THERMODYNAMICS OF KETONE + AMINE MIXTURES PART II. VOLUMETRIC AND SPEED OF SOUND DATA AT (293.15, 298.15 AND 303.15) K FOR 2-PROPANONE + DIPROPYLAMINE, + DIBUTYLAMINE OR + TRIETHYLAMINE SYSTEMS

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Abstract

Densities, ρ, and speeds of sound, u, of 2-propanone + dipropylamine, + dibutylamine or + triethylamine systems have been measured at (293.15, 298.15 and 303.15) K and atmospheric pressure using a vibrating tube densimeter and sound analyser Anton Paar model DSA-5000. The ρ and u values were used to calculate excess molar volumes, V^{E}, and the excess functions at 298.15 K for the thermal expansion coefficient, α_{P}^{E}, and for the isentropic compressibility, κ_{S}^{E} at 298.15 K. V^{E}, κ_{S}^{E} and α_{P}^{E} are positive magnitudes. When replacing dipropylamine by dibutylamine or triethylamine in the studied mixtures, the excess functions increase. This may be ascribed to the interactions between unlike molecules are more important in the former solutions. From the comparison with similar data obtained for 2-propanone + aniline, + N-methylaniline, or + pyridine systems, it is concluded that interactions between unlike molecules are stronger in mixtures containing aromatic amines. Free volume effects are present in solutions with dipropyl or dibutylamine as the V^{E} curves are shifted towards higher mole fractions of 2-propanone.

KEYWORDS: Densities, speeds of sound, compressibilities, 2-propanone, amines, interactions, structural effects

1. Introduction

Amides, amino acids, peptides and their derivatives are of interest because they are simple models in biochemistry. *N*-methylformamide possesses the basic ($-CO$) and acidic ($-NH$) groups of the very common, in nature, peptide bond [1]. For example, proteins are polymers of amino acids linked to each other by peptide bonds. Consequently, the understanding of liquid mixtures involving the amide functional group is necessary as a first step to a better knowledge of complex molecules of biological interest [2]. So, the aqueous solution of dimethylformamide is a model solvent representing the environment of the interior of proteins. Amides have many practical applications. Dimethylformamide and *N*-methylpyrrolidone are used as highly selective extractants for the recovery of aromatic and saturated hydrocarbons from petroleum feedstocks [3], and ε-caprolactam is used for the production of nylon 6, which is a polycaprolactam formed by ring-opening polymerization. The study of alkanone + amine mixtures, which contain the carbonyl and amine groups in separate molecules, is then pertinent in order to gain insight into amide solutions. In this article, we report densities, speeds of sound and excess molar volumes at 293.15 K, 298.15 K and 303.15 K, and the excess functions at 298.15 K for the isobaric thermal expansion coefficients and the isentropic compressibility for the mixtures 2-propanone + dipropylamine, + dibutylamine or + triethylamine. In the first work of this series we have provided similar data for 2-propanone + aniline, + *N*-methylaniline, or + pyridine [4].

2. Experimental

2.1 Materials

2-Propanone ($\geq$ 0.995) was from Sigma Aldrich; dipropylamine ($\geq$ 0.99) and dibutylmaine ($\geq$ 0.995) were from Aldrich and triethylamine ($\geq$ 0.995) was form Fluka and used without further purification (purities expressed in mass fraction). The ρ and u values of the pure liquids are in good agreement with those from the literature (Table 1).

2.2 Apparatus and procedure

Binary mixtures were prepared by mass in small vessels of about 10 cm^3. Caution was taken to prevent evaporation, and the error in the final mole fraction is estimated to be less than $\pm$ 0.0001. Conversion to molar quantities was based on the relative atomic mass table of 2006 issued by IUPAC [5].

