097 0.3996 0.5999 0.3906 0.5999 0.5999 0.5999 0.5999 0.5999 0.5999 0.5999 0.5177 0.4017 0.4017 0.4017 0.4017 0.4017 0.4018 0.4491 0.477 0.4017 0.4017 0.4018 0.4177 0.505	1.04002 1.85	1.85	4	1.49939	35.2	-0.029	-0.351	0.3000	0.4499	1.00350	1.714	1.48542	31.9	-0.266	-0.551
0 150605 359 -0002 -0.663 0.301 0.2502 0.9925 2.115 1,49705 33.1 -0.373 -0.663 65 15,3172 367 -0.008 -0.306 0.300 0.99674 2.460 1,49705 33.6 -0.407 -0.663 75 15,1772 370 -0.093 0.3990 0.5490 0.98944 1,373 1,4677 30.6 -0.477 -0.663 75 15,2116 37.3 -0.091 -0.332 0.3990 0.5490 0.98944 1,373 1,4677 30.6 -0.332 -0.417 -0.663 1 1,49510 34.1 -0.091 -0.332 0.4905 0.5490 0.98652 1,47767 30.6 -0.332 -0.417 -0.663 1 49610 34.2 -0.010 -0.332 0.4005 0.5490 0.5760 0.4477 20.6 -0.4375 -0.4475 -0.4475 1 1,49513 34.1 -0.110 -0.133	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	1.03920 1.95	1.9	54	1.50265	35.5	-0.043	-0.526	0.3008	0.3496	1.00139	1.896	1.48895	32.5	-0.327	-0.641
58 15.0972 56.3 -0.075 -0.786 0.13.09 0.147 -0.638 -0.447 -0.633 57 1.51.362 56.7 -0.092 -0.807 0.3006 0.1307 0.3996 1.1 0.1437 -0.1433 -0.0433 56 1.51.362 3.67 -0.092 -0.807 0.3096 0.3099 1.487 1.472 1.0 -0.433 -0.043 51 1.52216 3.74 -0.094 -0.497 0.3690 0.3501 0.98984 1.487 1.47296 3.00 -0.232 -0.033 51 1.52013 3.74 -0.094 -0.497 0.3690 0.3501 0.98935 1.47547 3.06 -0.322 -0.2349 51 1.4953 3.64 -0.101 -0.491 0.99535 1.47547 3.06 -0.323 -0.547 51 1.4963 3.55 -0.110 -0.491 0.3993 1.487 1.47241 2.0417 -0.549 51 1.5068	8 1.5072 363 -0.075 -0.768 0.2096 0.1503 0.99674 2.450 1.49705 33.6 -0.407 -0.638 7 1.5172 370 -0.008 -0.007 0.3099 0.54990 0.55990 1.50768 341 -0.133 -0.447 7 1.52016 373 -0.094 -0.707 0.4011 0.4491 0.98737 1.487 1.47796 300 -0.238 -0.177 1 1.52073 374 -0.094 -0.707 0.4011 0.4491 0.98737 1.487 1.47796 300 -0.238 -0.477 9 1.52019 375 -0.094 -0.739 0.3099 0.3501 0.99496 1.655 1.47747 30.6 -0.232 -0.234 9 1.4971 3.32 -0.094 -0.492 0.3090 0.1500 0.99786 1.557 1.487 3.12 -0.447 -0.695 9 1.49613 3.41 -0.061 $-0.333 0.4005 0.0198 0.97508 2.499 1.48787 3.23 -0.5199 -0.5099 1.49613 3.42 -0.0110 -0.331 0.4097 0.3501 0.94956 1.1297 1.4878 3.23 -0.5199 -0.5298 1.99961 3.35 -0.1120 -0.789 0.5001 0.4497 0.99652 1.428 1.4677 2.86 -0.349 -0.9477 1.51053 3.61 -0.1120 -0.789 0.5001 0.0499 0.1501 0.99893 1.836 1.4671 2.86 -0.349 -0.9471 1.51075 3.61 -0.1120 -0.789 0.9001 0.1499 0.95030 1.836 1.4671 2.93 -0.749 -0.9471 1.51075 3.61 -0.1130 -0.796 0.4999 0.1501 0.95893 1.836 1.46913 2.99 -0.5212 -0.5329 1.48677 3.26 -0.0130 -0.0260 0.02010 0.94548 1.314 1.4675 2.68 -0.538 -0.3491 1.5105 3.51 -0.0169 -0.331 0.6001 0.1499 0.95030 1.836 1.44613 2.93 -0.238 -0.7439 1.4867 3.24 -0.177 -0.0169 0.0200 0.02010 0.99103 1.565 1.4567 2.86 -0.538 -0.7341 1.51495 3.54 -0.0179 -0.0739 0.5001 0.1499 0.93031 1.565 1.45672 2.86 -0.238 -0.2381 1.5049 3.33 -0.119 -0.0560 0.0000 0.0001 0.1499 0.93031 1.566 1.4572 2.80 -0.338 -0.2341 1.4867 3.34 -0.218 -0.0739 0.5001 0.1499 0.93033 1.846 1.45672 2.80 -0.338 -0.2341 1.5049 3.33 -0.119 -0.2660 0.0000 0.0001 0.01990 0.07051 1.566 1.4363 2.67 -0.338 -0.2341 1.49664 3.33 -0.2191 -0.0500 0.01499 0.93033 1.846 1.44673 2.56 -0.238 -0.2341 1.49664 3.33 -0.2191 -0.0500 0.01499 0.93033 1.846 1.45672 2.80 -0.338 -0.2341 1.49664 3.33 -0.2191 -0.0500 0.01499 0.0500 0.01493 0.1566 1.4566 1.4566 1.4568 -0.238 -0.2346 -0.2381 1.49664 3.33 -0.2191 -0.2660 $	1.03828 2.0	2.0	90	1.50605	35.9	-0.062	-0.663	0.3001	0.2502	0.99925	2.125	1.49290	33.1	-0.373	-0.688
5 11362 367 -0.083 -0.807 0.3006 0.020 0.99275 2.999 150268 34.1 -0.433 -0.437 73 1.51772 37.0 -0.092 -0.803 0.3999 0.5499 0.98975 1.4774 306 -0.375 -0.038 31 1.51772 37.4 -0094 -0.472 0.3999 0.5499 0.98967 1.4754 306 -0.355 -0.0175 31 1.53673 37.4 -0094 -0.472 0.3999 0.5301 0.98967 1.47647 306 -0.355 -0.0247 31 1.49013 31.2 -0.032 0.1187 0.4907 0.5301 0.98965 1.49013 31.2 -0.477 0.5309 31 1.50687 35.6 -0.117 -0.490 0.5301 0.98652 1.439 1.46747 2.36 -0.379 -0.349 31 1.50687 35.6 -0.132 0.5010 0.5301 0.9497 0.5491 0.5301	5 1.51362 367 -0.085 -0.807 0.3006 0.0200 0.99375 1.373 1.6073 3.31 -0.4137 -0.433 3 1.51772 7.37 -0.002 -0.002 0.3999 0.5499 0.98757 1.475 2.35 -0.1187 -0.238 4 1.52673 37.4 -0.094 -0.332 0.3996 0.5301 0.98456 1.47647 3.06 -0.2187 -0.038 9 1.52673 37.4 -0.091 -0.332 0.3996 0.5301 0.98456 1.47647 3.06 -0.0277 -0.539 9 1.52673 37.4 -0.012 -0.033 0.4907 0.5301 0.98456 1.48013 3.12 -0.4177 -0.599 7 1.50368 35.2 -0.110 -0.681 0.4907 0.5301 0.9852 1.46747 2.83 -0.4177 -0.599 7 1.50108 35.5 -0.112 -0.129 0.4997 0.5301 0.5501 1.4674	1.03732 2.2	2.2	58	1.50972	36.3	-0.075	-0.768	0.2996	0.1503	0.99674	2.450	1.49705	33.6	-0.407	-0.638
$ \begin{array}{ ccccccccccccccccccccccccccccccccccc$	3 1.5172 37.0 -0.092 -0.803 0.3999 0.5499 0.98984 1.373 1.46975 2.35 -0.187 -0.035 5 1.5216 37.3 -0.096 -0.707 0.4011 0.4491 0.98737 1.487 1.47767 3.05 -0.235 -0.417 9 1.53013 37.4 -0.091 -0.332 0.3996 0.5014 0.98736 1.487 1.47767 3.05 -0.035 -0.6043 9 1.53010 34.4 -0.061 -0.332 0.3906 0.5016 0.97508 2.129 1.4877 3.13 -0.477 -0.539 9 1.49613 35.5 -0.110 -0.631 0.4005 0.5001 0.3502 1.4518 1.46247 3.25 -0.241 -0.247 1 1.51073 36.1 -0.132 -0.769 0.5001 0.3502 1.4524 2.213 1.4657 2.25 -0.241 -0.477 1 1.51073 36.4 -0.137	1.03631 2.4	2.4	95	1.51362	36.7	-0.085	-0.807	0.3006	0.0200	0.99275	2.999	1.50268	34.1	-0.433	-0.443
