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Thermodynamic and transport properties of 2-methoxyaniline with substituted ethanols at various temperatures

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ABSTRACT

Densities (ρ), the speed of sound (u) and viscosities (η) accounted for binary liquid combinations of 2-methoxyaniline with substituted ethanols (2-phenylethanol, 2-chloroethanol and 2-aminoethanol) over the whole arrangement scope of mole fraction at $T = 303.15–318.15$ K and at ambient pressure were measured. The excess and variable functions have been computed from the measured basic data. Excess and deviation functions have been correlated utilising the Redlich–Kister third-order polynomial equation. The excess partial functions have been figured for the binary systems all through the creation go and at infinite dilutions. The interpretations of these properties with the arrangement of investigated systems suggest the loss of dipolar association, deviation in size and fabrication of the segment molecules and hydrogen bonding between 2-methoxyaniline with substituted ethanols. V^E comes out have been anatomised on the part of Prigogine–Flory–Patterson theory.

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Density; speed of sound; viscosity; 2-methoxyaniline; substituted ethanol; FT-IR spectra

1. Introduction

The investigation of the thermodynamic functions of binary combinations is noteworthy for some reasons one of which is to get information on molecular features of the contemplated combinations. There has been an expanding enthusiasm for the investigation of systems containing not at all like parts with associations of fluctuating sort. The sign and magnitude of excess properties have been utilised to explore the associations between the parts of a system (Mehra and Sajnani 2000; Mehra and Sajnani 2001). The portrayal of the combinations through their thermodynamic and transport properties is viewed as a standout amongst the most stretched out and reliable approaches to acquire information about the intermolecular arrangement and interactions of mixed solvents (Acevedo et al. 2001). The molecular interactions play important role in determining the structure of biological systems and improving materials and drug design strategy.

The objective of this study is to investigate and provide information on the molecular interactions among solvents in binary systems (Mukesh et al. 2015). The major advantage of 2-methoxyaniline has been utilised in the manufacture of dyes, pharmaceuticals and fragrance. On the other hand, 2-chloroethanol has been utilised as a wide industrial protean solvent and a mutagenic chemical. 2-aminoethanol is widely used in the pharmaceutical industry, in applications such as synthesis of chemical intermediate, stabiliser and controlling of pH in the reaction medium. 2-phenylethanol has been utilising in food and beverages as counter fit essence and as a base solvent, for some flavour compounds and more interest due to its antimicrobial properties. So, the binary mixture combinations are wide scope in the pharmaceutical industry.

In this paper, the emphasis is on the investigation of substituted ethanols with 2-methoxyaniline in light of the fact that there have been few examinations on these combinations (Tsierkezos and Molinou 1999; Amundsen, Øi, and Eimer 2009; Kumar and Jeevanandham 2012b). We boom the densities, speeds of sound and viscosities for three binary combinations at $T = (303.15–318.15)$ K and under 0.1 MPa pressure. The exploratory information has been utilised to register excess volume (V^E), excess isentropic compressibility ($\kappa_s{}^E$), deviation in viscosity ($\Delta\eta$) and excess Gibbs free energy of activation of viscous flow (G^{*E}).

2. Experimental methods

2.1. Materials

2-methoxyaniline (Sigma Aldrich), 2-phenylethanol (Sigma Aldrich), 2-chloroethanol and 2-aminoethanol chemicals were procured from S.D. Fine Chemicals Ltd. 2-chloroethanol and 2-aminoethanol chemicals were additionally cleansed by standard strategies (Vogel 1989; Riddick and Bunger 1986) like distillation and fractional distillation under reduced pressure, and just the centre portions were gathered. Before utilising, the chemicals were put away more than 0.4 nm molecular sieves for about 72 h to evacuate water and gas. The appropriate elements of the chemicals and relating purification techniques were presented in Table 1.

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Table 1. List of chemicals with details of source, CAS number, purity and water content.

Name of the chemical	Source	CAS number	Purification method	Mass fraction purity	Water content mass fraction**	Analysis method*
2-methoxyaniline	Sigma Aldrich India	90-04-0	No purification	0.995	0.00042	GC
2-phenylethanol	Sigma Aldrich India	60-12-8	No purification	0.995	0.0004	GC
2-chloroethanol	S.D. Fine Chemicals, India	107-07-3	Distillation under reduced pressure	0.995	0.0004	GC
2-aminoethanol	S.D. Fine Chemicals, India	141-43-5	Fractional distillation	0.995	0.0004	GC

*Gas Chromatography; **Karl-Fischer method.

2.2. Apparatus and procedure

All the binary liquid mixtures were set up by weighing proper measure of pure liquids on an Afcoset-ER-120A electric balance utilising syringe in narrow mouth stoppered bottle. The uncertainty of electronic balance was ± 0.05 mg while the exactness of the mole division was $\pm 1 \times 10^{-4}$.

Pure liquids and their binary combination's densities and speeds of sound were measured by digital oscillating Density and Sound Analyzer (DSA 5000M, Anton Parr, Austria) with reproducibility of $\pm 1 \times 10^{-3}$ kg m^{-3} for density and $\pm 1 \times 10^{-2}$ ms^{-1} for the speed of sound. The densimeter automatically performs the viscosity changes for density during measurements up to 700 mPa. The speed of sound was measured using a propagation time technique at a frequency of 3 MHz. The densimeter was calibrated randomly with dry air (1.204×10^{-3} gcm^{-3} at 293.15 K) at atmospheric pressure and doubly distilled, freshly degassed deionised water (CAS: 77-32-18-5; Anton Paar GmbH, liquid standard density, 0.9982 ± 0.00002 gcm^{-3}(293.15 K), literature density 0.9982 gcm^{-3} (293.15 K, KNOVEL DIPPR); conductivity, $\kappa = 8$ µS). The distilled water and anhydrous ethanol have been used to clean the vibrating tube after every measurement. The standard uncertainty detailed in this study is absolute standard uncertainty and very alluding to the level of repeatability, and the level of confidence $k = 2$ (95%). The uncertainties associated with the measurements for temperature, density, and speed of sound were estimated to be within +0.01 K, $+1 \times 10^{-3}$ g cm^{-3} and +1 ms^{-1} respectively. The viscosities of pure and their binary combinations were measured at T/K = (303.15–318.15) at 0.1 Mpa by utilising an Ubbelohde viscometer, which was aligned with benzene, carbon tetrachloride, acetonitrile and doubly distilled water (https://www.accudynetest.com/visc_table.html). The viscometer arranged in a transparent walled bath with a thermal stability of ±0.1 K for around 20 min to acquire thermal equilibrium. An electronic digital stopwatch with an uncertainty of ±0.01 s was utilised for stream time estimations. The observed uncertainty of viscosity was assessed as ±1.03% and the uncertainty of temperature as ±0.1 K. The experimental values of densities, speeds of sound and viscosities of the pure liquids were correlated with the values accessible in the literature (Kumar and Jeevanandham 2012a; Papari et al. 2013; Kermanpour, Jahani, and Iloukhani 2009; Francesconi et al. 2005; Yeh and Tu 2007; Domańska, Zawadzki, and Lewandrowska 2012; Dyer 1978; Ferrari et al. 2003; Pandey, Awasthi, and Awasthi 2014; Baragi et al. 2005; Reddy, Rao, and Rambabu 2016; Águila-Hernández et al. 2008; García-Abuín et al. 2011; Aralaguppi, Jadar, and Aminabhavi 1999; Hawrylak, Burke, and Palepu 2000; Pouryousefi and Idem 2008; Han et al. 2012; Zábranský and Ruzicka Jr 2004; Perkin 1896), and these were enlisted in Table 2.

