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Thermodyanmic Properties of Binary Liquid Mixtures of Industrially important Acrylic Esters with Octane-1-Ol at Different Temperatures

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ABSTRACT

Densities, viscosities and ultrasonic velocities of binary liquid mixtures of octane-1-ol with methyl acrylate, ethyl acrylate, butyl acrylate and methyl methacrylate at 303.15 and 313.15 K temperatures have been measured over the entire range of composition. These values used in Jouyban-Acree model. Excess molar volume, deviation in viscosity and deviation in isentropic compressibility have been calculated and were fitted to Redlich-Kister equation to estimate the coefficients and their corresponding standard errors. The mixture viscosities were correlated by different semi empirical equations like Hind, Choudhary-Katti, Grunberg-Nissan, Tamura-Kurata, McAllister three and four body models.

Keywords: Octane-1-ol + acrylic esters, transport properties, excess molar volume, isentropic compressibility, Redlich-Kister equation.

INTRODUCTION

In the recent years much importance has been given to the behavior of mixed solvents rather than a single solvent because of their wide range of applications in many chemical industrial and biological processes. The physicochemical data are often required in many industrial processes like flow, mass transfer or heat transfer calculations, polymerization, solvolysis, etc. and this also leads to the formulations of a large no. of methods for correlating or predicting the physical property, composition data. Therefore in view of practical importance of mixed solvents, a deeper knowledge of their solution structure and intermolecular interactions between component molecules at molecular level thus becomes essential. The composition and temperature dependence of volumetric, acoustic transport and surface properties of associated liquid system provides substantial information of the molecular influence on the intensity of the intermolecular interactions among component molecules and can be used as a powerful tool for studying intermolecular interactions in these systems. Literature survey reveals that such type of combined study of these parameters of binary liquid systems of octane-1-ol with acrylic esters at 303.15 and 313.15 K temperatures has not been done[1-8].

MATERIALS AND METHODS

Chemicals used in the present study were AR grade and supplied by S.D. Fine Chemicals Pvt., Mumbai (India). Prior to use all liquids were stored over 0.4 nm molecular sieves to reduce the water content and were degassed. In addition, all four acrylic esters were distilled before use. The binary mixtures of varying composition were prepared by mass in special air-tight bottles. The masses were recorded on a Mettlar one pan balance, which can read up to fifth place of decimal , with an accuracy of ± 0.01 mg. Care was taken to avoid evaporation and contamination during mixing. The estimated uncertainty in mole fraction was $<1\times10^{-4}$.

The densities[9] of the solutions were measured using a single capillary pycnometer made up of borosil glass with a bulb of $8cm^3$ and capillary with internal diameter of 0.1cm was chosen for present work. The reproducibility of density measurement was ± $5x10^{-5}$ g/cm^3.The dynamic viscosities [9] were measured using an Ubbelohde suspended level viscometer calibrated with conductivity water. An electronic digital stop watch with readability of ± 0.01 s was used for the flow time measurements. The uncertainty in dynamic viscosities was ± $3x10^{-3}$ mPa.s. The ultrasonic velocities[9] were measured at a frequency of 2 MHz by a single crystal ultrasonic interferometer (model F-81 Mittal's Enterprises, New Delhi). Error in velocity measurements was ± 0.1 %.

Theory and calculations

Experimental values of densities (ρ), viscosities (η) and ultrasonic velocity (u) of these mixtures at T= (303.15 and 313.15) K as a function of acrylic esters mole fraction are listed in Table 2.The excess molar volumes, V^E were calculated as,

$$V^E(cm^3/\text{ mol }) = [x_1M_1+x_2M_2]/\rho_{12} - [(x_1M_1/\rho_1)+(x_2M_2/\rho_2)] \quad (1)$$

where ρ_{12} is the density of the mixture and x_1, M_1, ρ_1, and x_2, M_2, ρ_2 are the mole fraction, the molecular weight, and the density of pure components 1and 2, respectively.

The viscosity deviations ($\Delta\eta$) were calculated using equation,

$$\Delta\eta \text{ (mPa.s)} = \eta_{12} - x_1\eta_1 - x_2\eta_2 \quad (2)$$

where η_{12} is the viscosity of the mixture and x_1, x_2 and η_1, η_2 are the mole fraction and the viscosity of pure components 1and 2 respectively[10].The excess isentropic compressibility,κ_s^E, were obtained using the relation,

$$\kappa_s^E \text{ (TPa}^{-1}) = \kappa_s - \kappa_s^{id} \quad (3)$$

Where, κ_s is the isentropic compressibility and was calculated using the Laplace relation,

$$\kappa_s = (1/ u^2\rho) \quad (4)$$

and κ_s^{id} was calculated from the relation,

$$\kappa_s^{id} = \sum \phi i[\kappa_{s,i} + TV^o_i(\alpha^{o,2}_i)/C_{p,i}] - [T(\sum x_iV^o_i)(\sum \phi_i \alpha^o_i)^2 / \sum x_iC_{p,i}] \quad (5)$$

Where, ϕ_i is the ideal state volume fraction of the component i in the mixture stated and is defined by the relation ,

$$\phi_{i=} x_iV^o_i / (\sum x_iV^o_i) \quad (6)$$

T is the temperature, and $\kappa_{s,i}$, V^o_i, α^o_i, and $C_{p,i}$ are the isentropic compressibility, molar volume, coefficient of isobaric thermal expansion, and molar heat capacity respectively, for pure component i. α^o_i is calculated from the measured densities by the relation,

$$\alpha = [(\rho_1/ \rho_2)-1]/ (T_2-T_1) \quad (7)$$

The other required values were taken from literature[11,12]. The excess molar volume, deviation in viscosity and deviation in isentropic compressibility for binary liquid mixtures of acrylic esters with octane-1-ol are listed in Table-3.