45 132216 37.3 -0096 -0707 0.4011 0.4931 0.4871 1.47296 300 -0.235 -0.417 31 1.52673 37.4 -0094 -0.492 0.3939 0.3501 0.98496 1.655 1.477296 30.0 -0.2352 -0.537 30 1.49613 37.4 -0004 -0.332 0.3939 0.3501 0.98496 1.655 1.47731 30.6 -0.352 -0.537 31 1.49613 34.4 -0001 -0.383 0.4005 0.3501 0.98496 1.655 1.47313 31.2 -0.477 -0.532 31 1.49613 34.4 -0001 -0.383 0.4005 0.3501 0.98652 1.4951 1.4951 -0.519 -0.519 -0.519 -0.519 -0.519 -0.519 -0.519 -0.519 -0.519 -0.519 -0.519 -0.519 -0.519 -0.519 -0.519 -0.512 -0.519 -0.519 -0.519 -0.519 -0.519 -0.519	5 1.5216 37.3 -0.096 -0.77 0.4011 0.4491 0.98737 1.487 1.47296 300 -0.235 -0.417 1 1.52073 3.74 -0.094 -0.492 0.3999 0.3601 0.98496 1.655 1.47647 306 -0.4325 -0.605 1 1.49101 3.75 -0.0091 -0.339 0.3000 0.97868 1.499 1.4873 31.8 -0.477 -0.599 2 1.49061 3.48 -0.061 -0.383 0.4005 0.97508 2.499 1.48787 32.3 -0.519 -0.570 2 1.50087 3.64 -0.110 -0.681 0.4997 0.3502 0.96535 1.48787 23.3 -0.041 -0.491 2 1.51078 3.61 -0.112 -0.769 0.4995 0.5301 1.48787 23.8 -0.417 -0.2341 1 1.51078 3.64 -0.170 -0.6601 0.3501 0.95438 1.14673 2.86	1.03512 2.7	2.7	73	1.51772	37.0	-0.092	-0.803	0.3999	0.5499	0.98984	1.373	1.46975	29.5	-0.187	-0.258
31 1.52673 3.74 -0.094 -0.422 0.3300 0.3323 -0.332 -0.332 -0.332 -0.332 -0.332 -0.332 -0.332 -0.332 -0.332 -0.332 -0.332 0.3306 0.2504 0.88225 1.47647 3.16 -0.425 -0.059 70 1.49961 3.44 -0.0132 -0.333 0.4000 0.97506 2.499 1.48316 31.2 -0.424 -0.501 70 1.49961 34.4 -0.0681 0.4907 0.3502 1.496347 32.3 -0.241 -0.249 70 1.51075 361 -0.132 -0.769 0.4907 0.3502 1.46374 2.93 -0.332 0.501 71 1.51075 361 -0.117 -0.799 0.4907 0.3501 0.95622 1.46374 2.93 -0.574 -0.477 70 1.51075 366 -0.133 0.6000 0.5001 <	$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	1.03394 3.1	3.1	45	1.52216	37.3	-0.096	-0.707	0.4011	0.4491	0.98737	1.487	1.47296	30.0	-0.285	-0.417
29 1,2,919 37.5 -0.091 -0.332 0.3996 0.2504 0.98222 1.8490 1.48013 31.2 -0.425 -0.603 79 1.49510 34.4 -0.032 -0.187 0.4000 0.1500 0.97866 2.129 1.48786 3.18 -0.477 -0.593 78 1.4961 -0.383 -0.1010 -0.681 0.4005 0.1500 0.97866 2.129 1.48787 3.23 -0.547 -0.501 78 1.50078 35.5 -0.110 -0.681 0.4999 0.5001 0.95592 1.4673 283 -0.344 -0.347 70 1.51075 36.1 -0.179 0.4999 0.1501 0.95592 1.4673 283 -0.444 -0.444 71 1.51075 36.1 -0.179 0.4999 0.5001 0.95592 1.4673 286 -0.444 -0.477 70 1.51075 36.4 -0.179 0.4999 0.5001 0.95592 1.4673 286 </td <td>9 152919 37.5 -0091 -0.332 0.3966 0.2304 0.98232 1.8491 31.2 -0.425 -0.605 1 149610 34.2 -0001 -0.333 0.4005 0.1300 0.97866 2.129 1.48365 31.8 -0.417 -0.503 9 149610 34.8 -0061 -0.333 0.4005 0.9786 2.129 1.4878 31.3 -0.241 -0.503 7 150087 35.6 -0112 -0.630 0.96532 1.4951 2.86 -0.349 -0.323 6 151075 36.1 -01132 -0.766 0.4999 0.1501 0.95633 1.836 1.44613 2.93 -0.531 -0.531 1 151075 36.4 -01169 0.5001 0.5301 0.9533 1.8463 31.8 -0.533 -0.533 -0.533 -0.533 -0.533 -0.533 -0.533 -0.533 -0.534 -0.544 -0.544 -0.534 -0.533 -0.534</td> <td>1.03239 3.6</td> <td>3.6</td> <td>31</td> <td>1.52673</td> <td>37.4</td> <td>-0.094</td> <td>-0.492</td> <td>0.3999</td> <td>0.3501</td> <td>0.98496</td> <td>1.655</td> <td>1.47647</td> <td>30.6</td> <td>-0.352</td> <td>-0.524</td>	9 152919 37.5 -0091 -0.332 0.3966 0.2304 0.98232 1.8491 31.2 -0.425 -0.605 1 149610 34.2 -0001 -0.333 0.4005 0.1300 0.97866 2.129 1.48365 31.8 -0.417 -0.503 9 149610 34.8 -0061 -0.333 0.4005 0.9786 2.129 1.4878 31.3 -0.241 -0.503 7 150087 35.6 -0112 -0.630 0.96532 1.4951 2.86 -0.349 -0.323 6 151075 36.1 -01132 -0.766 0.4999 0.1501 0.95633 1.836 1.44613 2.93 -0.531 -0.531 1 151075 36.4 -01169 0.5001 0.5301 0.9533 1.8463 31.8 -0.533 -0.533 -0.533 -0.533 -0.533 -0.533 -0.533 -0.533 -0.534 -0.544 -0.544 -0.534 -0.533 -0.534	1.03239 3.6	3.6	31	1.52673	37.4	-0.094	-0.492	0.3999	0.3501	0.98496	1.655	1.47647	30.6	-0.352	-0.524
	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	1.03165 3.9	3.9	929	1.52919	37.5	-0.091	-0.332	0.3996	0.2504	0.98222	1.849	1.48013	31.2	-0.425	-0.605
779 149623 344 -0.061 -0.383 0.4005 0.0493 0.97508 2.499 1.48787 3.23 -0.519 -0.501 888 149961 348 -0.088 -0.547 0.5001 0.4497 0.36956 1.297 1.45928 28.1 -0.249 -0.249 217 1.50308 35.2 -0.110 -0.681 0.4997 0.3502 0.96552 1.428 1.46574 286 -0.349 -0.329 215 1.50687 35.6 -0.132 -0.769 0.5001 0.2500 0.96522 1.46574 29.3 -0.444 -0.491 610 1.51197 3.66 -0.132 -0.779 0.4999 0.1501 0.95430 1.46574 29.3 -0.444 -0.477 70 1.511495 3.64 -0.167 0.7790 0.95301 0.95430 1.216 1.46574 29.3 -0.232 -0.232 70 1.511495 3.64 -0.1670 0.5000 0.3501 0.95430 1.214 1.46574 29.3 -0.233 -0.244 70 1.51495 3.66 -0.179 0.4996 0.5001 0.9503 1.8160 1.46574 29.3 -0.233 -0.244 70 1.51495 3.66 -0.1170 -0.233 0.6001 0.1499 0.9503 1.1467 2.92 -0.233 -0.243 70 1.51495 3.26 -0.1132 -0.1149 0.5000 0.2500 <	9 149623 344 -0061 -0.383 0.4005 0.9498 0.97508 2.499 148787 3.23 -0.519 -0.501 -0.541 -0.501 -0.541 -0.501 -0.547 0.5001 0.4497 0.96556 1.297 145928 28.1 -0.519 -0.549 -0.549 -0.541 -0.241 -0.241 -0.249 7 150087 35.6 -0.112 -0.769 0.5001 0.4997 0.3502 1.602 1.46574 29.3 -0.349 -0.353 1 151075 36.1 -0.113 -0.779 0.3501 0.3502 1.602 1.46574 29.3 -0.374 -0.477 1 1.51075 36.6 -0.170 -0.739 0.5001 0.1499 0.3501 1.46574 29.3 -0.476 -0.477 0 1.51045 3.6 -0.170 -0.636 0.5001 0.1499 0.5601 0.4499 0.574 -0.473 0.443 1.51147 1.5167 1.446	1.03479 1.7	1.1	701	1.49310	34.2	-0.032	-0.187	0.4000	0.1500	0.97886	2.129	1.48386	31.8	-0.477	-0.599
88 149961 348 -0088 -0.547 0.501 0.4497 0.96956 1.297 1.45928 28.1 -0.241 -0.243 217 150308 35.2 -0110 -0.681 0.4997 0.3502 0.96652 1.428 1.46247 28.6 -0.349 -0.332 215 150687 35.6 -0113 -0.796 0.4999 0.5001 0.95593 1.836 1.46913 293 -0.444 -0.491 61 151075 36.1 -0167 0.796 0.4999 0.1501 0.95893 1.836 1.4673 28.6 -0.531 -0.431 70 151495 36.6 -0.160 -0.330 0.3501 0.95430 21.66 1.47281 30.5 -0.533 -0.544 70 151495 36.6 -0.133 0.4010 0.3501 0.95430 1.44675 28.6 -0.533 -0.544 70 1.51495 3.58 -0.160 0.5000 0.9503 1.565	8 149961 34.8 -0.088 -0.547 0.501 0.4497 0.96556 1.297 1.45928 28.1 -0.241 -0.249 7 1.50388 35.2 -0.110 -0.681 0.4997 0.5302 0.96522 1.4524 28.6 -0.349 -0.392 1 1.51075 36.1 -0.113 -0.769 0.5001 0.2500 0.96522 1.4674 28.6 -0.349 -0.323 1 1.51075 36.1 -0.117 -0.576 0.4999 0.1501 0.95592 1.4671 28.6 -0.349 -0.323 0 1.51495 36.6 -0.170 -0.600 0.3501 0.95430 1.4671 28.6 -0.333 -0.245 0 1.51495 36.6 -0.133 -0.144 0.600 0.3501 0.94943 1.4673 26.8 -0.243 -0.443 1.5144 1.5141 1.41467 2.6 -0.367 -0.367 -0.434 1.51244 1.46731	1.03382 1.7	1	779	1.49623	34.4	-0.061	-0.383	0.4005	0.0498	0.97508	2.499	1.48787	32.3	-0.519	-0.502