3. Results and discussion

With measured basic values such as densities and viscosities for all the binary combinations at various ratios have been used to calculate the excess thermodynamic functions and deviations:

$$V^E(\mathrm{m^3.mol^{-1}}) = [x_1M_1 + x_2M_2]/\rho - [x_1M_1/\rho_1 + x_2M_2/\rho_2] \quad (1)$$

$$\Delta h(\mathrm{mPa}\cdots) = h - (x_1h_1 + x_2h_2) \quad (2)$$

$$G^{*E}(\mathrm{J \times mol^{-1}}) = RT[\ln hV - (x_1 \ln h_1V_1 + x_2 \ln h_2V_2)] \quad (3)$$

where ρ, η and V are density, viscosity and molar volume of the binary mixture. x_1, M_1, ρ_1, η_1, V_1 and x_2, M_2, ρ_2, η_2, V_2 are the mole fraction, molar mass, density, viscosity and molar volume of pure components 1 and 2 respectively. R is the gas constant and T is the absolute temperature.

The observed data are used to compute isentropic compressibility (κ_s) by utilising the following relation:

$$\kappa_s = (u^2\rho)^{-1} \quad (4)$$

The technique used for computing ${\kappa_s}^{\mathrm{E}}$ (Benson–Kiyohara approach) is reported previously (Benson and Kiyohara 1979).

V^{E}, κ_s^E and Δ values are fitted to a Redlich–Kister (Redlich and Kister 1948) polynomial equation

$$Y^{\mathrm{E}} = x_1x_2\sum_{i=0}^{j} A_i(1 - 2x_1)^i \quad (5)$$

where Y^{E} is the V^{E}, κ_s^E and Δ. Values of the coefficients A_i have been evaluated by the technique of least-squares. The standard deviations σ (Y^{E}) have been computed by utilising the formula

$$\sigma(Y^E) = [\Sigma({Y^E}_{\mathrm{exp}} - {Y^E}_{\mathrm{cal}})^2/(m-n)]^{1/2} \quad (6)$$

where m is the total number of obtained points and n is the number of parameters. The coefficients A_i and corresponding standard deviation values (σ) are furnished in Table 4.

Figure 1 represents the comparison of the observed density of 2-methoxyaniline and references (Perkin 1896) and (Kumar and Jeevanandham 2012a) respectively. Figure 2 shows the comparison of the observed speed of sound of 2-methoxyaniline and reference (Mukesh et al. 2015) at various temperatures. In reference (Mukesh et al. 2015) at higher temperatures 313.15 and 318.15 K, a speed of sound data was typographical mistake.

Table 2. Densities, speeds of sounds, viscosity and specific heat of pure components at different temperatures and 0.1 MPa pressure.

Component	Density (ρ) (g/cm^3)		Speed of sound (u, ms^{-1})		Viscosity (mPa·s)		
	Experimental	Literature	Experimental	Literature	Experimental	Literature	C_P (JK^{-1}mol^{-1})
2-methoxyaniline							
303.15 K	1.09175[a]	1.0917[a]	1595.4[a]		4.92[a]	4.9236[a]	190.52[a]
		1.0885[a]					
308.15 K	1.08735[a]	10857[a]	1579.2[a]		4.51[a]		192.05[a]
313.15 K	1.08378[a]	1.0832[a]	1566.3		4.19[a]		193.62[a]
318.15 K	1.08080[a]	1.0808[a]	1544.8		3.88[a]		195.25[a]
2-phenylethanol							
303.15 K	1.01234	1.01234[a]	1509.6	1510.5[a]	9.05		235.4[a]
		1.01265[a]		1506.8[a]			
308.15 K	1.00847	1.00856[a]	1490.8	1494.75[a]	7.19	7.518[a]	238.8[a]
		1.00863[a]		1488.6[a]		7.438[a]	
		1.00879[a]				7.19[a]	
		1.00861[a]				7.190[a]	
		1.00878[a]					
313.15 K	1.00473	1.00476[a]	1473.8	1479.12[a]	6.09	7.438[a]	242.2[a]
		1.00504[a]		1467.4[a]			
318.15 K	1.00094	1.00098[a]	1457.7	1463.59[a]	4.98	4.98[a]	245.5[a]
		1.00095[a]		1445.5[a]		5.232[a]	
		1.00096[a]					
		1.00098[a]					
2-chloroethanol							
303.15 K	1.19212	1.19248[a]	1342.8	1339.6[a]	2.58	2.669[a]	131.6[a]
						2.580[a]	
		1.1925[a]					
		1.1921[a]					
308.15 K	1.18526	1.1871[a]	1328.9	1329.9[a]	2.26	2.261[a]	133.8[a]
		1.18644[a]		1319.6[a]		2.347[a]	
		1.1849[a]					
		1.1866[a]					
313.15 K	1.17837	1.17803[a]	1315.5	1315.0[a]	1.85	–	136.0[a]
318.15 K	1.17087	1.1738[a]	1301.2	1300.2[a]	1.56	–	138.2[a]
		1.1736[a]					
		1.17089[a]					
2-aminoethanol							
303.15 K	1.00872	1.00874[a]	1704.9	1703.7[a]	14.42	14.423[a]	164.6[a]
		1.0081[a]				14.956[a]	
308.15 K	1.00477	1.0041[a]	1690.1	1686.7[a]	11.71	-	
		1.00467[a]					
		1.00445[a]					167.8[a]
313.15 K	1.00057	1.00077[a]	1675.2	1671.2[a]	9.56	9.562[a]	171.0[a]
		1.0004[a]				9.839[a]	
318.15 K	0.99604	0.99648[a]	1659.4	1653.5[a]	7.56	–	
		0.9960[a]					

[a]Source: Mukesh et al. (2015); Kumar and Jeevanandham (2012a); Perkin (1896); Papari et al. (2013); Reddy, Rao, and Rambabu (2016); Kermanpour, Jahani, and Iloukhani (2009); Yeh and Tu (2007); Francesconi et al. (2005); Domańska, Zawadzki, and Lewandrowska (2012); Baragi (2005); Aralaguppi, Jadar, and Aminabhavi (1999); Ferrari (2003); Pandey, Awasthi, and Awasthi (2014); García-Abuín (2011); Águila-Hernández (2008); Hawrylak, Burke, and Palepu (2000); Pouryousefi and Idem (2008); Han (2012); Dyer (1978); Zábranský and Ruzicka (2004).

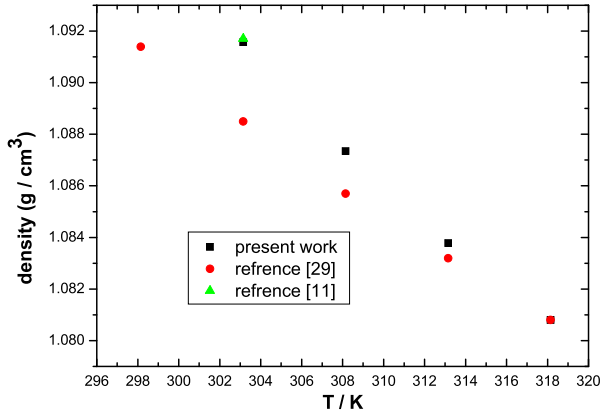

Figure 1. Comparison of experimental density of 2-methoxyaniline ■, this work at T = (303.15–318.15) K: ●, Perkin (1896) at T = (303.15–318.15) K, ▲, Kumar and Jeevanandham (2012a) at 303.15 K.

In general, excess functions are influenced by two factors: (i) cleavage of associated intermolecular interactions of the component molecules and (ii) heteromolecular interactions between the components in liquid combinations. The experimental values indicated that the latter factor is predominating in these mixtures.

Table 3 shows that the values of excess functions are negative throughout the composition range and can be observed graphically in Figures 3 and 4 which support the existence of attractive forces in the binary combinations through hydrogen bond (Oswal and Desai 1998; Petersen 1960; Nakanishi, Ichinose, and Shirai 1968). In the case of water + ethanolamine (Kapadi et al. 2002), similar trend was noticed.