The densities and speeds of sound of both pure liquids and of the mixtures were measured using a vibrating-tube densimeter and sound analyser, Anton Paar model DSA-5000, automatically thermostated within $\pm$ 0.01 K. The calibration of the apparatus was carried out

with deionised double-distilled water, heptane, octane, isooctane, cyclohexane and benzene, using ρ values from the literature [6-8]. The accuracy for the ρ and u measurements are ± 1 10^{-2} kg•m^{-3} and ± 0.1 m s^{-1}, respectively, and the corresponding precisions are ± 1 10^{-3} kg m^{-3} and ± 0.01 m s^{-1}. The experimental technique was checked by determining V^E and u of the standard mixtures: (cyclohexane + benzene) at the temperatures (293.15, 298.15 and 303.15) K and 2-ethoxyethanol + heptane at 298.15 K. Our results agree well with published values [9-12]. The accuracy in V^E is believed to be less than $\pm(0.01|V^E_{max}|+0.005)$ cm^3 mol^{-1}, where $|V^E_{max}|$ denotes the maximum experimental value of the excess molar volume with respect to the mole fraction.

3. Equations

The thermodynamic properties for which values are derived most directly from the experimental measurements are the density, ρ, the molar volume, V, the coefficient of thermal expansion, $\alpha_P = -\dfrac{1}{\rho}\left(\dfrac{\partial \rho}{\partial T}\right)_P$ and the isentropic compressibility, κ_S. In this work, α_P values were obtained from a linear dependence of ρ with T. Assuming that the absorption of the acoustic wave is negligible, κ_s can be calculated using the Newton-Laplace's equation:

$$\kappa_S = \frac{1}{\rho u^2} \tag{1}$$

For an ideal mixture at the same temperature and pressure than the system under study, the values F^{id} of the thermodynamic property, F, are calculated using the equations [9,13]:

$$F^{id} = x_1 F_1 + x_2 F_2 \qquad (F = V; C_P) \tag{2}$$

and

$$F^{id} = \phi_1 F_1 + \phi_2 F_2 \qquad (F = \alpha_P; \kappa_T) \tag{3}$$

where C_p is the isobaric heat capacity, $\phi_i = \dfrac{x_i V_i}{V^{id}}$ the volume fraction, κ_T, the isothermal compressibility, and F_i, the F value of component i, respectively. For κ_S the ideal values are calculated according to [13]:

$$\kappa_{\mathrm{S}}^{\mathrm{id}} = \kappa_{\mathrm{T}}^{\mathrm{id}} - \frac{TV^{\mathrm{id}}\alpha_{\mathrm{P}}^{\mathrm{id}2}}{C_{\mathrm{P}}^{\mathrm{id}}} \qquad (4)$$

In this work, we have determined the excess functions:

$$F^{\mathrm{E}} = F - F^{\mathrm{id}} \qquad (5)$$

for $F = V^{E}$, κ_{S} and α_{P}

4. Results and Discussion

Table 2 lists values of densities, calculated V^{E} and of u vs. x_1, the mole fraction of the 2-propanone. Table 3 contains the derived quantities $\kappa_{\mathrm{S}}^{\mathrm{E}}$ and $\alpha_{\mathrm{P}}^{\mathrm{E}}$. The data were fitted by unweighted least-squares polynomial regression to the equation:

$$F^{\mathrm{E}} = x_1(1-x_1)\sum_{i=0}^{k-1} A_i(2x_1-1)^i \qquad (6)$$

where F stands for the properties cited above. The number of coefficients k used in eq. (6) for each mixture was determined by applying an F-test [14] at the 99.5 % confidence level. Table 4 lists the parameters A_i obtained in the regression, together with the standard deviations σ, defined by:

$$\sigma\left(F^{\mathrm{E}}\right) = \left[\frac{1}{N-k}\sum\left(F_{\mathrm{cal}}^{\mathrm{E}} - F_{\mathrm{exp}}^{\mathrm{E}}\right)^2 \right]^{1/2} \qquad (7)$$

where N is the number of direct experimental values. Results on V^{E} and $\kappa_{\mathrm{S}}^{\mathrm{E}}$ are shown graphically in Figs 1 and 2. No data have been encountered in the literature for comparison.

Hereafter, we are referring to values of the excess molar properties at equimolar composition and 298.15 K.