The excess molar volumes, deviations in viscosity and isentropic compressibility were fitted to Redlich- Kister equation of the type,

$$Y = x_1x_2 \sum_i^n a_i (x_1 - x_2)^i \quad (8)$$

Where Y is either V^E or $\Delta\eta$ or κ_s^E and n is the degree of polynomial. Coefficient a_i was obtained by fitting Eq (8) to experimental results using a least-squares regression method. In each case, the optimum number of coefficients is ascertained from an examination of the variation in standard deviation (σ).

σ was calculated using the relation,

$$\sigma(Y) = \left[\frac{\sum (Y_{exp\,t} - Y_{calc})^2}{N-n}\right]^{1/2} \quad (9)$$

Where N is the number of data points and n is the number of coefficients[11].The calculated values of the coefficients a_i along with the standard deviations (σ) are given in Table 4.

Several relations have been proposed to evaluate the dynamic viscosity η of liquid mixtures [13]. The equations of Hind, Choudhary-Katti, Grunberg-Nissan and Tamura-Kurata have one adjustable parameter. The expression for Hind equation is,

$$\eta_{12} = x_1^2\eta_1 + x_2^2\eta_2 + 2x_1x_2H_{12} \quad (10)$$

Where, H_{12} is the interaction parameter.

The expression for Choudhary-Katti equation is,

$$\ln(\eta_n V_m) = x_1\ln(\eta_1V_1) + x_2\ln(\eta_2V_2) + x_1x_2[Wvis/(_{RT})] \quad (11)$$

Where, Wvis is the interaction energy for activation of viscous flow.

The expression for Grunberg-Nissan equation is,

$$\ln \eta_{12=} x_1 \ln \eta_1 + x_2 \ln \eta_2 + x_1x_2G_{12} \quad (12)$$

Where, G_{12} is a parameter proportional to the interchange energy.

Tamura and Kurata developed expression for viscosity of binary mixtures as,

$$\eta = x_1\phi_1\,\eta_1 + x_2\phi_2\,\eta_2 + 2(x_1x_2\phi_1\phi_2)^{1/2}T_{12} \quad (13)$$

Where, T_{12} is the interaction parameter , ϕ_1 and ϕ_2 are the volume fractions. The calculated values of adjustable parameters $H_{12,}$ Wvis, G_{12} and T_{12} with their standard deviations (σ) calculated using equation (16) are given in Table 5.

Table-1: Densities, ρ, Viscosities, η, Ultrasonic Velocities, u, for Pure Components at T= (303.15 and 313.15) K.

	T=303.15K		T=313.15K	
	Expt.	Lit.	Expt	Lit.
Octane-1-ol				
ρ (g/m^3)	0.81839	0.81817[16]	0.81100	0.81117[16]
η (mPa.s)	6.430	---	4.572	---
u (m/s)	1333	1332[17]	1304	---
Methyl Acrylate				
ρ (g/m^3)	0.9413	---	0.9292	---
η (mPa.s)	0.420	---	0.361	---
u (m/s)	1163	---	1118	---
Ethyl Acrylate				
ρ (g/m^3)	0.9095	---	0.8972	---
η (mPa.s)	0.487	---	0.425	---
u (m/s)	1152	---	1123	---
Butyl Acrylate				
ρ (g/m^3)	0.89000	---	0.8817	---
η (mPa.s)	0.737	---	0.636	---
u (m/s)	1190	---	1157	---
Methyl Methacrylate				
ρ (g/m^3)	0.93172	0.93174[18]	0.92024	0.92026[18]
η (mPa.s)	0.549	---	0.479	---
u (m/s)	1168	---	1139	---

McAllister's multibody interaction model was widely used to correlate kinematic viscosity (υ) data. The two parameter McAllister equation based on Eyring's theory of absolute reaction rates, taken into account interactions of both like and unlike molecules by a two dimensional three body model. The three body model was defined by the relation,

$$\ln \nu = x_1^3 \ln \nu_1 + x_2^3 \ln \nu_2 + 3x_1^2 x_2 \ln Z_{12} + 3x_1 x_2^2 \ln Z_{21} - \ln [x_1 + (x_2M_2/M_1)] + 3x_1^2 x_2 \ln[(2/3) + (M_2/3M_1)] + 3x_1x_2^2 \ln[(1/3) + (2M_2/3M_1)] + x_2^3 \ln(M_2/M_1) \quad (14)$$

Similarly, the four body model was defined by the relation,

$$\ln \nu = x_1^4 \ln \nu_1 + 4x_1^3x_2 \ln Z_{1112} + 6x_1^2x_2^2 \ln Z_{1122} + 4x_1x_2^3 \ln Z_{2221} + x_2^4 \ln \nu_2 - \ln [x_1 + x_2 (M_2/M_1)] + 4x_1^3x_2 \ln [(3 + M_2/M_1)/4] + 6x_1^2 2x_2^2 \ln[1 + M_2/M_1)/2] + 4x_1x_2^3 \ln [(1 + 3M_2/M_1)/4] + x_2^4 \ln (M_2/M_1) \quad (15)$$

Where Z_{12}, Z_{21}, Z_{1112}, Z_{1122} and Z_{2221} are model parameters and M_i and ν_i are the molecular mass and kinematic viscosity of pure component i.