The binary combinations of 2-methoxyaniline with substituted ethanols of excess functions has been noticed in the following order:

$$2-\text{aminoethanol} < 2-\text{chloroethanol} < 2-\text{phenylethanol}$$

The negative values of excess functions of 2-methoxy aniline with 2-phenylethanol are not as much as when compared in the binary combinations containing 2-methoxy aniline with 2-aminoethanol and 2-chloroethanol when they were contrasted with the binary combinations, in light of the fact that the phenyl group ($-C_6H_5$) is putting forth to steric hindrance with $-NH_2$ group (Rauf and Arfan 1983; Ali et al. 2004; Krestov 1991). Comparable outcomes have been accounted for before (Brocos et al. 1999; Amigo, Bravo, and Pintos 1993). Henceforth, the above order was supported.

With an increase in temperature, the thermal energy of the investigated molecules gains, more and more of pure substituted ethanols would be accessible in the investigated systems due to the breaking of H-bonds. These free substituted ethanol molecules interact more with phenyl group presence due to completely dissociated 2-methoxyaniline and

Table 3. Density (ρ), excess molar volumes (VE), speed of sound (u), excess isentropic compressibility (κsE), viscosity (η), deviation in viscosity ($\Delta\eta$) and excess Gibbs energy of activation of viscous flow (G*E) of binary liquid mixtures of 2-methoxyaniline with substituted ethanols at T = (303.15–318.15) K and 0.1 MPa pressure.

	Density (ρ) (g/cm^3)				V^E (cm^3 mol^{-1})			
x_1	303.15 K	308.15 K	313.15 K	318.15 K	303.15 K	308.15 K	313.15 K	318.15 K
2-methoxyaniline (1) + 2-phenylethanol (2)								
0.0000	1.01234	1.00847	1.00473	1.00094	0.0000	0.0000	0.0000	0.0000
0.0957	1.01974	1.01587	1.01220	1.00853	−0.0308	−0.0357	−0.0424	−0.0494
0.1852	1.02672	1.02285	1.01920	1.01561	−0.0574	−0.0646	−0.0731	−0.0819
0.2904	1.03499	1.03109	1.02744	1.02391	−0.0833	−0.0912	−0.0973	−0.1042
0.3921	1.04303	1.03908	1.03544	1.03199	−0.0998	−0.1068	−0.1120	−0.1189
0.4911	1.05088	1.04689	1.04327	1.03988	−0.1068	−0.1132	−0.1185	−0.1242
0.6027	1.05975	1.05573	1.05213	1.04883	−0.1033	−0.1099	−0.1160	−0.1211
0.7023	1.06768	1.06363	1.06006	1.05687	−0.0887	−0.0958	−0.1040	−0.1112
0.8005	1.07551	1.07144	1.06790	1.06479	−0.0658	−0.0735	−0.0818	−0.0887
0.8904	1.08272	1.07859	1.07506	1.07204	−0.0390	−0.0443	−0.0508	−0.0578
1.0000	1.09175[a]	1.08735[a]	1.08378[a]	1.08080[a]	0.0000	0.0000	0.0000	0.0000
2-methoxyaniline (1) + 2-chloroethanol (2)								
0.0000	1.19212	1.18526	1.17837	1.17087	0.0000	0.0000	0.0000	0.0000
0.1041	1.17642	1.17008	1.16383	1.15724	−0.0392	−0.0440	−0.0486	−0.0577
0.2448	1.15798	1.15216	1.14659	1.14086	−0.0803	−0.0858	−0.0933	−0.1021
0.3401	1.14698	1.14146	1.13624	1.13099	−0.0993	−0.1056	−0.1120	−0.1197
0.4623	1.13428	1.12908	1.12427	1.11957	−0.1121	−0.1179	−0.1238	−0.1296
0.5621	1.12491	1.11994	1.11542	1.11113	−0.1124	−0.1177	−0.1232	−0.1293
0.6825	1.11461	1.10989	1.10572	1.10186	−0.1000	−0.1053	−0.1136	−0.1190
0.7612	1.10838	1.10383	1.09985	1.09625	−0.0843	−0.0905	−0.0988	−0.1046
0.8484	1.10191	1.09752	1.09370	1.09037	−0.0598	−0.0667	−0.0724	−0.0789
0.9217	1.09677	1.09248	1.08881	1.08566	−0.0336	−0.0381	−0.0433	−0.0476
1.0000	1.09175[a]	1.08735[a]	1.08378[a]	1.08080[a]	0.0000	0.0000	0.0000	0.0000
2-methoxyaniline (1) + 2-aminoethanol (2)								
0.0000	1.00872	1.00477	1.00057	0.99604	0.0000	0.0000	0.0000	0.0000
0.0897	1.02223	1.01827	1.01425	1.01003	−0.0419	−0.0441	−0.0505	−0.0572
0.1649	1.03203	1.02802	1.02411	1.02006	−0.0685	−0.0704	−0.0802	−0.0870
0.2579	1.04259	1.03855	1.03471	1.03084	−0.0926	−0.0951	−0.1049	−0.1123
0.3519	1.05183	1.04780	1.04397	1.04029	−0.1084	−0.1138	−0.1200	−0.1290
0.4497	1.06020	1.05616	1.05236	1.04883	−0.1170	−0.1239	−0.1278	−0.1367
0.5507	1.06775	1.06368	1.05994	1.05653	−0.1180	−0.1245	−0.1287	−0.1360
0.6549	1.07455	1.07043	1.06678	1.06350	−0.1102	−0.1148	−0.1220	−0.1287
0.7626	1.08070	1.07656	1.07296	1.06980	−0.0917	−0.0963	−0.1042	−0.1107
0.8735	1.08620	1.08203	1.07848	1.07544	−0.0590	−0.0626	−0.0696	−0.0762
1.0000	1.09157	1.08735	1.08378	1.08080	0.0000	0.0000	0.0000	0.0000
	speed of sound (u, ms^{-1})					κ_s^E (TPa^{-1})		
2-methoxyaniline (1) + 2-phenylethanol (2)								
0.0000	1509.6	1490.8	1473.8	1457.7	0.000	0.000	0.000	0.000
0.0957	1518.3	1499.8	1483.4	1467.3	−1.452	−1.590	−1.848	−2.215
0.1852	1526.7	1508.3	1492.3	1475.9	−2.729	−2.882	−3.215	−3.677
0.2904	1536.7	1518.4	1502.7	1485.5	−3.942	−4.073	−4.456	−4.788
0.3921	1546.3	1527.9	1512.5	1494.7	−4.804	−4.792	−5.137	−5.417
0.4911	1555.4	1537.0	1521.9	1503.5	−5.227	−5.093	−5.421	−5.649
0.6027	1565.3	1547.0	1532.3	1513.3	−5.195	−4.994	−5.266	−5.470
0.7023	1573.6	1555.6	1541.3	1522.0	−4.638	−4.387	−4.640	−4.970
0.8005	1581.4	1563.6	1550.1	1530.3	−3.611	−3.284	−3.650	−4.019
0.8904	1588.4	1570.8	1557.8	1537.4	−2.423	−2.020	−2.338	−2.654
1.0000	1595.4[a]	1579.2[a]	1566.3	1544.8	0.000	0.000	0.000	0.000
2-methoxyaniline (1) + 2-chloroethanol (2)								
0.0000	1342.4	1328.4	1314.9	1302.1	0.000	0.000	0.000	0.000
0.1041	1383.0	1368.4	1354.7	1340.6	−3.811	−3.914	−3.955	−3.979
0.2448	1433.0	1417.8	1404.4	1388.9	−7.670	−7.978	−8.219	−8.362
0.3401	1463.6	1448.2	1435.0	1418.7	−9.384	−9.849	−10.25	−10.52
0.4623	1498.9	1483.3	1470.5	1453.4	−10.48	−11.11	−11.70	−12.13
0.5621	1524.2	1508.5	1496.1	1478.3	−10.45	−11.16	−11.86	−12.40
0.6825	1550.6	1534.6	1522.5	1504.0	−9.286	−10.01	−10.74	−11.33
0.7612	1565.2	1549.1	1537.1	1518.1	−7.841	−8.500	−9.183	−9.735

(*continued*).

Table 3. Continued.