Mixtures of 2-propanone with a given alkane are characterized by strong dipolar interactions between the ketone molecules, which leads to miscibility gaps at temperatures near to 298.15. For the heptane system, the upper critical solution temperature is 245.22 K [15], and the H^{E} and V^{E} values are 1704 J•mol⁻¹ [16] and $= 1.130$ cm³•mol⁻¹ [17], respectively. The large positive V^{E} value indicates that the interactional contribution to this excess function, due to the disruption of the ketone-ketone interactions upon mixing, is much more important than those related to effects which contribute negatively to V^{E} (structural effects arising from interstitial accommodation of one component into the other and free volume effects). Dipropylamine and

dibutylamine are secondary amines, and are weakly self-associated [18]. Accordingly, the corresponding mixtures with alkanes show relatively low H^E values: 456 J•mol^{-1} for DPA + heptane [19], and 277 J•mol^{-1} for DBA + heptane (at 303.15 K) [20]. The corresponding V^E values are lower than in the case of 2-propanone solutions: 0.268 cm^3•mol^{-1} (DPA + heptane) and 0.052 cm^3•mol^{-1} (DBA + heptane) [21]. The latter value suggests that structural effects may become important, which is supported by the negative V^E of the DBA + hexane system, -0.185 cm^3•mol^{-1} [21]. Such effects are also relevant in mixtures including TEA [22], a weakly polar tertiary amine. In solutions with heptane, $H^E = 112$ J•mol^{-1} and $V^E = 0.1255$ cm^3•mol^{-1} [23], while in the hexadecane system, $H^E = 322$ J•mol^{-1} [24] $V^E = -0.0979$ cm^3•mol^{-1} [25].

We note that for the studied mixtures, V^E is positive. Therefore, the contribution to V^E from the breaking of the interactions between like molecules upon mixing is predominant over the negative contributions from structural effects and interactions between unlike molecules. The existence of such interactions is supported by the V^E decrease observed in 2-propanone mixtures when heptane is replaced by DPA, two solvents of similar size. The strength of the interaction between unlike molecules for the 2-propanone-aniline system has been estimated to be -30.50 kJ•mol^{-1} [4]. Moreover, V^E, α_p^E and κ_S^E are negative for 2-propanone + aniline, + N-metrhylaniline or + pyridine mixtures [4]. In the case of the aniline solution, $V^E = -1.133$ cm^3•mol^{-1}, $\alpha_p^E = -94.4 \cdot 10^{-6}$ K^{-1} and $\kappa_S^E = -142.5$ TPa^{-1} [4]. This remarks that the amine-ketone interactions are much stronger than in mixtures including DPA, DBA or TEA, which are characterized by positive values of V^E, α_p^E and κ_S^E (Table 4, Figs, 1-2). Negative $\left(\dfrac{\partial V^E}{\partial T}\right)_P$ values have been interpreted in terms of a decrease in the molar volume of complex formation, which overcompensates for the decrease in the extent of complex formation, and have been encountered, e.g., in amine + trichloromethane mixtures [26,27].

The V^E increase observed when replacing DPA by DBA may be ascribed to the interactions between 2-propanone molecules are broken more easily by DBA, due to its larger aliphatic surface. Moreover, the creation of the amine-ketone interactions is more difficult as the amine group is more sterically hindered in this amine. On the other hand, V^E is higher for the TEA solution than for the DPA mixture. This reveals that the interactions between unlike molecules are more important in the latter system, which is confirmed by the larger α_p^E value encountered for the TEA solution.

The parameter $\chi = \left(\dfrac{u}{u^{\text{id}}}\right)^2 - 1$ is widely used to estimate the non-ideality of a system, [28-31] as solutions with strong deviations from the ideal behavior are characterized by high χ values.

For example, for 2-pyrrolidone mixtures, χ (methanol) = 0.8 and χ (ethanol) = 0.35 [29]. In the case of systems containing 2-propanone, χ (DPA) = -0.021 > χ (DBA) = -0.041 > χ (TEA) = -0.142; and χ (aniline) = 0.463 > χ (N-methylaniline) = 0.275 > χ (pyridine) = 0.159. This is in agreement with our previous findings: interactions between unlike molecules become weaker in the sequence DPA > DBA > TEA. Such interactions are much stronger in those systems with aromatic amines.

