Excess Volumes of Tetralin + Toluene, + Ethylbenzene, and + Propylbenzene at 298.15 and 308.15 K

Wan-Ching Nung

Department of Chemical Engineering, Tung Fang College of Technology and Commerce, Hunei, Kaohsiung, Taiwan 82901, Republic of China

Wai-Ting Vong and Fuan-Nan Tsai*

Department of Chemical Engineering, National Cheng Kung University, Tainan, Taiwan 70101, Republic of China

Densities of binary mixtures of tetralin + toluene, + ethylbenzene, and + propylbenzene have been measured over the whole composition range at 298.15 and 308.15 K by using a vibrating-tube densimeter. Excess molar volumes V^E of these binary mixtures are obtained from the measured densities. The values of V^E are negative over the entire range of composition for these mixtures.

Introduction

The variations of excess volumes with temperature and composition for mixtures may be complex due to specific interactions in mixtures. Excess volumes of binary mixtures containing one-ring aromatic compounds (*1*, *2*), alkanes (*3*–*5*), or alcohols (*6*–*8*) have been measured by many researchers. However, measurements on the excess volumes of two-ring aromatic compounds are limited to ambient conditions. In a previous paper (*9*) we reported the excess molar volumes of tetralin with 1-alkanols.

In this work, densities and excess molar volumes of tetralin + toluene, + ethylbenzene, and + propylbenzene were measured at atmospheric pressure (nominal value 0.1 MPa) and at 298.15 and 308.15 K over the entire range of composition.

Experimental Section

The chemicals used in this study, their suppliers, and their purities are listed in Table 1. All of the chemicals were used without further purification. Table 1 also gives density measurements for these components together with values obtained from the literature (*10*, *11*).

Excess volumes V^E were determined from densities ϱ measured by use of a vibrating-tube densimeter (Anton Paar DMA 60/602 H) with a precision of $\pm 1.5 \times 10^{-6}$ g cm^{-3}. The measuring cell of the apparatus was thermostated with a Haake F3-K thermostat bath to within ±0.01 K. The densimeter was calibrated with redistilled degassed water and dry air at atmospheric pressure. Mixtures were prepared on a mass basis by using a Simadzu analytical balance (Model AEG-120) with an accuracy of $\pm 1 \times 10^{-4}$ in mole fraction. The accuracy of the density is estimated to be $\pm 1 \times 10^{-5}$ g cm^{-3}. The estimated uncertainty in V^E is less than 0.003 cm^3 mol^{-1}. The technique was checked by determining V^E for benzene + cyclohexane at 298.15 K; our results are in good agreement (better than $0.005V^E$) with literature values (*12*).

* Author to whom correspondence should be addressed.

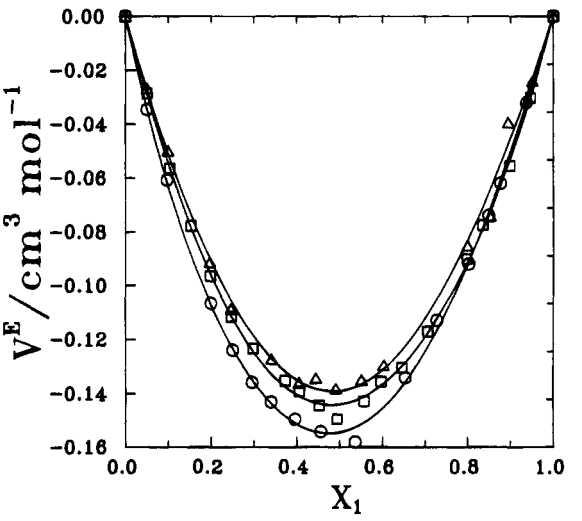

Figure 1. Excess molar volumes at 298.15 K for the binary mixtures of tetralin (1) + toluene (2) (○), + ethylbenzene (2) (□), + *n*-propylbenzene (2) (△); —, calculated from eq 1.