	Density (ρ) (g/cm^3)				V^E (cm^3 mol^{-1})			
x_1	303.15 K	308.15 K	313.15 K	318.15 K	303.15 K	308.15 K	313.15 K	318.15 K
0.8484	1579.0	1562.5	1550.5	1530.9	−5.594	−6.106	−6.635	−7.079
0.9217	1588.6	1571.7	1559.5	1539.4	−3.164	−3.471	−3.797	−4.069
1.0000	1595.4[a]	1579.2[a]	1566.3	1544.8	0.000	0.000	0.000	0.000
2-methoxyaniline (1) + 2-aminoethanol (2)								
0.0000	1704.9	1689.7	1674.8	1659.4	0.000	0.000	0.000	0.000
0.0897	1702.5	1689.1	1675.5	1660.0	−6.500	−7.494	−8.184	−8.897
0.1649	1701.6	1686.3	1673.2	1657.1	−11.50	−11.95	−12.86	−13.80
0.2579	1695.9	1680.4	1667.3	1650.0	−15.00	−15.52	−16.45	−17.37
0.3519	1688.1	1671.9	1658.7	1640.2	−16.91	−17.30	−18.12	−18.89
0.4497	1677.7	1660.9	1647.7	1628.1	−17.35	−17.56	−18.26	−18.88
0.5507	1665.1	1648.0	1634.9	1614.7	−16.37	−16.46	−17.12	−17.65
0.6549	1650.3	1633.3	1620.7	1600.2	−14.07	−14.13	−14.86	−15.41
0.7626	1633.9	1617.2	1605.1	1584.6	−10.59	−10.70	−11.51	−12.13
0.8735	1616.3	1599.8	1587.9	1567.3	−6.150	−6.223	−6.938	−7.513
1.0000	1595.4	1579.2	1566.3	1544.8	0.000	0.000	0.000	0.000
	viscosity (η, mPa·s)				$\Delta\eta$ (mPa·s)			
2-methoxyaniline (1) + 2-phenylethanol (2)								
0.0000	9.05	7.19	6.09	4.98	0.000	0.000	0.000	0.000
0.0957	8.66	6.95	5.91	4.89	0.008	0.009	0.009	0.011
0.1852	8.29	6.71	5.75	4.80	0.013	0.015	0.016	0.017
0.2904	7.87	6.43	5.55	4.69	0.018	0.020	0.021	0.022
0.3921	7.45	6.16	5.36	4.58	0.021	0.023	0.024	0.025
0.4911	7.04	5.90	5.18	4.47	0.023	0.024	0.025	0.026
0.6027	6.58	5.60	4.97	4.35	0.022	0.023	0.025	0.026
0.7023	6.17	5.33	4.77	4.23	0.020	0.021	0.023	0.024
0.8005	5.76	5.06	4.58	4.12	0.016	0.017	0.019	0.019
0.8904	5.38	4.82	4.41	4.02	0.010	0.011	0.012	0.013
1.0000	4.92[a]	4.51[a]	4.19[a]	3.88[a]	0.000	0.000	0.000	0.000
2-methoxyaniline (1) + 2-chloroethanol (2)								
0.0000	2.58	2.26	1.85	1.56	0.000	0.000	0.000	0.000
0.1041	2.83	2.50	2.11	1.82	0.009	0.010	0.011	0.012
0.2448	3.17	2.83	2.44	2.15	0.018	0.020	0.021	0.022
0.3401	3.40	3.05	2.67	2.38	0.021	0.023	0.025	0.025
0.4623	3.69	3.33	2.96	2.66	0.024	0.025	0.027	0.028
0.5621	3.92	3.55	3.19	2.90	0.024	0.025	0.027	0.028
0.6825	4.20	3.82	3.47	3.17	0.022	0.023	0.025	0.027
0.7612	4.38	4.00	3.65	3.35	0.020	0.021	0.022	0.024
0.8484	4.58	4.19	3.85	3.55	0.015	0.015	0.017	0.018
0.9217	4.75	4.35	4.01	3.71	0.009	0.009	0.010	0.011
1.0000	4.92[a]	4.51[a]	4.19[a]	3.88[a]	0.000	0.000	0.000	0.000
2-methoxyaniline (1) + 2-aminoethanol (2)								
0.0000	14.42	11.71	9.56	7.56	0.000	0.000	0.000	0.000
0.0897	13.58	11.07	9.09	7.24	0.009	0.010	0.011	0.013
0.1649	12.87	10.54	8.70	6.97	0.015	0.017	0.018	0.019
0.2579	11.99	9.87	8.20	6.64	0.020	0.021	0.023	0.025
0.3519	11.10	9.20	7.70	6.29	0.023	0.025	0.027	0.028
0.4497	10.18	8.50	7.17	5.94	0.025	0.027	0.028	0.030
0.5507	9.22	7.77	6.63	5.56	0.025	0.027	0.029	0.030
0.6549	8.23	7.02	6.07	5.18	0.024	0.026	0.028	0.029
0.7626	7.20	6.24	5.49	4.78	0.021	0.022	0.024	0.026
0.8735	6.14	5.44	4.88	4.37	0.015	0.015	0.017	0.018
1.0000	4.92[a]	4.51[a]	4.19[a]	3.88[a]	0.000	0.000	0.000	0.000

G^{*E} (Jmol^{-1})

2-methoxyaniline (1) + 2-phenylethanol (2)					2-methoxyaniline(1) + 2-chloroethanol(2)					2-methoxyaniline(1) + 2-aminoethanol(2)				
x_1	303.15 K	308.15 K	313.15 K	318.15 K	x_1	303.15 K	308.15 K	313.15 K	318.15 K	x_1	303.15 K	308.15 K	313.15 K	318.15 K
0.0000	0.000	0.000	0.000	0.000	0.0000	0.000	0.000	0.000	0.000	0.0000	0.000	0.000	0.000	0.000
0.0957	0.361	0.240	0.176	0.118	0.1041	0.991	1.118	1.462	1.790	0.0897	1.352	1.209	1.067	0.905
0.1852	0.646	0.425	0.314	0.201	0.2448	1.834	2.053	2.633	3.169	0.1649	2.313	2.059	1.806	1.513
0.2904	0.915	0.598	0.439	0.275	0.3401	2.126	2.374	3.023	3.611	0.2579	3.285	2.902	2.525	2.095
0.3921	1.101	0.713	0.520	0.322	0.4623	2.240	2.484	3.137	3.721	0.3519	4.021	3.525	3.044	2.492
0.4911	1.203	0.771	0.562	0.344	0.5621	2.132	2.359	2.964	3.497	0.4497	4.514	3.923	3.354	2.715
0.6027	1.209	0.770	0.560	0.342	0.6825	1.798	1.986	2.479	2.911	0.5507	4.705	4.051	3.432	2.738
0.7023	1.107	0.701	0.508	0.311	0.7612	1.474	1.624	2.017	2.363	0.6549	4.524	3.855	3.230	2.541
0.8005	0.890	0.559	0.405	0.250	0.8484	1.016	1.116	1.385	1.618	0.7626	3.863	3.252	2.688	2.087
0.8904	0.569	0.356	0.257	0.162	0.9217	0.559	0.614	0.756	0.886	0.8735	2.556	2.118	1.728	1.318
1.0000	0.000	0.000	0.000	0.000	1.0000	0.000	0.000	0.000	0.000	1.0000	0.000	0.000	0.000	0.000

[a]Source: Mukesh et al. (2015).

The standard uncertainties are $u(\rho) = \pm 0.5 \times 10^{-3}$ gcm^{-3}, $u(u) = 0.5$ ms^{-1}, $u(\eta) = 1.03\%$, $u(T) = 0.01$ K for density and speed of sound, $u(T) = 0.1$ K for viscosity and $u(p) = 1$ kPa.

Table 4. Coefficients of Redlich–Kister equation and standard deviation (σ) values for liquid mixtures of 2-methoxyaniline with substituted ethanol at T = (303.15–318.15) K.