127 1.50308 35.2 -0.110 -0.681 0.497 0.3502 0.96552 1.428 1.46247 28.6 -0.349 -0.392 115 1.50687 35.6 -0.132 -0.769 0.5001 0.2500 0.96522 1.602 1.46574 29.3 -0.4441 -0.491 161 1.51075 36.1 -0.153 -0.796 0.4999 0.1501 0.95893 1.836 1.46913 29.9 -0.572 -0.574 751 1.51495 36.6 -0.170 -0.779 0.4996 0.5001 0.95430 2.166 1.47281 30.5 -0.574 -0.477 751 1.51495 3.66 -0.170 -0.636 0.6000 0.3501 0.95430 2.166 1.47281 30.5 -0.574 -0.477 750 1.51495 3.66 -0.179 -0.539 0.6001 0.1499 0.93633 1.44660 2.74 -0.233 -0.248 560 1.48637 3.26 -0.133 -0.144 0.6001 0.1499 0.93633 1.44660 2.74 -0.476 561 1.48637 3.26 -0.133 -0.144 0.6001 0.1499 0.93033 1.848 1.45572 2.86 -0.369 562 1.48637 3.29 -0.133 -0.149 0.6001 0.1499 0.93033 1.848 1.45572 2.86 -0.36 561 1.49664 3.33 -0.149 0.6001 0.1962	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	1.03293 1.8	1.8	388	1.49961	34.8	-0.088	-0.547	0.5001	0.4497	0.96956	1.297	1.45928	28.1	-0.241	-0.249
15 1.50687 35.6 -0.132 -0.769 0.5001 0.2500 0.96292 1.602 1.46574 29.3 -0.444 -0.961 461 1.51075 36.1 -0.153 -0.796 0.4999 0.1501 0.95893 1.836 1.46913 29.9 -0.522 -0.532 751 1.51945 36.4 -0.167 -0.779 0.4996 0.0502 0.95430 2.166 1.47281 30.5 -0.574 -0.477 751 1.51945 36.6 -0.170 -0.636 0.6000 0.3501 0.9448 1.214 1.44675 26.8 -0.233 -0.243 60 1.51945 36.6 -0.0169 -0.389 0.6001 0.1490 0.3501 1.44675 26.8 -0.283 -0.243 60 1.48637 32.6 -0.0133 0.414 0.6003 0.3603 1.565 1.44675 26.8 -0.243 -0.243 60 1.48617 32.9 -0.144 0.6003 0.24	51.5068735.6-0.132-0.7690.50010.25000.962921.6021.4657429.3-0.444-0.49111.5107536.1-0.153-0.7790.49960.15010.958931.8361.469132.99-0.572-0.53211.5107536.4-0.167-0.7790.49960.05020.954302.1661.4728130.5-0.574-0.47701.5194536.6-0.0170-0.6360.60000.35010.945481.2141.446752.68-0.233-0.24501.5241936.8-0.0169-0.3390.60010.14990.936031.5651.4526228.0-0.574-0.44321.4863732.6-0.0130-0.2330.60010.14990.930031.5651.4526228.0-0.537-0.44321.4864732.9-0.133-0.1440.60000.50110.14990.930331.8481.4557228.6-0.507-0.43321.4930733.3-0.179-0.5560.69990.25000.916231.1441.4315125.6-0.536-0.53621.4996433.8-0.0179-0.5560.69990.50000.900941.3101.4356228.6-0.536-0.54621.4996433.8-0.218-0.7730.70020.14990.970611.43662.56-0.546-0.56621.5004934.3-0.2280	1.03181 2.	i,	027	1.50308	35.2	-0.110	-0.681	0.4997	0.3502	0.96652	1.428	1.46247	28.6	-0.349	-0.392
461 1.51075 36.1 -0.153 -0.796 0.4999 0.1501 0.5893 1.836 1.46913 299 -0.522 -0.537 751 1.51475 36.4 -0.167 -0.779 0.4996 0.0502 0.95430 2.166 1.47281 305 -0.574 -0.477 170 1.51945 36.6 -0.170 -0.636 0.6000 0.3501 0.94548 1.214 1.44675 26.8 -0.283 -0.245 690 1.52419 36.8 -0.169 -0.389 0.6001 0.1499 0.94105 1.360 1.44960 27.4 -0.408 602 1.48637 32.9 -0.169 -0.233 0.6001 0.1499 0.93603 1.565 1.44960 27.4 -0.408 -0.373 602 1.48961 32.9 -0.080 -0.233 0.6001 0.1499 0.93603 1.565 1.44960 27.4 -0.408 -0.373 603 1.48637 32.9 -0.133 -0.141 0.6000 0.5010 0.93033 1.848 1.45572 28.6 -0.507 -0.434 774 1.49307 32.3 -0.179 -0.6700 0.7002 0.1499 0.991623 1.14146 1.44675 2.62 -0.507 -0.366 774 32.8 -0.218 -0.218 0.6000 0.5000 0.5000 0.991623 1.1416 1.43151 2.67 -0.548 -0.366 779 1.49664 33.8 <td>1 1.51075 36.1 -0.153 -0.796 0.4999 0.1501 0.95893 1.836 1.46913 29.9 -0.522 -0.532 1 1.51495 36.4 -0.167 -0.779 0.4996 0.0502 0.95430 2.166 1.47281 30.5 -0.574 -0.477 0 1.51495 36.6 -0.170 -0.636 0.6000 0.3501 0.95438 1.214 1.44675 26.8 -0.283 -0.245 0 1.5149 36.8 -0.0169 -0.339 0.6001 0.1499 0.93503 1.366 1.44675 26.8 -0.373 -0.243 2 1.48637 32.6 -0.0133 -0.414 0.6000 0.3503 1.366 1.44675 26.8 -0.367 -0.433 2 1.48637 32.6 -0.0133 -0.414 0.6000 0.03503 1.848 1.45572 28.6 -0.366 -0.336 2 1.49664 33.8 -0.243 0.6012 0.1499</td> <td>1.03076 2.</td> <td>6</td> <td>215</td> <td>1.50687</td> <td>35.6</td> <td>-0.132</td> <td>-0.769</td> <td>0.5001</td> <td>0.2500</td> <td>0.96292</td> <td>1.602</td> <td>1.46574</td> <td>29.3</td> <td>-0.444</td> <td>-0.491</td>	1 1.51075 36.1 -0.153 -0.796 0.4999 0.1501 0.95893 1.836 1.46913 29.9 -0.522 -0.532 1 1.51495 36.4 -0.167 -0.779 0.4996 0.0502 0.95430 2.166 1.47281 30.5 -0.574 -0.477 0 1.51495 36.6 -0.170 -0.636 0.6000 0.3501 0.95438 1.214 1.44675 26.8 -0.283 -0.245 0 1.5149 36.8 -0.0169 -0.339 0.6001 0.1499 0.93503 1.366 1.44675 26.8 -0.373 -0.243 2 1.48637 32.6 -0.0133 -0.414 0.6000 0.3503 1.366 1.44675 26.8 -0.367 -0.433 2 1.48637 32.6 -0.0133 -0.414 0.6000 0.03503 1.848 1.45572 28.6 -0.366 -0.336 2 1.49664 33.8 -0.243 0.6012 0.1499	1.03076 2.	6	215	1.50687	35.6	-0.132	-0.769	0.5001	0.2500	0.96292	1.602	1.46574	29.3	-0.444	-0.491
751 1.51495 364 -0.167 -0.779 0.4996 0.0502 0.95430 2.166 1.47281 30.5 -0.574 -0.477 170 1.51945 36.6 -0.170 -0.636 0.6000 0.3501 0.94548 1.214 1.44675 26.8 -0.283 -0.245 690 1.52419 36.8 -0.169 -0.389 0.6001 0.1499 0.94105 1.360 1.44675 26.8 -0.283 -0.245 662 1.48637 3.26 -0.0380 -0.233 0.6001 0.1499 0.93603 1.565 1.44572 28.0 -0.507 -0.443 662 1.48961 3.29 -0.133 -0.144 0.6000 0.3501 0.1499 0.93603 1.565 1.45572 28.6 -0.537 -0.443 744 1.49307 3.23 -0.179 -0.556 0.6000 0.3500 0.991623 1.144 1.45572 28.6 -0.537 -0.434 774 -0.238 -0.743 0.6000 0.5000 0.5000 0.91623 1.144 1.45572 28.6 -0.536 -0.346 74964 3.33 -0.218 -0.743 0.6000 0.7002 0.1499 0.99094 1.310 1.43151 2.74 -0.408 -0.336 74964 3.48 -0.228 -0.743 0.7002 0.7002 0.91623 1.144 1.45572 2.86 -0.346 -0.346 150447	$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	1.02944 2.	5	461	1.51075	36.1	-0.153	-0.796	0.4999	0.1501	0.95893	1.836	1.46913	29.9	-0.522	-0.532