Table 1. Source, Purity, and Densities ϱ of the Pure Components at 298.15 K

component	source	purity/ (mass %)	ϱ/(g cm^{-3}) this work	ϱ/(g cm^{-3}) literature
tetralin	Aldrich	99.0	0.96497	0.96600 (*10*)
toluene	Fluka	>99.5	0.86225	0.86219 (*10*)
ethylbenzene	Fluka	>99.0	0.86249	0.86253 (*10*)
propylbenzene	Fluka	99.0	0.85776	0.85799 (*11*)

Results and Discussion

Excess molar volumes are listed in Table 2 for each binary mixture at 298.15 and 308.15 K. Excess molar volumes were correlated as a function of composition using (*13*)

$$V^E\ (\text{cm}^3\ \text{mol}^{-1}) = x_1(1 - x_1)[a_0 + a_1(2x_1 - 1) + a_2(2x_1 - 1)^2 + a_3(2x_1 - 1)^3] \quad (1)$$

where a_i are adjustable parameters. The values of a_i were

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Table 2. Densities ϱ and Excess Molar Volumes V^E for Binary Mixtures of Tetralin (1) + Aromatic Hydrocarbon (2) at 298.15 and 308.15 K

T = 298.15 K			T = 308.15 K		
x_1	ϱ/(g cm^{-3})	V^E/(cm^3 mol^{-1})	x_1	ϱ/(g cm^{-3})	V^E/(cm^3 mol^{-1})
Tetralin (1) + Toluene (2)					
0.0000	0.86255	0.0000	0.0000	0.85290	0.0000
0.0501	0.86904	−0.0345	0.0501	0.85979	−0.0380
0.0975	0.87523	−0.0607	0.0975	0.86608	−0.0682
0.2002	0.88805	−0.1067	0.2002	0.87911	−0.1206
0.2505	0.89403	−0.1239	0.2505	0.88520	−0.1414
0.2960	0.89928	−0.1359	0.2960	0.89051	−0.1523
0.3399	0.90421	−0.1431	0.3399	0.89552	−0.1616
0.3953	0.91024	−0.1496	0.3953	0.90163	−0.1678
0.4561	0.91664	−0.1542	0.4561	0.90812	−0.1711
0.5357	0.92473	−0.1580	0.4964	0.91232	−0.1745
0.6535	0.93591	−0.1341	0.6535	0.92770	−0.1531
0.7275	0.94257	−0.1129	0.7275	0.93450	−0.1342
0.8023	0.94908	−0.0920	0.8023	0.94104	−0.1034
0.8482	0.95292	−0.0738	0.8482	0.94497	−0.0877
0.8764	0.95524	−0.0620	0.8764	0.94729	−0.0698
0.9365	0.96003	−0.0320	0.9365	0.95217	−0.0394
1.0000	0.96497	0.0000	1.0000	0.95715	0.0000
Tetralin (1) + Ethylbenzene (2)					
0.0000	0.86249	0.0000	0.0000	0.85378	0.0000
0.0499	0.86835	−0.0286	0.0499	0.85971	−0.0344
0.1046	0.87468	−0.0565	0.1046	0.86609	−0.0641
0.1536	0.88026	−0.0777	0.1536	0.87174	−0.0910
0.1987	0.88534	−0.0966	0.1987	0.87686	−0.1096
0.2477	0.89076	−0.1116	0.2477	0.88231	−0.1237
0.2981	0.89625	−0.1234	0.2981	0.88788	−0.1406
0.3731	0.90428	−0.1352	0.3731	0.89598	−0.1535
0.4061	0.90776	−0.1391	0.4061	0.89949	−0.1587
0.4523	0.91259	−0.1445	0.4523	0.90434	−0.1600
0.4940	0.91691	−0.1495	0.5566	0.91509	−0.1608
0.5566	0.92322	−0.1430	0.5966	0.91910	−0.1532
0.5966	0.92720	−0.1356	0.6456	0.92395	−0.1431
0.6456	0.93204	−0.1304	0.7064	0.92986	−0.1229
0.7064	0.93794	−0.1171	0.8353	0.94217	−0.0869
0.7981	0.94663	−0.0902	0.8985	0.94804	−0.0626
0.8353	0.95009	−0.0775	0.9455	0.95228	−0.0334
0.8985	0.95593	−0.0556	1.0000	0.95715	0.0000
0.9455	0.96014	−0.0302			
1.0000	0.96497	0.0000			
Tetralin (1) + Propylbenzene (2)					
0.0000	0.85776	0.0000	0.0000	0.84942	0.0000
0.0502	0.86320	−0.0267	0.0502	0.85489	−0.0199
0.0994	0.86851	−0.0498	0.0994	0.86022	−0.0525
0.1974	0.87912	−0.0914	0.1472	0.86545	−0.0798
0.2469	0.88447	−0.1087	0.1974	0.87087	−0.0963
0.3418	0.89468	−0.1272	0.2469	0.87622	−0.1090
0.4054	0.90152	−0.1359	0.3035	0.88238	−0.1272
0.4448	0.90573	−0.1343	0.3418	0.88650	−0.1322
0.4914	0.91075	−0.1381	0.4054	0.89337	−0.1414
0.5510	0.91713	−0.1349	0.4448	0.89764	−0.1458
0.6026	0.92265	−0.1294	0.4914	0.90265	−0.1446
0.7991	0.94362	−0.0851	0.5510	0.90908	−0.1449
0.8516	0.94926	−0.0741	0.6026	0.91464	−0.1403
0.8941	0.95365	−0.0394	0.6521	0.91993	−0.1291
0.9502	0.95968	−0.0239	0.7991	0.93568	−0.0887
1.0000	0.96497	0.0000	0.8516	0.94132	−0.0713
			0.9502	0.95185	−0.0274
			1.0000	0.95715	0.0000