Binary mixtures	Functions	A_0	A_1	A_2	σ
303.15 K					
2-methoxyaniline + 2-phenylethanol	V^E (cm^3 mol^{-1})	−0.428	−0.025	0.080	0.001
	$\Delta\eta$ (mPa·s)	0.092	0.009	0.010	0.001
	κ_s^E (TPa^{-1})	−19.33	−0.714	4.750	0.054
2-methoxyaniline + 2-chloroethanol	V^E (cm^3 mol^{-1})	−0.453	−0.029	0.016	0.001
	$\Delta\eta$ (mPa·s)	0.096	0.013	0.024	0.001
	κ_s^E (TPa^{-1})	−42.28	−2.491	10.03	0.083
2-methoxyaniline + 2-aminoethanol	V^E (cm^3·mol^{-1})	−0.474	−0.019	−0.082	0.001
	$\Delta\eta$ (mPa· s)	0.101	0.015	0.037	0.001
	κ_s^E (TPa^{-1})	−66.54	21.29	5.069	0.239
308.15 K					
2-methoxyaniline + 2-phenylethanol	V^E (cm^3·mol^{-1})	−0.455	−0.024	0.033	0.001
	$\Delta\eta$ (mPa· s)	0.096	0.006	0.020	0.001
	κ_s^E (TPa^{-1})	−20.54	−1.353	1.585	0.027
2-methoxyaniline + 2-chloroethanol	V^E (cm^3·mol^{-1})	−0.474	−0.032	−0.038	0.001
	$\Delta\eta$ (mPa·s)	0.102	0.009	0.025	0.001
	κ_s^E (TPa^{-1})	−44.98	−3.363	−2.072	0.001
2-methoxyaniline + 2-aminoethanol	V^E (cm^3·mol^{-1})	−0.496	−0.026	−0.087	0.001
	$\Delta\eta$ (mPa·s)	0.108	0.011	0.039	0.001
	κ_s^E (TPa^{-1})	−68.67	22.07	−7.414	0.001
313.15 K					
2-methoxyaniline + 2-phenylethanol	V^E (cm^3·mol^{-1})	−0.476	−0.024	−0.050	0.001
	$\Delta\eta$ (mPa·s)	0.103	0.011	0.016	0.001
	κ_s^E (TPa^{-1})	−21.41	−1.407	−1.465	0.041
2-methoxyaniline + 2-chloroethanol	V^E (cm^3·mol^{-1})	−0.499	−0.038	−0.089	0.001
	$\Delta\eta$ (mPa·s)	0.109	0.010	0.031	0.001
	κ_s^E (TPa^{-1})	−47.98	−4.682	−9.532	0.001
2-methoxyaniline + 2-aminoethanol	V^E (cm^3·mol^{-1})	−0.516	−0.020	−0.177	0.001
	$\Delta\eta$ (mPa·s)	0.115	0.013	0.048	0.001
	κ_s^E (TPa^{-1})	−71.34	22.76	−15.13	0.001
318.15 K					
2-methoxyaniline + 2-phenylethanol	V^E (cm^3·mol^{-1})	−0.497	−0.019	−0.136	0.001
	$\Delta\eta$ (mPa·s)	0.104	0.008	0.041	0.001
	κ_s^E (TPa^{-1})	−29.76	0.177	−7.762	0.026
2-methoxyaniline + 2-chloroethanol	V^E (cm^3·mol^{-1})	−0.519	−0.17	−0.176	0.001
	$\Delta\eta$ (mPa·s)	0.112	0.012	0.048	0.001
	κ_s^E (TPa^{-1})	−48.01	−18.54	−22.32	0.109
2-methoxyaniline + 2-aminoethanol	V^E (cm^3·mol^{-1})	−0.545	−0.014	−0.236	0.001
	$\Delta\eta$ (mPa·s)	0.119	0.009	0.065	0.001
	κ_s^E (TPa^{-1})	−73.53	24.42	−22.69	0.001

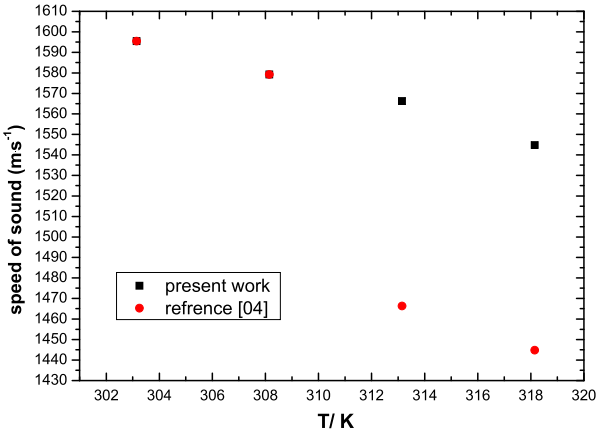

Figure 2. Comparison of experimental speed of sound of 2-methoxyaniline ■, this work at T = (303.15–318.15) K: ●, Mukesh et al. (2015) at T = (303.15–318.15) K.

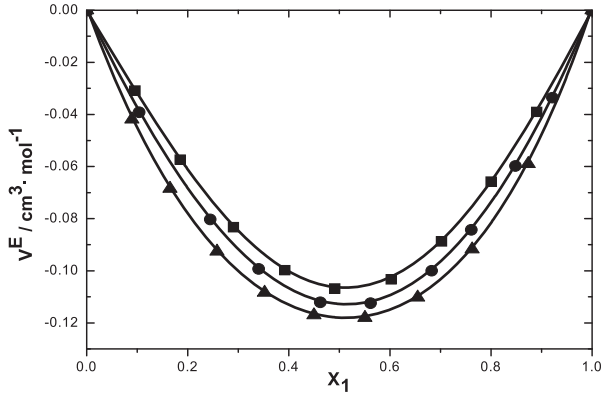

Figure 3. Variation of excess molar volume (V^E) with mole fraction (x_1) of 2-methoxyaniline for the binary liquid mixtures of 2-methoxyaniline with 2-aminoethanol (▲): 2-chloroethanol (●) and 2-phenylethanol (■) at 303.15 K.

form new H-bonds at the higher temperature. Hence, resulting values are more negative with an increase of temperature. 1-alkanol + hexane (Heintz et al. 1986), alcohol + Triethylene glycol (Valtz et al. 2004) and 1-hexanol + ether (Villa et al. 2000) systems, similar results were noticed.

Figures 5 and 6 state that the deviation in viscosity and excess Gibbs energy of activation of viscous flow values is positive for three binary mixtures over the whole arrangement got at all explored temperatures. This indicates the presence of a clear-cut interaction such as the formation of hetero associates complex between dissimilar molecules. A comparison of our results

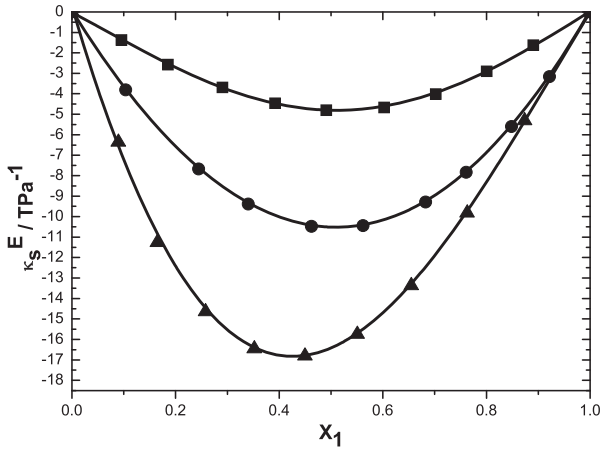

Figure 4. Excess isentropic compressibility (κ_s^E) with mole fraction (x_1) of 2-methoxyaniline in the binary liquid mixtures of 2-methoxyaniline with 2-aminoethanol (▲): 2-chloroethanol (●) and 2-phenylethanol (■) at 303.15 K.