$ \begin{array}{ ccccccccccccccccccccccccccccccccccc$	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	1.02809 2	4	751	1.51495	36.4	-0.167	-0.779	0.4996	0.0502	0.95430	2.166	1.47281	30.5	-0.574	-0.477
690 1.52419 36.8 -0.169 -0.389 0.6003 0.2498 0.94105 1.360 1.44960 27.4 -0.408 -0.373 569 1.48637 3.2.6 -0080 -0.233 0.6001 0.1499 0.93603 1.555 1.45262 28.0 -0.408 -0.434 562 1.48961 3.2.9 -0.133 -0414 0.6000 0.0501 0.93603 1.865 1.45262 28.0 -0.538 -0.434 562 1.48961 3.2.3 -0.179 -0.556 0.6999 0.2500 0.91623 1.144 1.43151 2.56 -0.306 -0.336 561 1.49664 3.3.3 -0.2179 -0.702 0.1499 0.99094 1.310 1.43351 2.56 -0.306 -0.336 5161 1.50049 3.4.3 -0.238 0.7439 0.7020 0.0500 0.90276 1.43351 2.56 -0.346 -0.366 429 1.50447 3.48 -0.238 2.67	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	1.02653 3.	ς.	170	1.51945	36.6	-0.170	-0.636	0.6000	0.3501	0.94548	1.214	1.44675	26.8	-0.283	-0.245
569 1.48637 32.6 -0.080 -0.233 0.6001 0.1499 0.93603 1.555 1.45262 28.0 -0.507 -0.433 662 1.48961 32.9 -0.133 -0.414 0.6000 0.0501 0.93033 1.848 1.45572 28.6 -0.538 -0.434 794 1.49307 33.3 -0.179 -0.556 0.6999 0.2500 0.91623 1.144 1.43151 25.6 -0.306 -0.230 952 1.49664 33.8 -0.218 -0.670 0.7002 0.1498 0.90994 1.310 1.43151 25.6 -0.306 -0.336 .161 1.50049 34.3 -0.218 -0.6702 0.7002 0.01499 0.80094 1.310 1.43336 26.7 -0.346 -0.336 .150447 34.8 -0.238 0.7002 0.0500 0.90276 1.556 1.43633 26.7 -0.346 -0.366 .784 1.50447 34.8 -0.238 0.8000	9 148637 32.6 -0.080 -0.233 0.6001 0.1499 0.93603 1.565 1.45262 28.0 -0.507 -0.443 2 148961 32.9 -0.113 -0.414 0.6000 0.0501 0.93033 1.848 1.45572 28.6 -0.538 -0.434 4 149307 33.3 -0.179 -0.556 0.6999 0.2500 0.91623 1.144 1.43151 25.6 -0.306 -0.306 2 149664 33.8 -0.218 -0.670 0.7002 0.1498 0.90994 1.310 1.43151 25.6 -0.306 -0.336 9 1.50049 34.3 -0.220 -0.743 0.7002 0.0500 0.9776 1.556 1.43633 26.7 -0.545 -0.366 9 1.50447 34.8 -0.238 -0.743 0.8000 0.0501 0.87985 1.3163 1.41408 25.0 -0.243 -0.236 1 1.50885 35.2 -0.312	1.02479 3	ŝ	069.	1.52419	36.8	-0.169	-0.389	0.6003	0.2498	0.94105	1.360	1.44960	27.4	-0.408	-0.373
662 1.48961 32.9 -0.133 -0.414 0.6000 0.0501 0.93033 1.848 1.4572 28.6 -0.588 -0.434 794 1.49307 33.3 -0.179 -0.556 0.6999 0.2500 0.91623 1.144 1.43151 25.6 -0.306 -0.306 952 1.49664 33.8 -0.218 -0.670 0.7002 0.1498 0.90994 1.310 1.43386 26.2 -0.443 -0.336 161 1.50049 34.3 -0.220 0.7002 0.1498 0.90976 1.556 1.43633 26.7 -0.545 -0.366 429 1.50049 34.3 -0.228 -0.743 0.8000 0.90276 1.556 1.43633 26.7 -0.546 -0.366 7429 1.50049 34.8 -0.743 0.8000 0.87095 1.284 1.41233 26.7 -0.246 -0.208 745 1.50885 35.2 -0.311 -0.660 0.8000 0.87095 <t< td=""><td>2 148961 32.9 -0.133 -0.414 0.6000 0.0501 0.93033 1.848 1.45572 28.6 -0.588 -0.434 4 149307 33.3 -0.179 -0.556 0.6999 0.2500 0.91623 1.144 1.43151 25.6 -0.306 -0.230 2 149664 33.8 -0.218 -0.670 0.7002 0.1498 0.90994 1.310 1.43386 26.2 -0.443 -0.338 1 150049 34.3 -0.250 -0.737 0.7002 0.0500 0.90276 1.556 1.43633 26.7 -0.545 -0.366 6 1.5085 35.2 -0.301 -0.660 0.8000 0.1499 0.87984 1.081 1.411253 24.5 -0.298 -0.208 4 1.51350 35.5 -0.312 -0.469 0.9000 0.0501 0.87095 1.284 1.41408 25.0 -0.436 -0.278 1 1.47869 31.1 -0.134 -0.255 1 0.05, 0.0500 0.83350 1.056 1.586 1.43633 26.7 -0.545 -0.268 1 0.05, 0.35, 0.5000 0.83350 1.056 1.586 1.41408 25.0 -0.436 -0.278 1 1.47869 31.1 -0.134 -0.255 1 0.0500 0.8000 0.0500 0.83350 1.056 1.58825 2.32 -0.250 -0.447 1 0.05, 0.05, and 0.5 K for p, n_{D} and σ respectively, and the combined expanded uncertainties U_c are $U_c(p) = 0.08 \text{ kg·m}^{-3}$, $U_c(n) = 0.08 \text{ mPa·s}$, $U_c(n_D)$</td><td>1.02172 1</td><td>Г</td><td>.569</td><td>1.48637</td><td>32.6</td><td>-0.080</td><td>-0.233</td><td>0.6001</td><td>0.1499</td><td>0.93603</td><td>1.565</td><td>1.45262</td><td>28.0</td><td>-0.507</td><td>-0.443</td></t<>	2 148961 32.9 -0.133 -0.414 0.6000 0.0501 0.93033 1.848 1.45572 28.6 -0.588 -0.434 4 149307 33.3 -0.179 -0.556 0.6999 0.2500 0.91623 1.144 1.43151 25.6 -0.306 -0.230 2 149664 33.8 -0.218 -0.670 0.7002 0.1498 0.90994 1.310 1.43386 26.2 -0.443 -0.338 1 150049 34.3 -0.250 -0.737 0.7002 0.0500 0.90276 1.556 1.43633 26.7 -0.545 -0.366 6 1.5085 35.2 -0.301 -0.660 0.8000 0.1499 0.87984 1.081 1.411253 24.5 -0.298 -0.208 4 1.51350 35.5 -0.312 -0.469 0.9000 0.0501 0.87095 1.284 1.41408 25.0 -0.436 -0.278 1 1.47869 31.1 -0.134 -0.255 1 0.05, 0.0500 0.83350 1.056 1.586 1.43633 26.7 -0.545 -0.268 1 0.05, 0.35, 0.5000 0.83350 1.056 1.586 1.41408 25.0 -0.436 -0.278 1 1.47869 31.1 -0.134 -0.255 1 0.0500 0.8000 0.0500 0.83350 1.056 1.58825 2.32 -0.250 -0.447 1 0.05, 0.05, and 0.5 K for p, n_{D} and σ respectively, and the combined expanded uncertainties U_c are $U_c(p) = 0.08 \text{ kg·m}^{-3}$, $U_c(n) = 0.08 \text{ mPa·s}$, $U_c(n_D)$	1.02172 1	Г	.569	1.48637	32.6	-0.080	-0.233	0.6001	0.1499	0.93603	1.565	1.45262	28.0	-0.507	-0.443