Finally, we note that the V^E curves are shifted to higher mole fractions of 2-propanone, the smaller component, in solutions with DPA, or DBA (Fig. 1), which is typical of systems where free volume effects are present [18].

5.   CONCLUSIONS

In this work, we have determined V^E, κ_S^E and α_p^E for 2-propanone + DPA, + DBA, or + TEA. These excess functions are positive. It is observed that they increase when replacing DPA by DBA or TEA. This may be attributed to interactions between unlike molecules are more important in the DPA solution. The data suggest that the interactions between unlike molecules are weaker than in 2-propanone + aromatic amine mixtures. Free volume effects are present in systems with DPA or DBA, as the V^E curves are shifted towards higher mole fractions of 2-propanone, the smaller component

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ACKNOWLEDGEMENTS

TABLE 1

Physical properties of pure compounds, 2-propanone, dipropylamine, dibutylamine and triethylamine at temperature T: ρ, density; u, speed of sound; α_P, isobaric thermal expansion coefficient; κ_S, adiabatic compressibility; κ_T, isothermal compressibility and C_P, isobaric heat capacity.

Property	T/K	2-propanone		dipropylamine		dibutylamine		triethylamine	
		Exp	Lit	Exp.	Lit	Exp.	Lit.	Exp.	Lit.
ρ/g cm³	293.15	0.790546	0.78998[a]	0.738301	0.73720[b]	0.759591	0.762022[c]	0.727514	0.7276[a]
									0.72753[d]
	298.15	0.784868	0.784431[e]	0.733676	0.73336[f]	0.755549	0.75553[f]	0.722892	0.72318[g]
			0.78428[h]		0.73368[g]		0.75570[i]		0.72376[j]
			0.78457[k]		0.73333[l]		0.75572[g]		
							0.75595[j]		
	303.15	0.779169	0.77914[h]	0.729102	0.72820[b]	0.751481	0.75194[j]	0.718332	0.71836[d]
					0.73121[j]		0.75248[m]		
					0.73019[m]				
u/m s⁻¹	293.15	1182.5	1192[k]	1209.1		1261.3	1269.47[c]	1132.7	
	298.15	1160.4	1161.72[e]	1187.8	1198[j]	1241.4	1248[j]	1111.2	1123[j]
			1154[h]						
			1160.6[n]				1246.7[c]		1115.1[o]
	303.15	1139.2	1131.2[h]	1167.4	1174[j]	1222.6	1227[j]	1091.1	1101[j]
α_P/10⁻³K⁻¹	298.15	1.45	1.426[h]	1.25	1.201[j]	1.07	1.059[j]	1.27	1.24[o]
κ_S/Tpa⁻¹	293.15	904.66		926.5		827.6	814.31[c]	1071.29	
	298.15	946.29	944.59[e]	966.1	947[j]	858.8	849[j]	1120.39	1113[o]
			958[h]						
			946[n]						
	303.15	988.80	1003[h]	1006.4	992[j]	890.2	883[j]	1169.44	1135[j]
κ_T/Tpa⁻¹	298.15	1317.5	1324[a]	1221.8	1183[j]	1053.4	1039[j]	1432.2	1404[o]
			1330[h]						
C_P/ J mol⁻¹K⁻¹	298.15		124.9[a]		252.84[a]		302[j]		216.43[p]

[a] [6]; [b] [32]; [c] [33]; [d] [34]; [e] [17]; [f] [35]; [g] [21]; [h] [36]; [i] [37]; [j] [38]; [k] [39]; [l] [40]; [m] [41]; [n] [42]; [o] [43]; [p] [44]

TABLE 2

Densities, ρ, molar excess volumes, V^E, and speeds of sound for 2-propanone(1) + amine(2) mixtures at temperature T.