To perform a numerical comparison of the correlating capability of above Eq (10 to 15) we have calculated the standard percentage deviation (σ %) using the relation,

$$\sigma\ \% = [1/(\eta_{expt} - k) \times \sum (100\,(\eta_{expt} - \eta_{cal}) / \eta_{expt})^2]^{1/2} \quad (16)$$

where k represents the number of numerical coefficients in the respective equations. These parameters estimated by a non-linear regression analysis based on a least-squares method and presented with their standard percentage deviation (σ %) in Table 6.

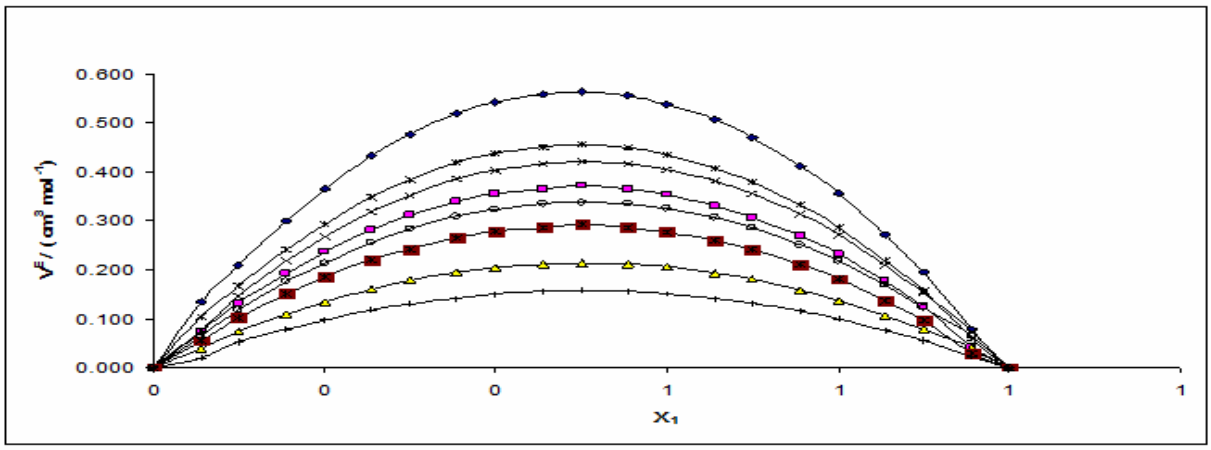

Fig.-1: Variation of excess molar volumes for binary mixtures of Acrylic esters (1)+ Octane-1-ol (2) at 303.15 K:♦, Methyl acrylate; ▪,Ethyl acrylate; ▲, Butyl acrylate; ×, Methyl methacrylate and at 313.15 K: ∗, Methyl acrylate; ■,Ethyl acrylate; +, Butyl acrylate; ○ , Methyl methacrylate

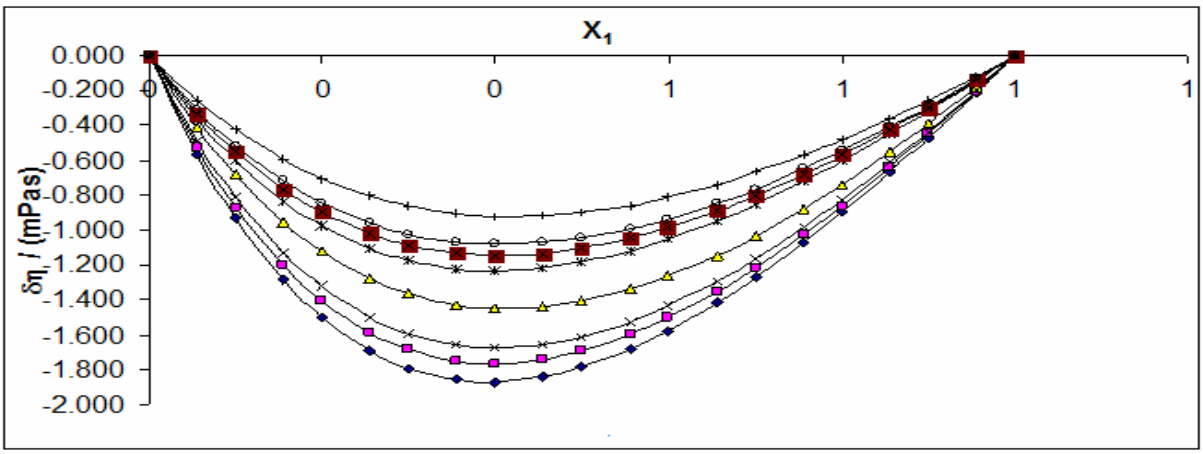

Fig.-2:Variation of deviation in viscosity for binary mixtures of Acrylic esters (1)+ Octane-1-ol (2) at 303.15 K:♦, Methyl acrylate; ▪,Ethyl acrylate; ▲, Butyl acrylate; ×, Methyl methacrylate and at 313.15 K: ∗, Methyl acrylate; ■,Ethyl acrylate; +, Butyl acrylate; ○ , Methyl methacrylate