.794 1.49307 33.3 -0.179 -0.556 0.6999 0.2500 0.91623 1.144 1.43151 25.6 -0.306 -0.230 .952 1.49664 3.8 -0.218 -0.670 0.7002 0.1498 0.90994 1.310 1.43386 26.7 -0.306 -0.338 .161 1.50049 34.3 -0.220 -0.7702 0.1498 0.909276 1.556 1.43633 26.7 -0.545 -0.366 .429 1.50047 34.8 -0.228 -0.743 0.8000 0.1499 0.87984 1.081 1.41253 24.5 -0.248 -0.268 .786 1.50885 35.2 -0.301 -0.660 0.8000 0.0501 0.87095 1.284 1.41408 25.0 -0.436 -0.278 .254 1.51350 35.5 -0.312 -0.469 0.90000 0.83795 1.284 1.41408 25.0 -0.436 -0.278 .461 1.47869 31.1 -0.134 -0.250 0.9000 0.83350 1.056 1.38825 23.2 -0.250 -0.147	4 149307 33.3 -0.179 -0.556 0.6999 0.2500 0.91623 1.144 1.43151 25.6 -0.306 -0.230 2 149664 33.8 -0.218 -0.670 0.7002 0.1498 0.90994 1.310 1.43386 26.2 -0.443 -0.338 1 1.50049 34.3 -0.250 -0.737 0.7002 0.0500 0.90276 1.556 1.43633 26.7 -0.545 -0.366 9 1.50447 34.8 -0.238 -0.743 0.8000 0.1499 0.87984 1.081 1.41253 24.5 -0.545 -0.366 6 1.50885 35.2 -0.301 -0.660 0.8000 0.0501 0.87995 1.284 1.41408 25.0 -0.436 -0.278 4 1.51350 35.5 -0.312 -0.469 0.9000 0.0500 0.83350 1.056 1.38825 2.3.2 -0.236 -0.243 -0.258 1 1.47869 31.1 -0.134 -0.250 0.0435 1.056 1.38825 2.3.2 -0.250	1.02055 1	1	.662	1.48961	32.9	-0.133	-0.414	0.6000	0.0501	0.93033	1.848	1.45572	28.6	-0.588	-0.434
952 1.49664 33.8 -0.218 -0.670 0.7002 0.1498 0.90994 1.310 1.4336 26.2 -0.443 -0.338 1.61 1.50049 34.3 -0.250 -0.737 0.7002 0.0500 0.90276 1.556 1.43633 26.7 -0.545 -0.366 729 1.50447 34.8 -0.288 -0.743 0.8000 0.1499 0.87984 1.081 1.41253 24.5 -0.268 -0.208 786 1.50885 35.2 -0.301 -0.660 0.8000 0.0501 0.87095 1.284 1.41408 25.0 -0.436 -0.278 254 1.51350 35.5 -0.311 -0.469 0.9000 0.0500 0.87095 1.284 1.41408 25.0 -0.436 -0.278 461 1.477869 31.1 -0.134 -0.250 -0.143 -0.250 -0.147	2 14964 33.8 -0.218 -0.670 0.7002 0.1498 0.90994 1.310 1.43386 26.2 -0.443 -0.338 1 1.50049 34.3 -0.250 -0.737 0.7002 0.0500 0.90276 1.556 1.43633 26.7 -0.545 -0.366 9 1.50447 34.8 -0.288 -0.743 0.8000 0.1499 0.87984 1.081 1.41253 24.5 -0.298 -0.208 6 1.50885 35.2 -0.301 -0.660 0.8000 0.0501 0.87095 1.284 1.41408 25.0 -0.436 -0.278 1 1.47869 31.1 -0.134 -0.255 0.9000 0.0500 0.83350 1.056 1.38825 23.2 -0.256 -0.445 -0.278 01, 0.05, 0.03, and 0.05) K for ρ , η , η_{D} , and σ , respectively, and the combined expanded uncertainties U_c are $U_c(\rho) = 0.08$ kg·m ⁻³ , $U_c(\eta) = 0.008$ mPa·s, $U_c(\eta_D)$	1.01932 1	Г	.794	1.49307	33.3	-0.179	-0.556	0.6999	0.2500	0.91623	1.144	1.43151	25.6	-0.306	-0.230
.161 1.50049 34.3 -0.250 -0.737 0.7002 0.0500 0.90276 1.556 1.43633 26.7 -0.545 -0.366 .429 1.50447 34.8 -0.288 -0.743 0.8000 0.1499 0.87984 1.081 1.41253 24.5 -0.298 -0.208 .786 1.50885 35.2 -0.301 -0.660 0.8000 0.0501 0.87095 1.284 1.41408 25.0 -0.436 -0.278 .254 1.51350 35.5 -0.312 -0.469 0.9000 0.0500 0.83350 1.056 1.38825 23.2 -0.230 -0.147 .461 1.47869 31.1 -0.134 -0.255 -0.147	1 1.50049 34.3 -0.250 -0.737 0.7002 0.0500 0.90276 1.556 1.43633 26.7 -0.545 -0.366 9 1.50447 34.8 -0.288 -0.743 0.8000 0.1499 0.87984 1.081 1.41253 24.5 -0.298 -0.208 6 1.50885 35.2 -0.301 -0.660 0.8000 0.0501 0.87095 1.284 1.41408 25.0 -0.436 -0.278 1 1.47869 31.1 -0.134 -0.255 -0.469 0.9000 0.0500 0.83350 1.056 1.38825 23.2 -0.250 -0.147 0 1.005, 0.03, and 0.05) K for $p, n_{D,}$ and $\sigma,$ respectively, and the combined expanded uncertainties U_c are $U_c(p) = 0.08$ kg·m ⁻³ , $U_c(\eta) = 0.008$ mPa·s, $U_c(n_D)$	1.01774 1	Г	.952	1.49664	33.8	-0.218	-0.670	0.7002	0.1498	0.90994	1.310	1.43386	26.2	-0.443	-0.338
.429 1.50447 34.8 -0.288 -0.743 0.8000 0.1499 0.87984 1.081 1.41253 24.5 -0.298 -0208 .786 1.50885 35.2 -0.301 -0.660 0.8000 0.0501 0.87095 1.284 1.41408 25.0 -0.436 -0.278 .254 1.51350 35.5 -0.312 -0.469 0.9000 0.0500 0.83350 1.056 1.38825 23.2 -0.230 -0.147 .461 1.47869 31.1 -0.134 -0.255 -0.147	9 1.5047 34.8 -0.288 -0.743 0.8000 0.1499 0.87984 1.081 1.41253 24.5 -0.298 -0.208 6 1.50885 35.2 -0.301 -0.660 0.8000 0.0501 0.87095 1.284 1.41408 25.0 -0.436 -0.278 4 1.51350 35.5 -0.312 -0.469 0.9000 0.0500 0.83350 1.056 1.38825 23.2 -0.250 -0.147 1 1.47869 31.1 -0.134 -0.255 -0.255 -0.147 01, 0.05, 0.05, and 0.05) K for p, η, n_{D} , and σ , respectively, and the combined expanded uncertainties U_c are $U_c(p) = 0.08$ kg·m ⁻³ , $U_c(\eta) = 0.008$ mPa·s, $U_c(n_D)$	1.01621 2	0	.161	1.50049	34.3	-0.250	-0.737	0.7002	0.0500	0.90276	1.556	1.43633	26.7	-0.545	-0.366
786 1.50885 35.2 -0.301 -0.660 0.8000 0.0501 0.87095 1.284 1.41408 25.0 -0.436 -0.278 254 1.51350 35.5 -0.312 -0.469 0.9000 0.0500 0.83350 1.056 1.38825 23.2 -0.250 -0.147 461 1.47869 31.1 -0.134 -0.255 -0.147	6 1.50885 35.2 -0.301 -0.660 0.8000 0.0501 0.87095 1.284 1.41408 25.0 -0.436 -0.278 4 1.51350 35.5 -0.312 -0.469 0.9000 0.0500 0.83350 1.056 1.38825 23.2 -0.250 -0.147 1 1.47869 31.1 -0.134 -0.255 0.9000 0.0500 0.83350 1.056 1.38825 23.2 -0.250 -0.147 01, 0.05, 0.03, and 0.05) K for p_1 , n_{D_1} and σ_1 respectively, and the combined expanded uncertainties U_c are $U_c(p) = 0.08$ kg·m ⁻³ , $U_c(\eta) = 0.008$ mPa·s, $U_c(n_D)$	1.01446 2.	4	429	1.50447	34.8	-0.288	-0.743	0.8000	0.1499	0.87984	1.081	1.41253	24.5	-0.298	-0.208
254 1.51350 35.5 -0.312 -0.469 0.9000 0.0500 0.83350 1.056 1.38825 23.2 -0.250 -0.147 461 1.47869 31.1 -0.134 -0.255 -0.255 -0.147	4 1.51350 35.5 -0.312 -0.469 0.9000 0.0500 0.83350 1.056 1.38825 23.2 -0.250 -0.147 1 1.47869 31.1 -0.134 -0.255 0.005, 0.03, and 0.05) K for ρ , η , η , η , and σ , respectively, and the combined expanded uncertainties U_c are $U_c(\rho) = 0.08$ kg·m ⁻³ , $U_c(\eta) = 0.008$ mPa·s, $U_c(\eta_D)$	1.01235 2	6	.786	1.50885	35.2	-0.301	-0.660	0.8000	0.0501	0.87095	1.284	1.41408	25.0	-0.436	-0.278
.461 1.47869 31.1 -0.134 -0.255	1 1.47869 31.1 -0.134 -0.255 01, 0.05, 0.03, and 0.05) K for ρ , η	1.01017 3	ŝ	.254	1.51350	35.5	-0.312	-0.469	0.9000	0.0500	0.83350	1.056	1.38825	23.2	-0.250	-0.147
	01, 0.05, 0.03, and 0.05) K for ρ , η , n_D , and σ , respectively, and the combined expanded uncertainties U_c are $U_c(\rho) = 0.08$ kg·m ⁻³ , $U_c(\eta) = 0.008$ mPa·s, $U_c(n_D)$	1.00685 1.		461	1.47869	31.1	-0.134	-0.255								