x_1	ρ/g cm^{-3}	V^E/ cm^3 mol^{-1}	u /m s^{-1}	x_1	ρ/g cm^{-3}	V^E/ cm^3 mol^{-1}	u /m s^{-1}
			2-propanone(1) + dipropylamine(2) ; T = 293.15 K				
0.0681	0.739993	0.0474	1205.77	0.5443	0.756750	0.2440	1184.18
0.1143	0.741208	0.0788	1203.43	0.5928	0.759180	0.2433	1182.35
0.1667	0.742666	0.1126	1200.78	0.6511	0.762365	0.2354	1180.47
0.2117	0.744010	0.1360	1198.65	0.7007	0.765284	0.2278	1179.56
0.2523	0.745280	0.1574	1196.68	0.7489	0.768408	0.2099	1178.75
0.3075	0.747112	0.1832	1194.10	0.7947	0.771624	0.1879	1178.27
0.3567	0.748857	0.2034	1191.86	0.8496	0.775792	0.1607	1178.25
0.4033	0.750616	0.2199	1189.81	0.8996	0.780162	0.1091	1178.88
0.4448	0.752285	0.2316	1187.98	0.9460	0.784521	0.0643	1180.06
0.4951	0.754452	0.2409	1185.98				
			2-propanone(1) + dipropylamine(2); T = 298.15 K				
0.0541	0.735054	0.0246	1185.12	0.5502	0.751994	0.2458	1162.14
0.1087	0.736435	0.0637	1182.30	0.5945	0.754194	0.2432	1160.66
0.1626	0.737883	0.1010	1179.58	0.6466	0.756950	0.2389	1159.08
0.2081	0.739179	0.1299	1177.24	0.6924	0.759575	0.2307	1157.96
0.2518	0.740501	0.1547	1175.13	0.7444	0.762840	0.2120	1156.89
0.2988	0.742014	0.1780	1172.85	0.7963	0.766389	0.1889	1156.28
0.3473	0.743660	0.2011	1170.58	0.8448	0.769995	0.1624	1156.25
0.3927	0.745318	0.2177	1168.54	0.8965	0.774358	0.1131	1156.74
0.4488	0.747521	0.2328	1166.33	0.9443	0.778758	0.0644	1157.98
0.4918	0.749317	0.2432	1164.45				
			2-propanone(1) + dipropylamine(2); T = 303.15 K				
0.0655	0.730643	0.0472	1163.99	0.5527	0.746973	0.2616	1141.10
0.1125	0.731795	0.0839	1161.46	0.5959	0.749047	0.2618	1139.59
0.1636	0.733130	0.1193	1158.87	0.6487	0.751779	0.2565	1137.91
0.2007	0.734156	0.1431	1156.87	0.6959	0.754441	0.2458	1136.70
0.2594	0.735888	0.1758	1154.06	0.7493	0.757725	0.2265	1135.79
0.3080	0.737419	0.2007	1151.73	0.7940	0.760769	0.1998	1135.26
0.3537	0.738962	0.2193	1149.54	0.8513	0.765043	0.1568	1135.20

TABLE 2 (continued)

0.4034	0.740751	0.2364	1147.22	0.8993	0.768986	0.1152	1135.66
0.4499	0.742530	0.2503	1145.25	0.9486	0.773476	0.0611	1136.92
0.5001	0.744620	0.2571	1143.12				

2-propanone(1) + dibutylamine(2); $T = 293.15$ K

0.0617	0.760123	0.0738	1256.07	0.5423	0.767568	0.4189	1213.62
0.1067	0.760523	0.1303	1252.21	0.5934	0.768974	0.4178	1208.95
0.1645	0.761115	0.1936	1247.33	0.6613	0.771131	0.4044	1202.92
0.2213	0.761798	0.2443	1242.45	0.6995	0.772514	0.3904	1199.57
0.2624	0.762317	0.2825	1238.78	0.7456	0.774389	0.3650	1195.69
0.3027	0.762916	0.3085	1235.31	0.7953	0.776805	0.3140	1191.97
0.3513	0.763667	0.3424	1231.00	0.8542	0.779951	0.2610	1187.73
0.3892	0.764326	0.3627	1227.60	0.9052	0.783274	0.1896	1184.96
0.4490	0.765488	0.3873	1222.20	0.9503	0.786761	0.1065	1183.42
0.4963	0.766488	0.4059	1217.82				