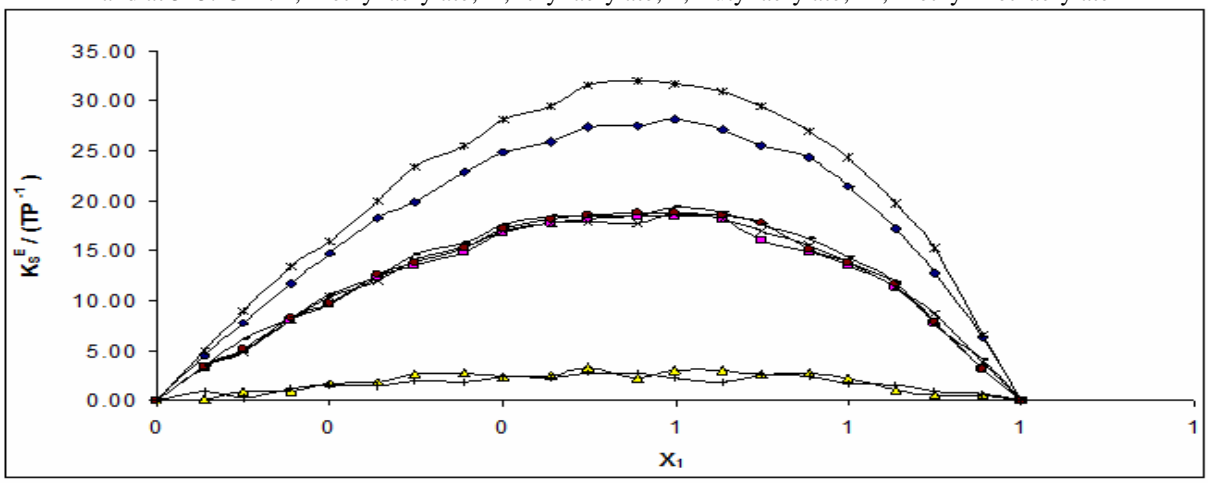

Fig.-3: Variation of deviation in isentropic compressibility for binary mixtures of Acrylic esters (1) + Octane-1-ol (2) at 303.15 K:♦, Methyl acrylate; ▪,Ethyl acrylate;▲, Butyl acrylate; ×, Methyl methacrylate and at 313.15 K: ∗, Methyl acrylate; ■,Ethyl acrylate ; +, Butyl acrylate; ○ , Methyl methacrylate

Table-2: Densities, ρ, Viscosities, η, Ultrasonic Velocities, u, for Acrylic esters (1) + Octane-1-ol (2) at T= (303.15 and 313.15) K

	T=303.15K			T=313.15K		
	ρ	η	u	ρ	η	u
x_1	(g/cm^3)	(mPa.s)	(m/s)	(g/cm^3)	(mPa.s)	(m/s)
MA (1) + Octane-1-ol (2)						
0	0.81839	6.430	1333	0.81100	4.572	1304
0.0552	0.82167	5.531	1323	0.81431	3.974	1293
0.0997	0.82461	4.899	1315	0.81720	3.550	1284
0.1553	0.82846	4.208	1305	0.82101	3.082	1273
0.1997	0.83172	3.729	1297	0.82423	2.753	1265
0.2554	0.83608	3.203	1287	0.82851	2.391	1254
0.2991	0.83972	2.843	1280	0.83207	2.140	1245
0.3550	0.84469	2.440	1270	0.83693	1.856	1235
0.3999	0.84894	2.159	1262	0.84106	1.656	1226
0.4554	0.85456	1.856	1253	0.84652	1.438	1216
0.4998	0.85937	1.644	1245	0.85117	1.285	1207
0.5555	0.86581	1.412	1236	0.85739	1.116	1197
0.5999	0.87133	1.251	1228	0.86269	0.997	1189
0.6554	0.87871	1.075	1219	0.86979	0.866	1179
0.6999	0.88507	0.952	1212	0.87588	0.773	1171
0.7556	0.89362	0.818	1202	0.88405	0.671	1161
0.7998	0.90097	0.725	1195	0.89104	0.600	1153
0.8554	0.91091	0.623	1186	0.90050	0.521	1143
0.8999	0.91954	0.552	1179	0.90866	0.465	1135
0.9555	0.93130	0.474	1170	0.91980	0.404	1126
1	0.94130	0.420	1163	0.92920	0.361	1118
EA (1) + Octane-1-ol (2)						
0	0.81839	6.430	1333	0.81100	4.572	1304
0.0555	0.82155	5.572	1322	0.81410	4.007	1293
0.0999	0.82417	4.969	1314	0.81663	3.606	1285
0.1555	0.82762	4.305	1303	0.81997	3.160	1274
0.1998	0.83049	3.840	1295	0.82273	2.844	1266
0.2556	0.83427	3.325	1284	0.82637	2.491	1255
0.2997	0.83740	2.966	1276	0.82938	2.243	1247
0.3551	0.84151	2.572	1266	0.83331	1.967	1237
0.3999	0.84499	2.290	1257	0.83664	1.768	1228
0.4551	0.84948	1.987	1247	0.84091	1.551	1218
0.4998	0.85327	1.770	1239	0.84451	1.395	1210
0.5555	0.85827	1.533	1229	0.84925	1.222	1200
0.5998	0.86242	1.367	1221	0.85318	1.099	1192
0.6550	0.86785	1.186	1211	0.85830	0.964	1182
0.6999	0.87249	1.056	1204	0.86267	0.867	1174
0.7555	0.87853	0.915	1194	0.86833	0.759	1165
0.7998	0.88358	0.816	1186	0.87307	0.684	1157