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Table 7. Coefficients (B_k) and Standard Deviations (δ) of Equation 1 in the Correlation of ρ , η , n_D , and σ for the Pure Components from T = (293.15 to 323.15) K

component	Q	B_0	$B_1 \cdot 10^3$	$B_2 \cdot 10^6$	δ ·10 ³
ethanol	$ ho/ m g\cdot cm^{-3}$	0.897	0.085	-1.550	0.05
	$\eta/\mathrm{mPa}\cdot\mathrm{s}$	24.620	-137.849	197.500	2.5
	n _D	1.499	-0.514	0.150	0.009
	$\sigma/{ m mN}{\cdot}{ m m}^{-1}$	-20.924	367.225	-750.000	112
benzyl acetate	$ ho/ extrm{g}\cdot extrm{cm}^{-3}$	1.133	0.352	-2.100	0.07
	$\eta/\mathrm{mPa}\cdot\mathrm{s}$	76.722	-451.663	675.000	4.0
	n _D	1.626	-0.377	-0.150	0.02
	$\sigma/{ m mN}{\cdot}{ m m}^{-1}$	219.255	-1060.450	1500.000	45
benzyl alcohol	$ ho/ extrm{g}\cdot extrm{cm}^{-3}$	1.250	-0.612	-0.300	0.09
	$\eta/\mathrm{mPa}\cdot\mathrm{s}$	260.251	-1539.110	2295.000	2.2
	n _D	1.651	-0.341	-0.125	0.02
	$\sigma/{ m mN}{ m \cdot m}^{-1}$	114.698	-404.150	500.000	45