2-propanone(1) + dibutylamine(2); $T = 298.15$ K

0.0579	0,756021	0.0664	1236.50	0.5507	0.763139	0.4294	1187.27
0.1092	0.756419	0.1353	1231.98	0.5996	0.764405	0.4304	1182.37
0.1498	0.756795	0.1808	1228.39	0.6520	0.765956	0.4220	1178.06
0.2099	0.757425	0.2407	1223.10	0.6999	0.767576	0.4046	1173.52
0.2537	0.757962	0.2754	1219.33	0.7529	0.769637	0.3743	1169.76
0.3010	0.758582	0.3121	1215.00	0.8005	0.771785	0.3346	1165.81
0.3563	0.759402	0.3471	1210.01	0.8556	0.774693	0.2731	1163.20
0.4086	0.760258	0.3768	1205.30	0.9035	0.777804	0.1894	1161.40
0.4582	0.761161	0.4003	1200.74	0.9520	0.781451	0.0934	1187.27
0.5016	0.762025	0.4188	1196.47				

2-propanone(1) + dibutylamine(2); $T = 303.15$ K

0.0563	0.751852	0.0733	1217.73	0.4982	0.757338	0.4321	1177.49
0.1072	0.752233	0.1369	1213.28	0.5486	0.758426	0.4398	1172.42
0.1559	0.752644	0.1926	1208.96	0.6004	0.759686	0.4412	1167.37
0.2030	0.753101	0.2392	1205.08	0.6503	0.761095	0.4303	1162.88
0.2398	0.753461	0.2789	1201.43	0.7509	0.764591	0.3779	1153.57
0.2977	0.754122	0.3304	1196.07	0.8002	0.766620	0.3462	1149.45
0.3441	0.754926	0.3593	1191.88	0.8488	0.769033	0.2919	1145.76

TABLE 2 (continued)

0.3955	0.755499	0.3934	1187.01	0.9066	0.772605	0.1903	1142.50
0.4560	0.756564	0.4134	1181.34	0.9518	0.775714	0.1150	1140.34

2-propanone(1) + triethylamine(2); $T = 293.15$ K

0.0599	0.729078	0.0897	1131.39	0.5516	0.749498	0.3738	1136.76
0.1079	0.730405	0.1587	1130.60	0.6046	0.752888	0.3597	1139.29
0.1594	0.731971	0.2205	1130.06	0.6537	0.756171	0.3365	1142.21
0.1894	0.732974	0.2456	1129.92	0.7021	0.759717	0.3141	1145.53
0.2528	0.735234	0.2962	1130.08	0.7509	0.763637	0.2764	1149.48
0.2930	0.736792	0.3209	1130.26	0.8040	0.768298	0.2372	1154.65
0.3369	0.738574	0.3473	1130.75	0.8480	0.772464	0.2003	1159.45
0.4069	0.741807	0.3692	1132.00	0.8919	0.777086	0.1417	1164.97
0.4498	0.743891	0.3746	1133.27	0.9515	0.784093	0.0571	1174.03
0.4940	0.746287	0.3756	1134.45				

2-propanone(1) + triethylamine(2); $T = 298.15$ K

0.0611	0.724409	0.1011	1109.75	0.5546	0.744523	0.4018	1114.46
0.1065	0.725617	0.1718	1108.88	0.6058	0.747700	0.3859	1116.97
0.1544	0.727020	0.2342	1108.18	0.6549	0.751001	0.3644	1119.87
0.1958	0.728349	0.2770	1108.09	0.7012	0.754363	0.3391	1123.07
0.2462	0.730099	0.3200	1107.83	0.7509	0.758296	0.3048	1127.06
0.2986	0.732114	0.3515	1107.99	0.8018	0.762708	0.2600	1131.90
0.3582	0.734593	0.3762	1109.00	0.8530	0.767596	0.2054	1137.79
0.3978	0.736340	0.3923	1109.54	0.8887	0.771293	0.1620	1142.34
0.4511	0.738891	0.4044	1110.91	0.9501	0.778305	0.0766	1151.43
0.5024	0.741579	0.4053	1112.40				