0.8554	0.89027	0.707	1176	0.87932	0.599	1147
0.8999	0.89590	0.630	1169	0.88456	0.539	1140
0.9550	0.90334	0.547	1160	0.89149	0.473	1131
1	0.90950	0.487	1152	0.89720	0.425	1123
BA (1) + Octane-1-ol (2)						
0	0.81839	6.430	1333	0.81100	4.572	1304
0.0552	0.82179	5.705	1325	0.81444	4.100	1295
0.0998	0.82453	5.179	1318	0.81718	3.755	1289
0.1555	0.82804	4.591	1310	0.82068	3.364	1280
0.1999	0.83088	4.169	1303	0.82353	3.082	1273
0.2554	0.83449	3.697	1295	0.82713	2.762	1265
0.2999	0.83743	3.357	1288	0.83006	2.530	1258
0.3554	0.84116	2.977	1280	0.83377	2.268	1250
0.3998	0.84419	2.704	1274	0.83678	2.077	1243
0.4556	0.84807	2.396	1266	0.84062	1.861	1235
0.5000	0.85121	2.176	1259	0.84371	1.705	1228
0.5551	0.85517	1.931	1252	0.84763	1.529	1220
0.5998	0.85843	1.753	1245	0.85063	1.400	1214
0.6554	0.86256	1.554	1237	0.85492	1.255	1206
0.7000	0.86593	1.411	1231	0.85823	1.149	1199
0.7554	0.87019	1.252	1223	0.86240	1.030	1191
0.8000	0.87368	1.136	1217	0.86581	0.943	1185
0.8554	0.87809	1.008	1210	0.87012	0.846	1177
0.8999	0.88168	0.915	1204	0.87363	0.775	1171
0.9555	0.88624	0.811	1196	0.87810	0.694	1163
1	0.89000	0.737	1190	0.88170	0.636	1157
MMA (1) + Octane-1-ol (2)						
0	0.81839	6.430	1333	0.81100	4.572	1304
0.0555	0.82231	5.610	1323	0.81484	4.034	1294
0.0999	0.82550	5.029	1316	0.81801	3.650	1286
0.1555	0.82973	4.386	1306	0.82217	3.219	1277
0.1998	0.83324	3.933	1298	0.82563	2.913	1269
0.2556	0.83789	3.428	1289	0.83017	2.569	1260
0.2997	0.84174	3.075	1281	0.83393	2.325	1252
0.3551	0.84679	2.684	1272	0.83887	2.052	1243
0.3999	0.85109	2.403	1264	0.84303	1.854	1235
0.4551	0.85662	2.098	1255	0.84840	1.637	1226
0.4998	0.86132	1.880	1248	0.85295	1.480	1219
0.5555	0.86749	1.639	1239	0.85891	1.305	1210
0.5998	0.87264	1.469	1231	0.86387	1.181	1202
0.6550	0.87938	1.283	1222	0.87035	1.043	1193
0.6999	0.88516	1.148	1215	0.87590	0.942	1186
0.7555	0.89268	1.002	1206	0.88310	0.831	1177
0.7998	0.89901	0.898	1199	0.88915	0.752	1170
0.8554	0.90738	0.783	1190	0.89712	0.664	1161
0.8999	0.91445	0.702	1183	0.90385	0.600	1155
0.9550	0.92369	0.613	1175	0.91260	0.530	1146
1	0.93172	0.549	1168	0.92024	0.479	1139

Table-3: Excess Molar Volumes, V^E, Viscosity Deviation, $\Delta\eta$, and Deviation in Isentropic Compressibilities, κ_s^E, of Acrylic esters (1) + Octane-1-ol (2) at T= (303.15 and 313.15) K