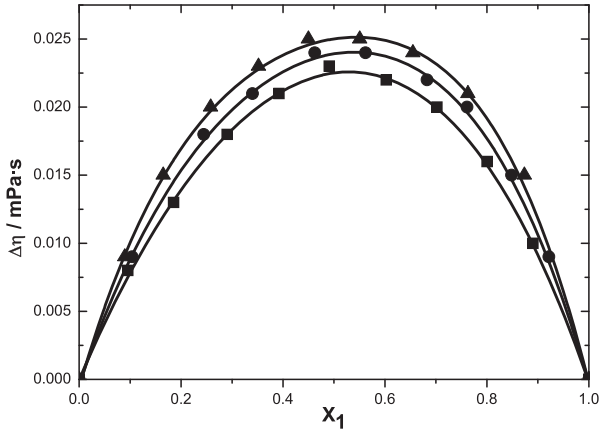

Figure 5. Variation of deviation in viscosity ($\Delta\eta$) with mole fraction (x_1) of 2-methoxyaniline in the binary liquid mixtures of 2-methoxyaniline with 2-aminoethanol (▲): 2-chloroethanol (●) and 2-phenylethanol (■) at 303.15 K.

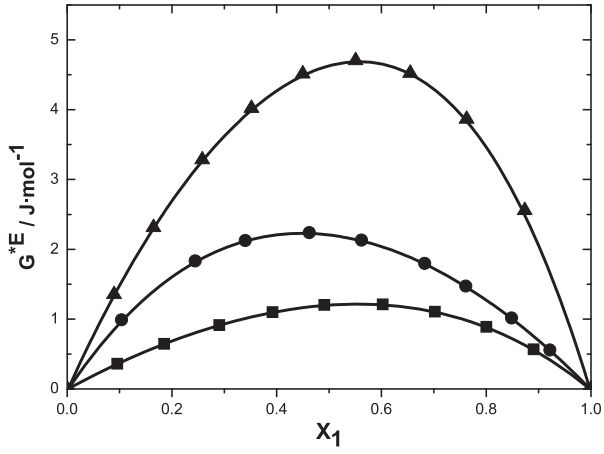

Figure 6. Excess Gibbs energy of activation of viscous flow (G^{*E}) with mole fraction (x_1) of 2-methoxyaniline in the binary liquid mixtures of 2-methoxyaniline with 2-aminoethanol (▲): 2-chloroethanol (●) and 2-phenylethanol (■) at 303.15 K.

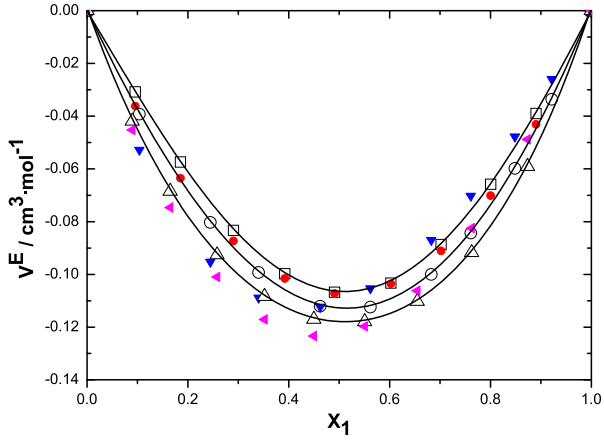

Figure 7. Excess molar volumes with mole fraction (x_1) of 2-methoxyaniline in the binary liquid mixtures of 2-methoxyaniline with 2-aminoethanol (▲): 2-chloroethanol (■) and 2-phenylethanol (♦) at 303.15 K and (—) calculated with PFP theory using χ_{12} parameters.

pertaining to densities and speeds of sound of the pure component with the stated values in the literature (Perkin 1896, Kumar and Jeevanandham 2012a; Mukesh et al. 2015) at various temperatures have been presented graphically in Figures 1 and 2. It can be inferred that the numerical value pertaining to the least AAD% value of density/speed of sound/**v**iscosity, is in good agreement with our observations.

4. Partial molar properties

The interpretations of excess partial molar properties ($\overline{V}^E_{m,1}$, $\overline{V}^E_{m,2}$, $\overline{K}^E_{s,m,1}$and $\overline{K}^E_{s,m,2}$) and excess partial molar properties at infinite dilution($\overline{V}^{\circ E}_{m,1}$, $\overline{V}^{\circ E}_{m,2}$, $\overline{K}^{\circ E}_{s,m,1}$ and $\overline{K}^{\circ E}_{s,m,2}$) of components 2 were described previously (Rao et al. 2016).

A close perusal of Table 5 indicates that the values of $\overline{V}^E_{m,1}$, $\overline{V}^E_{m,2}$, $\overline{K}^E_{s,m,1}$ and $\overline{K}^E_{s,m,2}$ are negative for the investigated combinations throughout mole fraction range. Negative values arise due to the formation of new H-bond between the investigated molecules of the combinations. From Table 6, it can be observed that the values of, $\overline{V}^{\circ E}_{m,1}$, $\overline{V}^{\circ E}_{m,2}$, $\overline{K}^{\circ E}_{s,m,1}$ and $\overline{K}^{\circ E}_{s,m,2}$ are negative for all the binary combinations, which indicate that the strong specific interactions through donor–acceptor interactions between 2-methoxyaniline and substituted ethanol molecules.

4.1. Prigogine–Flory–Patterson Theory

The parameter χ_{12} was required to calculate V^E utilising PFP theory. They were determined by fitting the V^E articulation to the exploratory equimolar estimation of V^E for each system examined. The ascertained equimolar estimation of the three contributions together with the χ_{12} parameter for each system was reported in Table 7. The analogy of experimental V^E_m values with those computed from PFP was graphically presented as Figure 7. By close examination of individual of three contributions to V^E indicates, the interactional contribution was positive, free volume contribution was negative and P^* contribution was negative for all investigated combinations except 2-phenyl ethanol, which had a positive internal pressure term. Table 7 reports that the free volume contribution plays

Table 5. The values $\bar{V}^{E}_{m,1}$,$\bar{V}^{E}_{m,2}$,$\bar{K}^{E}_{s,m,1}$,$\bar{K}^{E}_{s,m,2}$ of liquid mixtures of 2-methoxyaniline with substituted ethanol at T = (303.15 - 318.15) K