2-propanone(1) + triethylamine(2); $T = 303.15$ K

0.0707	0.719955	0.1358	1089.13	0.5499	0.739105	0.4327	1093.25
0.1190	0.721258	0.2063	1088.19	0.6036	0.742346	0.4179	1095.65
0.1589	0.722370	0.2659	1087.63	0.6534	0.745607	0.3979	1098.71
0.2188	0.724294	0.3262	1087.30	0.7023	0.749124	0.3670	1101.91
0.2986	0.727146	0.3898	1087.20	0.7443	0.752427	0.3310	1105.47
0.3474	0.729113	0.4133	1087.80	0.7964	0.756891	0.2770	1110.38
0.4004	0.731418	0.4315	1088.59	0.8481	0.761680	0.2241	1115.99
0.4514	0.733852	0.4372	1089.96	0.9028	0.767332	0.1532	1123.08
0.5221	0.737827	0.4378	1092.43	0.9496	0.772831	0.0692	1130.64

TABLE 3

Excess functions at 298.15 K for κ_S, adiabatic compressibility and α_P, isobaric thermal expansion coefficient of 2-propanone(1) + amine(2) mixtures.

x_1	κ_S^E /TPa^{-1}	α_P^E /$10^{-6} \cdot K^{-1}$
2-propanone(1) + dipropylamine(2)		
0.0541	2.58	0.52
0.1087	5.47	2.12
0.1626	8.17	4.31
0.2081	10.47	6.42
0.2518	12.42	8.52
0.2988	14.45	10.70
0.3473	16.38	12.75
0.3927	17.96	14.32
0.4488	19.28	15.68
0.4918	20.56	16.23
0.5502	21.73	16.11
0.5945	22.07	15.38
0.6466	22.12	13.90
0.6924	21.63	12.05
0.7444	20.60	9.42
0.7963	18.75	6.53
0.8448	16.05	3.88
0.8965	12.07	1.26
0.9443	7.14	− 0.21
2-propanone(1) + dibutylamine(2)		
0.0579	3.23	2.50
0.1092	6.27	4.53
0.1498	8.58	5.95
0.2099	11.79	7.87
0.2537	13.82	9.14
0.3010	16.25	10.49
0.3563	18.76	12.01
0.4086	20.89	13.45
0.4582	22.80	14.82
0.5016	24.71	16.01
0.5507	26.27	17.26

Table 3 (continued)

0.5996	27.39	18.35
0.6520	28.18	19.28
0.6999	28.22	19.78
0.7529	27.37	19.76
0.8005	25.54	18.98
0.8556	22.06	16.84
0.9035	16.80	13.22
0.9520	9.43	7.68

2-propanone(1) + triethylamine(2)

0.0611	6.28	17.68
0.1065	10.68	26.81
0.1544	14.92	33.78
0.1958	17.54	38.21
0.2462	21.15	42.31
0.2986	24.09	45.59
0.3582	25.97	48.73
0.3978	27.63	50.61
0.4511	28.76	52.82
0.5024	29.69	54.44
0.5546	29.88	55.38
0.6058	29.33	55.16
0.6549	28.21	53.61
0.7012	26.64	50.68
0.7509	24.35	45.69
0.8018	21.17	38.51
0.8530	16.78	29.34
0.8887	13.41	22.09
0.9501	6.53	9.12

TABLE 4

Coefficients A_i and standard deviations, $\sigma(F^E)$ (eq. 7) for representation of the $F^{E,a}$ property at 298.15 K for 2-propanone(1) + aromatic amine(2) systems by eq. 6

System[b]	T/K	Property F^E	A_0	A_1	A_2	A_3	A_4	$\sigma(F^E)$
2-propanone + dipropylamine	293.15	V^E	0.960	0.286	0.077			0.003
	298.15	V^E	0.971	0.252	-0.02	0.20		0.003
		κ_S^E	83.13	40.8	16.4	9.3		0.11
		α_P^E	64.92	8.9	-69.6	-20.9	-9.8	0.04
	303.15	V^E	1.043	0.279				0.002
2-propanone + dibutylamine	293.15	V^E	1.628	0.488	0.20			0.003
	298.15	V^E	1.670	0.549	0.21			0.005
		κ_S^E	98.19	69.8	46.5	15.4		0.12
		α_P^E	63.62	52.6	53.9	19.5		0.05
	303.15	V^E	1.727	0.529	0.24			0.005
2-propanone + triethylamine	293.15	V^E	1.511	-0.085	0.09			0.004
	298.15	V^E	1.622	-0.089	0.174			0.003
		κ_S^E	118.6	16.4	10.4			0.2
		α_P^E	218.9	54	59	-148		0.3
	303.15	V^E	1.767	-0.10	0.16	-0.18		0.004