	T=303.15K			T=313.15K		
x_1	V^E (cm^3/mol)	?η (mPa.s)	κ_s^E (TPa^{-1})	V^E (cm^3/mol)	?η (mPa.s)	κ_s^E (TPa^{-1})
MA (1) + Octane-1-ol (2)						
0	0.000	0.000	0.00	0.000	0.000	0.00
0.0552	0.135	-0.568	4.47	0.105	-0.366	4.96
0.0997	0.209	-0.932	7.77	0.168	-0.603	8.93
0.1553	0.301	-1.288	11.76	0.242	-0.836	13.44
0.1997	0.365	-1.501	14.78	0.294	-0.978	15.91
0.2554	0.432	-1.692	18.33	0.349	-1.106	19.97
0.2991	0.476	-1.790	19.93	0.384	-1.173	23.37
0.3550	0.518	-1.856	22.83	0.418	-1.221	25.49
0.3999	0.542	-1.867	24.87	0.438	-1.232	28.16
0.4554	0.559	-1.837	25.92	0.451	-1.216	29.53
0.4998	0.562	-1.782	27.39	0.455	-1.182	31.61
0.5555	0.555	-1.679	27.49	0.448	-1.117	31.95
0.5999	0.538	-1.574	28.14	0.435	-1.049	31.77
0.6554	0.506	-1.416	27.13	0.408	-0.946	30.87
0.6999	0.469	-1.271	25.49	0.379	-0.851	29.52
0.7556	0.412	-1.071	24.31	0.332	-0.719	26.99
0.7998	0.355	-0.898	21.46	0.286	-0.604	24.29
0.8554	0.273	-0.666	17.25	0.219	-0.449	19.78
0.8999	0.196	-0.470	12.76	0.157	-0.317	15.24
0.9555	0.080	-0.213	6.29	0.060	-0.144	6.63
1	0.000	0.000	0.00	0.000	0.000	0.00
EA (1) + Octane-1-ol (2)						
0	0.000	0.000	0.00	0.000	0.000	0.00
0.0555	0.075	-0.528	3.30	0.055	-0.335	3.36
0.0999	0.133	-0.868	5.03	0.103	-0.552	5.09
0.1555	0.194	-1.201	8.09	0.151	-0.767	8.25
0.1998	0.237	-1.403	9.59	0.185	-0.899	9.76
0.2556	0.281	-1.586	12.35	0.220	-1.021	12.61
0.2997	0.311	-1.682	13.59	0.243	-1.086	13.86
0.3551	0.339	-1.748	14.92	0.266	-1.133	15.20
0.3999	0.355	-1.763	16.88	0.278	-1.146	17.25
0.4551	0.366	-1.739	17.79	0.287	-1.134	18.19
0.4998	0.371	-1.690	18.21	0.292	-1.105	18.61
0.5555	0.364	-1.596	18.41	0.285	-1.047	18.82
0.5998	0.353	-1.498	18.41	0.277	-0.985	18.82
0.6550	0.331	-1.352	18.10	0.260	-0.891	18.54
0.6999	0.307	-1.214	16.04	0.241	-0.803	17.78

0.7555	0.269	-1.025	14.81	0.211	-0.679	15.13
0.7998	0.232	-0.861	13.52	0.181	-0.572	13.84
0.8554	0.177	-0.639	11.35	0.138	-0.426	11.66
0.8999	0.126	-0.452	7.78	0.098	-0.301	7.96
0.9550	0.043	-0.208	3.17	0.030	-0.139	3.21
1	0.000	0.000	0.00	0.000	0.000	0.00
BA (1) + Octane-1-ol (2)						
0	0.000	0.000	0.00	0.000	0.000	0.00
0.0552	0.039	-0.411	0.14	0.022	-0.255	0.87
0.0998	0.075	-0.682	0.86	0.053	-0.424	0.22
0.1555	0.110	-0.954	0.96	0.080	-0.596	1.13
0.1999	0.135	-1.122	1.70	0.098	-0.703	1.64
0.2554	0.161	-1.279	1.83	0.118	-0.804	1.44
0.2999	0.178	-1.365	2.59	0.131	-0.861	1.99
0.3554	0.195	-1.430	2.72	0.143	-0.905	1.79
0.3998	0.205	-1.450	2.37	0.151	-0.921	2.40
0.4556	0.212	-1.440	2.45	0.156	-0.918	2.18
0.5000	0.214	-1.407	3.24	0.159	-0.899	2.82
0.5551	0.211	-1.338	2.23	0.156	-0.858	2.72
0.5998	0.206	-1.262	2.99	0.151	-0.811	2.22
0.6554	0.194	-1.145	3.08	0.142	-0.738	1.84
0.7000	0.181	-1.034	2.65	0.132	-0.668	2.50
0.7554	0.159	-0.878	2.74	0.116	-0.569	2.39
0.8000	0.138	-0.740	2.26	0.100	-0.480	1.69
0.8554	0.107	-0.553	1.05	0.077	-0.360	1.56
0.8999	0.079	-0.392	0.55	0.056	-0.256	0.87
0.9555	0.041	-0.179	0.57	0.023	-0.117	0.69
1	0.000	0.000	0.00	0.000	0.000	0.00
MMA (1) + Octane-1-ol (2)						
0	0.000	0.000	0.00	0.000	0.000	0.00
0.0555	0.077	-0.494	3.28	0.065	-0.311	3.47
0.0999	0.147	-0.814	4.89	0.119	-0.514	6.19
0.1555	0.218	-1.130	7.98	0.176	-0.716	8.24
0.1998	0.267	-1.322	10.37	0.214	-0.841	10.71
0.2556	0.318	-1.499	11.99	0.256	-0.957	12.37
0.2997	0.352	-1.592	14.09	0.283	-1.026	14.57
0.3551	0.385	-1.658	15.36	0.309	-1.067	15.85
0.3999	0.403	-1.675	16.99	0.324	-1.081	17.58
0.4551	0.417	-1.656	17.79	0.335	-1.072	18.39
0.4998	0.422	-1.611	17.85	0.338	-1.046	18.44
0.5555	0.416	-1.524	17.70	0.334	-0.993	18.49
0.5998	0.405	-1.433	18.72	0.325	-0.936	19.38
0.6550	0.381	-1.295	18.20	0.306	-0.848	18.86
0.6999	0.355	-1.165	17.02	0.285	-0.765	17.63
0.7555	0.313	-0.985	15.57	0.252	-0.648	16.13
0.7998	0.271	-0.828	13.80	0.218	-0.546	14.30
0.8554	0.210	-0.616	11.34	0.170	-0.407	11.79
0.8999	0.153	-0.436	8.65	0.124	-0.289	7.57
0.9550	0.075	-0.201	3.88	0.064	-0.133	4.04
1	0.000	0.000	0.00	0.000	0.000	0.00

Table-4: Adjustable parameters of Eq 8 and 9 for the Mathematical Representation of Excess Functions for binary liquid mixture of Acrylic esters (1) + Octane-1-ol (2) at *T*= (303.15 and 313.15) K.