Figure 1. Variation of $V^{\mathbb{E}}$ with x_i at T = 303.15 K: \bigcirc , ethanol (1) + benzyl acetate (2), $x_i = x_1$; \triangle , ethanol (1) + benzyl alcohol (3), $x_i = x_1$; \diamondsuit , benzyl acetate (2) + benzyl alcohol (3), $x_i = x_2$; solid lines calculated from the Redlich–Kister equation.



Figure 2. Variation of $\Delta \eta$ with x_i at T = 303.15 K: \bigcirc , ethanol (1) + benzyl acetate (2), $x_i = x_1$; \triangle , ethanol (1) + benzyl alcohol (3), $x_i = x_1$; \diamondsuit , benzyl acetate (2) + benzyl alcohol (3), $x_i = x_2$; solid lines calculated from the Redlich–Kister equation.



Figure 3. Curves of constant $V^{E}/\text{cm}^{3} \cdot \text{mol}^{-1}$ for the ternary system of ethanol (1) + benzyl acetate (2) + benzyl alcohol (3) at T = 303.15 K.



Figure 4. Curves of constant $\Delta \eta$ /mPa·s for the ternary system of ethanol (1) + benzyl acetate (2) + benzyl alcohol (3) at *T* = 303.15 K.

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Table 8. Coefficients (a_k) of the Redlich-Kister Equation for the Binary Systems at T = (293.15, 303.15, 313.15, and 323.15) K and Coefficients (C_k) of the Cilbulka Equation for the Ternary System at T = 303.15 K in the Correlation of V^{E} , $\Delta \eta$, Δn_{D} , and $\Delta \sigma$

ΔQ_{ij}	T/K	a_0	a_1	<i>a</i> ₂	<i>a</i> ₃	a_4	$\delta \cdot 10^3$
			Ethanol (1) + Benz	yl Acetate (2)			
$V^{\rm E}/{\rm cm}^3 \cdot {\rm mol}^{-1}$	293.15	-1.1028	-0.7142	-0.0560	-0.1554	-1.4039	5.7
	303.15	-0.7894	-0.7418	0.0281	-0.3271	-0.6755	3.2
	313.15	-0.6168	-0.7629	-0.2530	-0.2347	-0.4860	2.6
	323.15	-0.5556	-0.7562	-0.1808	-0.2384	-0.3413	2.7
$\Delta \eta/mPa \cdot s$	293.15	-1.0272	0.1015	-0.5956	0.2497		3.6
1 ,	303.15	-0.6886	-0.0334	-0.4285			2.9
	313.15	-0.4655	-0.1633	-0.3552			3.1
	323.15	-0.2489	-0.1484	-0.1191	-0.1796		2.8
$\Delta n_{\rm D}$	293.15	0.0042	0.0045	0.0013	0.0039	0.0064	0.03
D	303.15	0.0038	0.0044	0.0016	0.0041	0.0039	0.03
	313.15	0.0028	0.0051	0.0021	0.0040	0.0045	0.03
	323.15	0.0020	0.0044	0.0010	0.0019		0.02
$\Delta\sigma/{ m mN}\cdot{ m m}^{-1}$	293.15	-4.9557	3.5392	4.6139			59
	303.15	-2.9350	0.5057	4.2544	2.5480		40
	313.15	-1.6428	1.7773	2.6885			25
	323.15	-1.1115	0.0872	3.7961	2.7768		27
			Ethanol (1) + Benzy	yl Alcohol (3)			
$V^{\rm E}/{\rm cm}^3 \cdot {\rm mol}^{-1}$	293.15	-2.3929	-0.9472	-0.4272	-0.1506		3.3
	303.15	-2.4559	-0.9090	-0.4907	-0.2215		3.4
	313.15	-2.5904	-1.0231	-0.4989			4.2
	323.15	-2.6916	-0.9555	-0.4520	-0.2944		4.1
$\Delta \eta/mPa \cdot s$	293.15	-2.4895	-0.1254	-0.2017			3.9
	303.15	-1.6201	0.2073	-0.7518	0.1423		4.2
	313.15	-1.0404	-0.3618	-0.0489	0.3637		3.7
	323.15	-0.2683	-0.0860	0.0756	0.0709	-0.1501	1.3
$\Delta n_{\rm D}$	293.15	0.0131	0.0040	0.0045	0.0006	0.0037	0.03
D	303.15	0.0126	0.0043	0.0041			0.04
	313.15	0.0123	0.0051	0.0032	-0.0012		0.04
	323.15	0.0121	0.0054	0.0022			0.05
$\Delta\sigma/{ m mN}\cdot{ m m}^{-1}$	293.15	4.1560	-3.5948	1.1099	2.1027		27
	303.15	3.7980	-3.3624	-1.8601	2.8776	2.4732	38
	313.15	3.6069	-3.7142	-2.0578	3.2503	1.6655	29
	323.15	3.4408	-3.3592	-3.7809	3.4379	2.9706	25
		Ber	zyl Acetate (2) + B	enzyl Alcohol (3)			
$V^{\rm E}/{\rm cm}^3 \cdot {\rm mol}^{-1}$	293.15	-0.1500	-0.0530	-0.0636	0.2103		0.7
	303.15	-0.0856	0.0711	0.0395	0.0362	-0.0718	0.5
	313.15	-0.0500	0.1044	0.0444			0.7
	323.15	-0.0110	0.0953	0.0296			0.5
$\Delta \eta/mPa \cdot s$	293.15	-4.8936	1.4784	-0.6168	-0.2073		3.7
	303.15	-3.1271	1.2788	-0.4623	0.1493		4.6
	313.15	-1.7515	0.5035	0.7552	-0.2670		2.7
	323.15	-1.1300	0.1875	0.6863			4.5
$\Delta n_{\rm D}$	293.15	0.0019	-0.0008	0.0001	-0.0016	0.0028	0.01
-	303.15	0.0011	-0.0006	-0.0005	-0.0000	0.0023	0.01
	313.15	0.0005	-0.0010	0.0000	-0.0009	0.0005	0.01
	323.15	0.0003	-0.0008	-0.0008	-0.0003	0.0009	0.01
$\Delta\sigma/{ m mN}\cdot{ m m}^{-1}$	293.15	1.8689	-1.7683	-1.0406	0.9809		21
	303.15	1.0648	-3.3539	-1.1042	3.1945	0.3216	17
	313.15	-0.6510	-2.6916	0.4107	1.0221		26
	323.15	-1.8219	-3.1161	1.1114	2.4124		36
		Ethanol (1) + Benzyl Acetate ((2) + Benzyl Alcohol	(3)		
۸0		C.		C.	C.		$\delta \cdot 10^3$
→ <123 T/E / 3 1-1		~0		~1 0100	0.2440		4.4
v / cm°·mol		0.1143	0	5025	-0.2449		4.4 4.0
Δη/mPa·s		-1.//28	2	.3023	1.2048		0.02
$\Delta n_{\rm D}$ $\Delta \sigma / m {\rm N} {\rm m}^{-1}$		-0.0059	0	.00 4 0 2707	0.0030		0.05
(AC/ 1111N*111		2.3334	-1	.2101	0.7147		-10