	303.15 K		308.15 K		313.15 K		318.15 K		303.15 K		308.15 K		313.15 K		318.15 K	
	$\bar{V}^{E}_{m,1}$	$\bar{V}^{E}_{m,2}$	$\bar{V}^{E}_{m,1}$	$\bar{V}^{E}_{m,2}$	$\bar{V}^{E}_{m,1}$	$\bar{V}^{E}_{m,2}$	$\bar{V}^{E}_{m,1}$	$\bar{V}^{E}_{m,2}$	$\bar{K}^{E}_{s,m,1}$	$\bar{K}^{E}_{s,m,2}$	$\bar{K}^{E}_{s,m,1}$	$\bar{K}^{E}_{s,m,2}$	$\bar{K}^{E}_{s,m,1}$	$\bar{K}^{E}_{s,m,2}$	$\bar{K}^{E}_{s,m,1}$	$\bar{K}^{E}_{s,m,2}$
x_1	($cm^3\ mol^{-1}$)								TPa^{-1}							
2-methoxyaniline (1) + 2-phenylethanol (2)																
0.0000	−0.373	0.000	−0.447	0.000	−0.550	0.000	−0.651	0.000	−18.66	0.000	−24.92	0.000	−30.57	0.000	−37.35	0.000
0.0957	−0.330	−0.002	−0.371	−0.004	−0.422	−0.007	−0.471	−0.009	−18.38	−0.034	−21.26	−0.190	−24.38	−0.333	−26.44	−0.523
0.1852	−0.280	−0.010	−0.303	−0.015	−0.326	−0.022	−0.348	−0.030	−16.51	−0.352	−17.66	−0.783	−19.40	−1.166	−19.37	−1.659
0.2904	−0.216	−0.031	−0.228	−0.038	−0.236	−0.050	−0.244	−0.060	−13.22	−1.399	−13.50	−2.087	−14.45	−2.676	−13.79	−3.377
0.3921	−0.157	−0.064	−0.165	−0.072	−0.169	−0.083	−0.173	−0.092	−9.647	−3.261	−9.788	−4.010	−10.47	−4.613	−10.20	−5.219
0.4911	−0.105	−0.109	−0.112	−0.116	−0.117	−0.121	−0.123	−0.126	−6.362	−5.864	−6.656	−6.488	−7.286	−6.939	−7.683	−7.203
0.6027	−0.058	−0.169	−0.065	−0.174	−0.072	−0.173	−0.080	−0.170	−3.342	−9.50	−3.826	−9.90	−4.433	−10.14	−5.396	−9.972
0.7023	−0.029	−0.226	−0.034	−0.232	−0.042	−0.229	−0.050	−0.225	−1.477	−12.98	−1.987	−13.34	−2.500	−13.63	−3.561	−13.45
0.8005	−0.011	−0.277	−0.014	−0.291	−0.020	−0.298	−0.025	−0.306	−0.432	−16.10	−0.802	−16.91	−1.133	−17.81	−1.906	−18.51
0.8904	−0.002	−0.311	−0.004	−0.343	−0.006	−0.378	−0.009	−0.414	−0.052	−18.10	−0.212	−20.10	−0.346	−22.45	−0.679	−25.32
1.0000	0.000	−0.323	0.000	−0.398	0.000	−0.503	0.000	−0.614	0.000	−18.49	0.000	−23.58	0.000	−29.45	0.000	−37.70
2-methoxyaniline (1) + 2-chloroethanol (2)																
0.0000	−0.465	0.000	−0.544	0.000	−0.626	0.000	−0.712	0.000	−42.01	0.000	−58.96	0.000	−72.10	0.000	−88.87	0.000
0.1041	−0.371	−0.005	−0.409	−0.007	−0.451	−0.010	−0.490	−0.013	−35.06	−0.406	−41.21	−0.946	−52.08	−1.334	−52.55	−1.877
0.2448	−0.259	−0.029	−0.271	−0.036	−0.285	−0.044	−0.298	−0.052	−24.16	−2.749	−24.10	−4.491	−32.26	−5.801	−24.56	−7.533
0.3401	−0.194	−0.056	−0.199	−0.065	−0.207	−0.075	−0.215	−0.082	−17.04	−5.695	−16.07	−7.789	−22.59	−9.462	−14.76	−11.51
0.4623	−0.124	−0.103	−0.128	−0.110	−0.133	−0.119	−0.143	−0.121	−9.324	−10.86	−8.951	−12.51	−13.57	−14.08	−8.467	−15.62
0.5621	−0.080	−0.151	−0.084	−0.155	−0.089	−0.161	−0.101	−0.157	−4.664	−15.73	−5.156	−16.47	−8.408	−17.58	−6.031	−18.15
0.6825	−0.040	−0.217	−0.045	−0.219	−0.049	−0.223	−0.061	−0.217	−1.211	−21.33	−2.309	−21.11	−4.154	−21.70	−4.149	−21.26
0.7612	−0.022	−0.264	−0.026	−0.268	−0.029	−0.276	−0.038	−0.278	−1.133	−24.08	−1.189	−24.00	−2.289	−24.69	−2.949	−24.41
0.8484	−0.008	−0.317	−0.011	−0.333	−0.013	−0.352	−0.018	−0.377	−0.227	−25.46	−0.439	−27.08	−0.909	−28.80	−1.546	−30.32
0.9217	−0.002	−0.362	−0.003	−0.398	−0.004	−0.435	−0.005	−0.499	−0.131	−24.59	−0.111	−29.59	−0.242	−33.39	−0.512	−38.45
1.0000	0.000	−0.408	0.000	−0.480	0.000	−0.550	0.000	−0.679	0.000	−20.85	0.000	−32.27	0.000	−40.02	0.000	−51.80
2-methoxyaniline (1) + 2-aminoethanol (2)																
0.0000	−0.575	0.000	−0.610	0.000	−0.713	0.000	−0.794	0.000	−48.78	0.000	−62.35	0.000	−72.62	0.000	−81.08	0.000
0.0897	−0.439	−0.007	−0.463	−0.007	−0.516	−0.010	−0.562	−0.012	−45.57	−0.177	−51.29	−0.517	−58.03	−0.755	−59.90	−0.956
0.1649	−0.348	−0.020	−0.366	−0.022	−0.393	−0.028	−0.421	−0.033	−41.03	−0.852	−42.99	−1.727	−47.58	−2.347	−46.69	−2.863
0.2579	−0.260	−0.043	−0.272	−0.046	−0.283	−0.057	−0.298	−0.064	−34.08	−2.739	−33.86	−4.173	−36.61	−5.216	−34.65	−6.056
0.3519	−0.192	−0.071	−0.199	−0.076	−0.205	−0.087	−0.214	−0.095	−26.48	−6.092	−25.83	−7.694	−27.40	−8.919	−25.94	−9.85
0.4497	−0.137	−0.104	−0.142	−0.111	−0.147	−0.118	−0.156	−0.125	−18.83	−11.22	−18.68	−12.47	−19.53	−13.56	−19.27	−14.30
0.5507	−0.093	−0.144	−0.096	−0.152	−0.104	−0.152	−0.112	−0.156	−11.93	−18.13	−12.53	−18.63	−12.98	−19.32	−13.90	−19.67
0.6549	−0.058	−0.195	−0.059	−0.205	−0.068	−0.200	−0.076	−0.202	−6.383	−26.54	−7.468	−26.32	−7.716	−26.66	−9.264	−26.73
0.7626	−0.029	−0.264	−0.030	−0.276	−0.037	−0.277	−0.043	−0.286	−2.559	−35.78	−3.583	−35.78	−3.717	−36.42	−5.116	−36.92
0.8735	−0.009	−0.365	−0.009	−0.381	−0.013	−0.411	−0.015	−0.443	−0.549	−44.66	−1.035	−47.25	−1.086	−49.80	−1.730	−52.40
1.0000	0.000	−0.536	0.000	−0.557	0.000	−0.673	0.000	−0.767	0.000	−51.82	0.000	−62.68	0.000	−70.97	0.000	−79.54

Table 6. The values of $\bar{V}^{\circ}_{m,1}$, $V^{*}_{m,1}$, $\bar{V}^{\circ E}_{m,1}$, $\bar{V}^{\circ}_{m,2}$, $V^{*}_{m,2}$, $\bar{V}^{\circ E}_{m,2}$$\bar{K}^{\circ}_{s,m,1}$, $K^{*}_{s,m,1}$, $\bar{K}^{\circ E}_{s,m,1}$, $\bar{K}^{\circ}_{s,m,2}$, $K^{*}_{s,m,2}$ and $\bar{K}^{\circ E}_{s,m,2}$ of the components for 2-methoxyaniline with substituted ethanol of binary mixtures at T = (303.15–318.15) K.