	T/K	a_0	a_1	a_2	a_3	a_4	σ
			MA (1) + Octane-1-ol (2)				
V^E (cm^3/mol)	303.15	2.2495	0.1126	0.0608	-0.5091	-0.0816	0.00651
	313.15	1.8101	0.0968	0.1656	-0.4347	-0.3206	0.00588
?η (mPa.s)	303.15	-7.1280	3.0487	-0.9993	0.2789	-0.0716	0.00086
	313.15	-4.7280	1.8956	-0.5784	0.1503	-0.0428	0.00038
κ_s^E (TPa^{-1})	303.15	55.6792	19.9947	10.7155	-0.4940	-6.7800	0.30184
	313.15	50.2946	24.7041	16.5109	-10.0695	-19.6878	0.50731
			EA (1) + Octane-1-ol (2)				
V^E (cm^3/mol)	303.15	1.4569	0.0788	0.3415	-0.3124	-0.7171	0.00610
	313.15	1.1351	0.0608	0.3880	-0.2331	-0.8226	0.00608
?η (mPa.s)	303.15	-6.7595	2.7379	-0.8213	0.2478	-0.1042	0.00152
	313.15	-4.4185	1.6673	-0.4852	0.1270	-0.0280	0.00035
κ_s^E (TPa^{-1})	303.15	20.6700	15.0321	8.5597	-16.6656	-17.0842	0.53408
	313.15	16.7804	17.3854	10.7335	-20.9443	-21.6551	0.49086
			BA (1) + Octane-1-ol (2)				
V^E (cm^3/mol)	303.15	0.8583	-0.0440	-0.0344	0.1775	0.0309	0.00245
	313.15	0.6467	0.0100	0.0466	0.0462	-0.2703	0.01019
?η (mPa.s)	303.15	-5.6295	1.9596	-0.5149	0.1020	-0.0322	0.00032
	313.15	-3.5972	1.1459	-0.2707	0.0511	-0.0200	0.00032
κ_s^E (TPa^{-1})	303.15	1.0922	0.4505	0.6208	2.7882	-7.8360	0.38007
	313.15	-1.7028	3.0576	-10.2990	-3.0412	18.0690	0.36125
			MMA (1) + Octane-1-ol (2)				
V^E (cm^3/mol)	303.15	1.6793	-0.0495	0.0942	0.2187	-0.2158	0.00296
	313.15	1.3558	-0.0386	-0.0485	0.1795	0.0914	0.00211
?η (mPa.s)	303.15	-6.4434	2.5176	-0.7596	0.1771	-0.0305	0.00032
	313.15	-4.1853	1.5073	-0.4044	0.0956	-0.0336	0.00029
κ_s^E (TPa^{-1})	303.15	34.1226	14.2405	8.1813	-3.6224	-6.3419	0.36718
	313.15	32.0064	14.6241	4.8100	-11.6817	-1.5409	0.41583

Table-5: Adjustable parameters of Eq 10,11,12,13 and 16 for binary liquid mixture Of Acrylic esters (1) + Octane-1-ol (2) at *T*= (303.15 and 313.15) K.

T/K	H_{12}	σ	Wvis	σ	G_{12}	σ	T_{12}	σ
				MA (1) + Octane-1-ol (2)				
303.15	-0.241	20.060	0.170	0.219	-0.001	0.029	-1.037	35.274
313.15	0.043	15.332	0.164	0.203	-0.001	0.034	-0.505	27.234
				EA (1) + Octane-1-ol (2)				
303.15	-0.007	16.319	0.078	0.062	-0.001	0.042	-0.534	24.559
313.15	0.240	11.952	0.074	0.067	-0.001	0.030	-0.121	18.293
				BA (1) + Octane-1-ol (2)				
303.15	0.717	8.509	0.009	0.022	-0.002	0.024	0.577	9.809
313.15	0.778	6.081	0.008	0.022	-0.001	0.022	0.682	7.084
				MMA (1) + Octane-1-ol (2)				
303.15	0.191	13.628	0.089	0.079	-0.001	0.028	-0.564	23.632
313.15	0.391	9.870	0.084	0.075	-0.001	0.026	0.014	15.723

Table-6: Adjustable parameters of Eq 14, 15 and 16 for binary liquid mixture of Acrylic esters (1) + Octane-1-ol (2) at *T*= (303.15 and 313.15) K.