obtained by least-squares method with all points weighted equally. The standard deviations were calculated by using

$$\sigma(V^E) = \left[\frac{\sum(V^E_{exptl} - V^E_{calcd})^2}{n - p}\right]^{1/2} \quad (2)$$

where n is the number of measurements and p is the number of parameters.

The values of the parameter a_i, along with the standard deviation $\sigma(V^E)$, are given in Table 3.

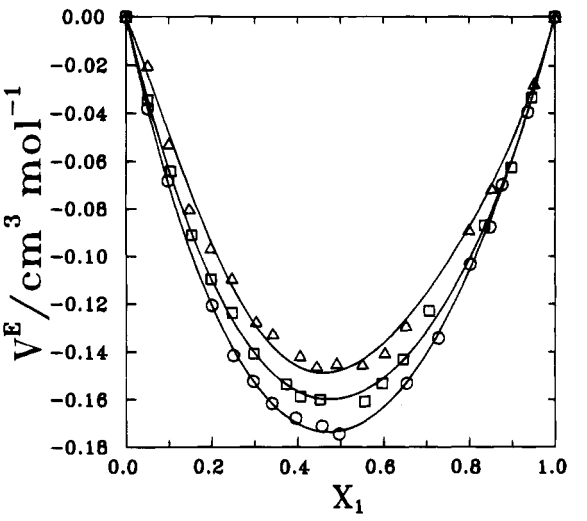

Figure 2. Excess molar volumes at 308.15 K for the binary mixtures of tetralin (1) + toluene (2) (○), + ethylbenzene (2) (□), + propylbenzene (2) (△); —, calculated from eq 1.

Table 3. Standard Deviation $\sigma(V^E)$ and Values of Parameters a_i in Eq 1 for Tetralin (1) + Aromatic Hydrocarbon (2)

component 2	a_0	a_1	a_2	a_3	$\sigma(V^E)$/(cm^3 mol^{-1})
		T = 298.15 K			
toluene	−0.6180	0.0598	−0.0138	0.0469	0.002
ethylbenzene	−0.5763	0.0419	−0.0269	−0.0481	0.002
propylbenzene	−0.5562	0.0385	0.0360	0.0025	0.004
		T = 308.15 K			
toluene	−0.5906	0.1092	0.0590	−0.2031	0.004
ethylbenzene	−0.6928	0.0727	−0.0430	0.0042	0.002
propylbenzene	−0.6308	0.0603	−0.0624	−0.0442	0.003

Figures 1 and 2 show that excess molar volumes are negative for these binary mixtures over the whole range of composition. Excess molar volumes increase in the sequence toluene < ethylbenzene < propylbenzene. The temperature coefficient $(\partial V^E/\partial T)_p$ is negative for these binary mixtures of tetralin + aromatic hydrocarbon.

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