where ΔQ_{123} refers to the ternary $V^{\text{E}}/\text{cm}^3 \cdot \text{mol}^{-1}$, $\Delta \eta/\text{mPa} \cdot s$, Δn_{D} , or $\Delta \sigma/\text{mN} \cdot \text{m}^{-1}$ and ΔQ_{ij} is the binary contribution given by eq 8. The ternary term Δ_{123} uses the expression suggested by Cibulka:²²

$$\Delta_{123} = C_0 + C_1 x_1 + C_2 x_2 \tag{10}$$

The ternary parameters, C_i , were determined with the optimization algorithm similar to that for the binary parameters, a_k . Estimated values of C_k and δ are also gathered in Table 8. The standard deviations (δ) are about 0.004 cm³·mol⁻¹, 0.006 mPa·s, 0.00003, and 0.1 mN·m⁻¹ for V^E , $\Delta\eta$, n_D , and $\Delta\sigma$, respectively.

The values of $V^{\rm E}$, which are negative over the entire composition range, for the binary systems at T = (293.15, 303.15,313.15, and 323.15) K are presented in Tables 3 to 5. The values of V^{E} becomes more negative from T = (293.15 to)323.15) K for ethanol + benzyl alcohol mixtures. However, with the remaining binary systems, V^{E} values are found to become less negative with the increase of temperature, indicating the positive contribution to the V^{E} values from the cleavage of the acetate-alcohol complexation is dominant for these mixtures. As illustrated in Figure 1 for T = 303.15 K, the V^{E} values of benzyl acetate + benzyl alcohol are larger in magnitude when compared with those of the ethanol + benzyl acetate or + benzyl alcohol, for which the $V^{\mathbb{E}}$ values are more negative, which may be due to the formation of weak molecule complexes. Alternately, the $V^{\rm E}$ values of ethanol + benzyl alcohol mixtures are more negative than those of the ethanol + benzyl acetate, which imply that a weaker interaction likely exists between ethanol and benzyl acetate molecules. The values of V^{E} (x = 0.5) vary from $-0.610 \text{ cm}^3 \cdot \text{mol}^{-1}$ to $-0.021 \text{ cm}^3 \cdot \text{mol}^{-1}$. As shown in Tables 3 to 5, the V^{E} results at other temperatures essentially follow the same trend as that of T =303.15 K.

The values of $\Delta \eta$ are negative over the entire mole fraction range for all binary systems (Tables 3 to 5). A more efficient packing in the pure liquids than in the mixtures is perhaps the major contribution to negative $\Delta \eta$ values. The $\Delta \eta$ values are found to increase with a rise in temperature. The $\Delta \eta$ values are also graphically represented as a function of mole fraction for these three binary systems at T = 303.15 K in Figure 2. It is observed that the values of $\Delta \eta$ (x = 0.5) show the order as: benzyl acetate + benzyl alcohol < ethanol + benzyl alcohol < ethanol + benzyl acetate < 0. The values of $\Delta \eta(x = 0.5)$ vary from -0.776 mPa·s to -0.175 mPa·s. The same order in $\Delta \eta(x = 0.5)$ can also be found for the other temperatures. The viscosity behavior may imply an easier accommodation of the ethanol molecules in the mixture with benzyl acetate than in those with benzyl alcohol. The largest negative values of $\Delta \eta$ for the binary mixtures of benzyl acetate with benzyl alcohol are probably due to a more steric obstacle to this accommodation.

The calculated results of $V^{\rm E}$ and $\Delta \eta$ for the ternary system (ethanol + benzyl acetate + benzyl alcohol) at T = 303.15 K are presented in Table 6. The curves of constant $V^{\rm E}$ and $\Delta \eta$ at T = 303.15 K for the ternary mixtures were calculated from eqs 8 to 10 and plotted in Figures 3 and 4, respectively. As can be expected from the behavior of binary mixtures, the values of ternary $V^{\rm E}$ and $\Delta \eta$ are negative at all compositions. The minimum $V^{\rm E}$ value is near the ethanol + benzyl alcohol side at $x \approx 0.60$ of ethanol, and the minimum $\Delta \eta$ value is near the benzyl acetate.

CONCLUSIONS

ternary system (ethanol + benzyl acetate + benzyl alcohol) at T = 303.15 K and its constituent binary systems (ethanol + benzyl acetate, ethanol + benzyl alcohol, and benzyl acetate + benzyl alcohol) at T = (293.15, 303.15, 313.15, and 323.15) K. Increasing temperatures from (293.15 to 323.15) K decreases the values of ρ , η , n_D , and σ for binary mixtures. The experimental ρ , η , n_D , and σ of pure components are correlated in terms of temperature with reasonably small deviations.

The calculated excess molar volumes $(V^{\rm E})$, deviations in viscosity $(\Delta \eta)$, deviations in refractive index $(\Delta n_{\rm D})$, and deviations in surface tension $(\Delta \sigma)$ were correlated satisfactorily using the Redlich–Kister equation and the Cibulka equation. The values of binary $V^{\rm E}$ are negative, but some small positive values are observed for benzyl acetate + benzyl alcohol in the region of high mole fractions of benzyl acetate at T = (313.15 and 323.15) K. The values of $V^{\rm E}$ for the ternary system of ethanol + benzyl acetate + benzyl alcohol are negative at all compositions. The predominant contribution to these excess values is likely from the breaking of the hydrogen bonding between alcohol molecules. The values of $\Delta \eta$ are negative at all compositions for both binary and ternary systems. These values suggest that the interstitial accommodation between unlike molecules is not an easy process in the mixtures analyzed.

AUTHOR INFORMATION

Corresponding Author

*E-mail: chtu@pu.edu.tw.

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