T/K	Z_{12}	Z_{21}	σ	Z_{1112}	Z_{1122}	Z_{2221}	σ
MA (1) + Octane-1-ol (2)							
303.15	1.271	3.109	0.040	0.945	1.541	3.918	2.254
313.15	0.990	2.377	0.033	0.782	1.218	2.095	1.408
EA (1) + Octane-1-ol (2)							
303.15	1.338	3.262	0.037	1.063	1.815	4.060	2.592
313.15	1.103	2.504	0.030	0.892	1.444	3.065	0.436
BA (1) + Octane-1-ol (2)							
303.15	1.756	3.725	0.032	1.453	2.545	4.484	4.410
313.15	1.I434	2.850	0.025	1.207	2.009	3.377	1.489
MMA (1) + Octane-1-ol (2)							
303.15	1.432	3.376	0.025	1.145	1.912	4.165	2.926
313.15	1.179	2.593	0.024	0.960	1.519	3.146	0.650

Table-7: Adjustable parameters of Eq 17 and 18 for binary liquid mixture of Acrylic esters (1) + Octane-1-ol (2).

	a_0	a_1	a_2	a_3	a_4	σ	*APD*
	MA (1) + Octane-1-ol (2)						
ρ (g/m^3)	-25.3934	-6.5289	-2.0030	0.9314	0.7739	5.8324	0.0277
η (mPa.s)	-0.2148	-0.0834	1.9863	-1.2031	-4.0086	2.5560	0.0234
u (m/s)	-0.0601	-0.1279	1.0583	0.5760	-1.9151	1280.4161	0.0187
EA (1) + Octane-1-ol (2)							
ρ (g/m^3)	-13.1672	-2.3792	-1.2754	0.7580	1.9006	3.4139	0.0256
η (mPa.s)	-0.2022	-0.6441	-0.2167	0.6273	0.0166	2.6572	0.0193
u (m/s)	0.0034	-1.0261	-1.0136	2.5006	2.1942	1276.7302	0.0211
BA (1) + Octane-1-ol (2)							
ρ (g/m^3)	-3.1146	-0.0857	-0.0010	-0.2408	0.1134	1.4583	0.0133
η (mPa.s)	-0.5732	0.6859	3.6548	-2.4582	-6.0224	2.9404	0.0233
u (m/s)	-0.1109	0.0718	1.6022	-0.3290	-2.2271	1296.2600	0.0200
MMA (1) + Octane-1-ol (2)							
ρ (g/m^3)	-16.4802	-2.7146	-0.5244	-0.5479	0.0619	4.0617	0.0212
η (mPa.s)	-0.3227	0.3503	1.4463	-2.1352	-3.5058	2.7374	0.0183
u (m/s)	-0.0587	-0.5032	-0.1906	1.1101	-0.2039	1285.1033	0.0200

Recently Jouyban and Acree[14,15] proposed a model for correlating the density and viscosity of liquid mixtures at various temperatures. The proposed equation is,

$$\ln y_{mT} = f_1 \ln y_{1T} + f_2 \ln y_{2T} + f_1 f_2 \sum [A_j (f_1 - f_2)^j / T] \quad (17)$$

where y_{mT}, y_{1T} and y_{2T} is density or viscosity of the mixture and solvents 1 and 2 at temperature T, respectively, $f_1$and f_2 are the volume fractions of solvents in case of density, and mole fraction in case of viscosity, and Aj are the model constants. The Jouyban – Acree model was not previously applied to ultrasonic velocity measurements, we extend the Jouyban – Acree model Eq (17) to ultrasonic velocity of the liquid mixtures with f as the mole fraction and again apply Eq (18) for correlating ability of the model. The correlating ability of the Jouyban - Acree model was tested by calculating the average percentage deviation (APD) between the experimental and calculated density, viscosity and ultrasonic velocity as,

$$APD = (100/N) \sum [(| y_{expt} - y_{cal} |)/ y_{expt})] \quad (18)$$

Where N is the number of data points in each set. The optimum numbers of constants Aj, in each case, were determined from the examination of the average percentage deviation value. The constants Aj calculated from the least square analysis along with the average percentage deviation (APD) are presented in Table 7.

RESULTS AND DISCUSSION

Observed positive values of excess molar volume shown in fig. 1 due to rupture of hydrogen bonded associates of alkanols dominates over that of hydrogen bonding between unlike molecules. As the temperature increases V^E values increases three is decrease in the strength of interactions between the component molecules. Excess molar volumes can be considered as arising from three types of interactions between the component molecules namely; physical, chemical and geometrical type of molecular interactions. Positive values of excess molar volumes can be visualized as being due to a closer approach of unlike molecules having significantly different molecular size. Due to presence of nonpolar molecule like acrylic esters, existing hydrogen bonding in alcohol molecule breaks and system shows weak intermolecular interactions. Longer the chain length of acrylic esters, weaker will be interaction between liquid components.

Negative values of $\Delta\eta$ in fig. 2 over whole composition range suggests that, viscosities of associates formed between unlike molecules are relatively less than those of pure components, which is exhibited by decreased values of viscosity with mole fraction. This decrease in viscosity attributed to breaking of dipolar association of alcohol into small dipoles. Weak types of dipole- induced dipole type of interactions are not sufficient to produce bulky or less mobile entities in system and hence decreased trend of viscosity is observed in the present binary liquid mixture of acrylics esters with the octane-1-ol.

Deviation in isentropic compressibility in fig. 3 attributed to relative strength of effects which influenced free space, according to which positive κ_s arise due to breaking of hydrogen bonds in self associated alkanols and physical dipole-dipole interactions between alkane-1-ol monomers and multimer contribute to increase in free space, decrease in sound velocity and positive deviation in isentropic compressibility this effect will be counteracted by changes of free volume in real mixtures.

Table 5 shows that, out of all four different equations used to correlate experimental data of mixture viscosity standard deviation of G_{12} parameter of Grunberg-Nissan equation have lowest values among any other equations. Hence, this model is more convenient and fits well. Table 6 shows that, among two different models suggested by McAllister, the standard deviations of three body model are least and it is more convenient than the four body models.

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