	$\bar{V}^{\circ}_{m,1}$	$V^{*}_{m,1}$	$\bar{V}^{\circ E}_{m,1}$	$\bar{V}^{\circ}_{m,2}$	$V^{*}_{m,2}$	$\bar{V}^{\circ E}_{m,2}$	$\bar{K}^{\circ}_{s,m,1}$	$K^{*}_{s,m,1}$	$\bar{K}^{\circ E}_{s,m,1}$	$\bar{K}^{\circ}_{s,m,2}$	$K^{*}_{s,m,2}$	$\bar{K}^{\circ E}_{s,m,2}$
T (K)	($cm^3\ mol^{-1}$)						TPa^{-1}					
2-methoxyaniline(1) +2-phenylethanol(2)												
303.15	112.45	112.82	−0.373	120.35	120.67	−0.323	−14.60	4.061	−18.66	−13.26	5.235	−18.49
308.15	112.76	113.21	−0.447	120.74	121.13	−0.398	−20.76	4.167	−24.92	−18.16	5.412	−23.58
313.15	113.08	113.63	−0.550	121.07	121.57	−0.503	−26.30	4.264	−30.57	−23.86	5.581	−29.45
318.15	113.29	113.94	−0.651	121.43	122.05	−0.614	−32.99	4.361	−37.35	−31.95	5.748	−37.70
2-methoxyaniline(1) +2-chloroethanol(2)												
303.15	112.35	112.82	−0.465	67.14	67.54	−0.408	−37.94	4.061	−42.01	−17.71	3.142	−20.85
308.15	112.71	113.21	−0.544	67.38	67.93	−0.480	−54.80	4.167	−58.96	−29.03	3.240	−32.27
313.15	113.00	113.63	−0.626	67.80	68.33	−0.550	−67.83	4.264	−72.10	−36.67	3.353	−40.02
318.15	113.23	113.94	−0.712	68.09	68.77	−0.679	−84.51	4.361	−88.87	−48.33	3.469	−51.80
2-methoxyaniline(1) +2-aminoethanol(2)												
303.15	112.24	112.82	−0.575	60.02	60.55	−0.536	−44.72	4.061	−48.78	−49.75	2.065	−51.82
308.15	112.65	113.21	−0.610	60.24	60.79	−0.557	−58.18	4.167	−62.35	−60.56	2.119	−62.68
313.15	112.92	113.63	−0.713	60.36	61.05	−0.673	−68.35	4.264	−72.62	−68.80	2.173	−70.97
318.15	113.15	113.94	−0.794	60.56	61.32	−0.767	−76.72	4.361	−81.08	−77.30	2.236	−79.54

a deciding role for sign and magnitude of excess volumes for 2-methoxyaniline + substituted ethanols.

5. FT-IR studies

FT-IR spectra support the formation of intermolecular hydrogen bonding (Hydroxyl group of substituted combinations and the nitrogen atom of the amino group) between unlike molecules for all the binary combinations, which are under investigation. Figures 8–10 show the broadband occurs at 3462.32 cm^{-1} (2-methoxyaniline + 2-chloroethanol); 3463.21 cm^{-1} (2-methoxyaniline + 2-aminoethanol) and 3457cm^{-1} (2-methoxyaniline + 2-phenylethanol) binary mixtures, respectively, at 298.15 K.

Table 7. PFP interaction parameter χ_{12} and calculated values of the three contributions from the PFP theory with experimental excess molar volumes at $x_1 = 0.5$ at 303.15 K.

		Calculated contributions			V^E ($x = 0.5$) (cm^3 mol^{-1})		
Binary mixtures	χ_{12} (10^6)	Interactional (10^{-8})	Free volume	P^* effect	EXP	PFP	δ (cm^3 mol^{-1})
2-methoxyaniline + 2-phenylethanol	−22.93	0.9884	−0.0211	0.1406	−0.1071	−0.1071	0.0000
2-methoxyaniline + 2-chloroethanol	−8.924	0.8439	−0.0342	−0.0038	−0.1133	−0.1134	0.0001
2-methoxyaniline + 2-aminoethanol	−14.61	0.6759	−0.0160	−0.0037	−0.1185	−0.1186	−0.0001

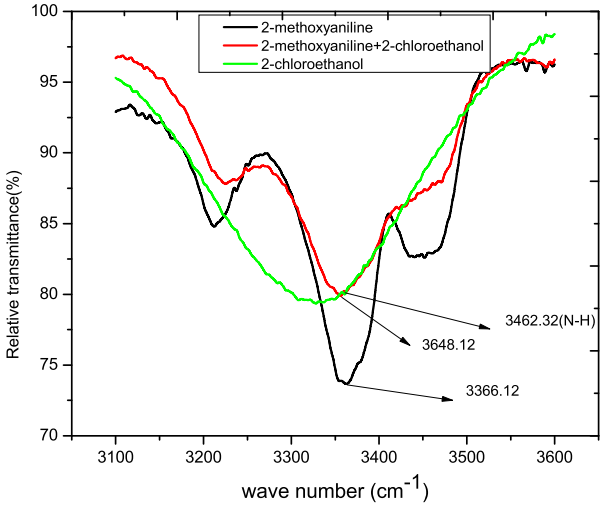

Figure 8. Experimental Fourier Transform Infrared spectra of pure 2-methoxyaniline (black), 2-chloroethanol (green) and 2-methoxyaniline+2-chloroethanol (red) in the ratio 1:1.

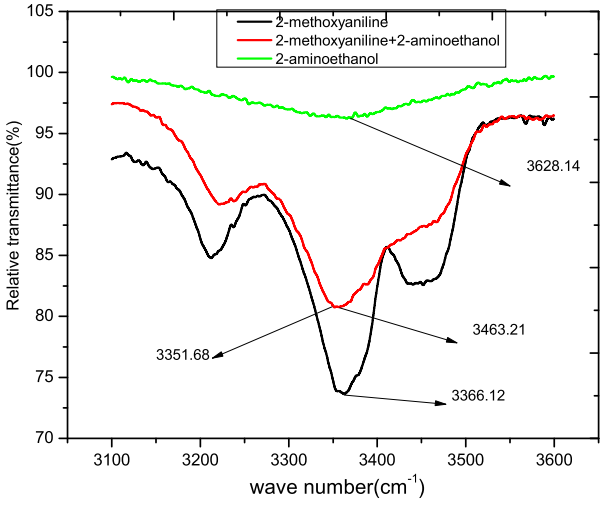

Figure 9. Experimental Fourier Transform Infrared spectra of pure 2-methoxyaniline (black), 2-aminoethanol (green) and 2-methoxyaniline+2-aminoethanol (red) in the ratio 1:1.

6. Conclusion

From the obtained data, various physicochemical parameters, viz., V^E_m, κ^E_s and $\Delta\eta$ of the combinations, the excess partial molar properties ($\overline{V}^E_{m,1}$, $\overline{V}^E_{m,2}$, $\overline{K}^E_{s,m,1}$ and $\overline{K}^E_{s,m,2}$) and excess partial molar properties at infinite dilution ($\overline{V}^{\circ E}_{m,1}$, $\overline{V}^{\circ E}_{m,2}$, $\overline{K}^{\circ E}_{s,m,1}$ and $\overline{K}^{\circ E}_{s,m,2}$) of components have been computed. The molecular interactions between Nitrogen of 2-methoxyaniline and the hydroxyl group of substituted ethanols for the investigated

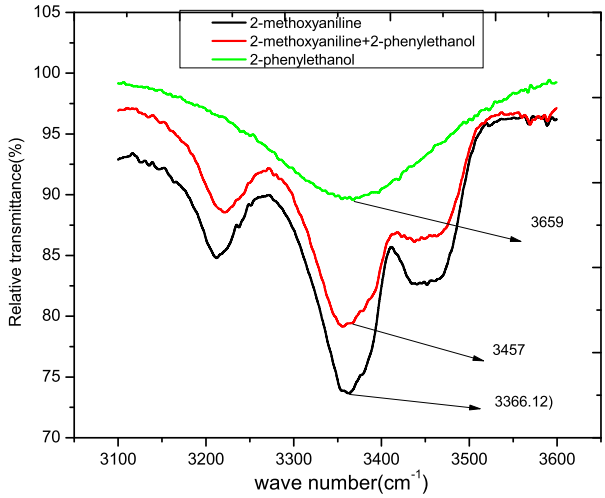

Figure 10. Experimental Fourier Transform Infrared spectra of pure 2-methoxyaniline (black), 2-Phenylethanol (green) and 2-methoxyaniline+2-phenylethanol (red) in the ratio 1:1.

binary combinations were confirmed by FT-IR. From the excess properties 2-methoxyaniline with 2-aminoethanol is more interactive than other two combinations due to steric hindrance and hydrogen bond and it was supported by FT-IR.

Disclosure statement

No potential conflict of interest was reported by the authors.

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