[a] $F^E = V^E$, units: cm^3 mol^{-1}; $F^E = \kappa_S^E$, units: TPa^{-1}; $F^E = \alpha_P^E$, units: 10^{-6} K^{-1}

CAPTION TO FIGURES

Fig. 1. V^E for the 2-propanone(1) + amine(2) systems at atmospheric pressure and 298.15 K. Full symbols (this work): ($\bullet$), dipropylamiane; ($\blacksquare$), dibutylamine; ($\blacktriangle$), triethylamine. Solid lines, calculations with eq. (6) using the coefficients from Table 4.

Fig. 2. κ_S^E for the for the 2-propanone(1) + amine(2) systems at atmospheric pressure and 298.15 K. Full symbols (this work): ($\bullet$), dipropylamiane; ($\blacksquare$), dibutylamine; ($\blacktriangle$), triethylamine. Solid lines, calculations with eq. (6) using the coefficients from Table 4.
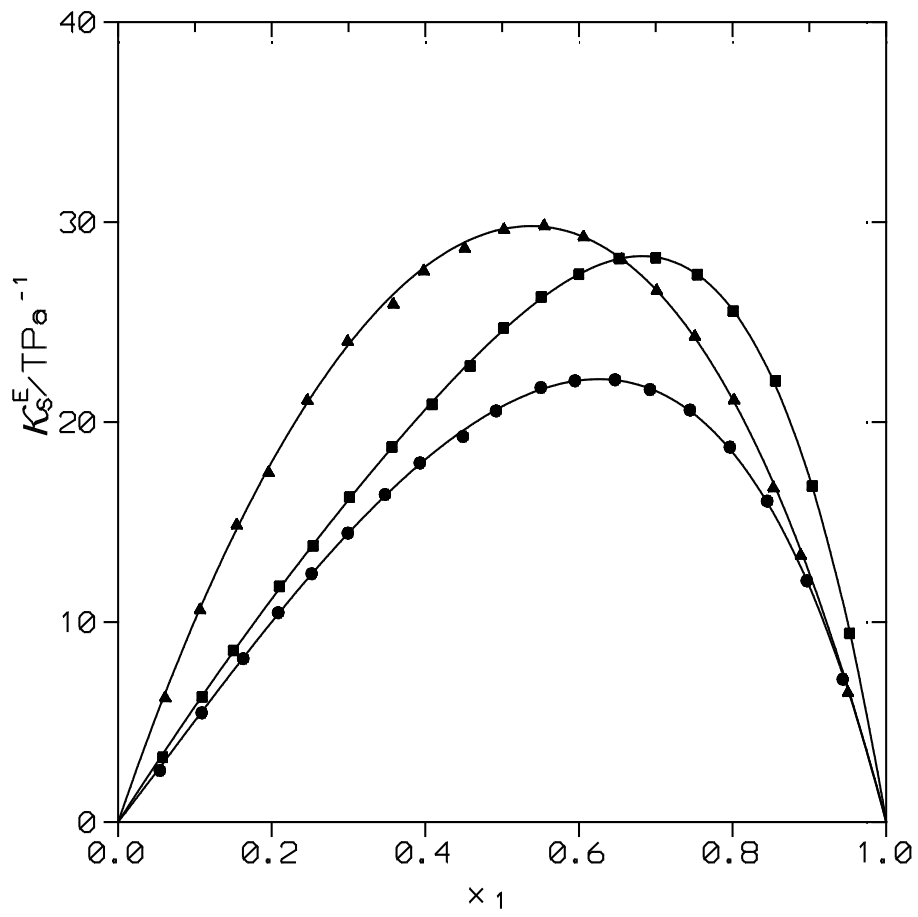
FIG. 1

FIG. 2