Ultrasonic Study of Molecular Interactions in Binary Mixtures of Benzyl Benzoate with 2-alkaxyethanols at Various Temperatures

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ABSTRACT

Ultrasonic velocity, density and kinematic viscosity for the binary mixtures of benzyl benzoate with 2-methoxyethanol, 2-ethoxyethanol and 2-butoxyethanol measured experimentally over the entire composition range at constant temperatures 303.15, 313.15 and 323.15 K. Using this data calculated excess thermo dynamic parameters such as excess molar volume, excess free length, excess Gibbs activation energy, deviation in isentropic compressibility and deviation in kinematic viscosity. In the light of excess/deviation parameters estimated the molecular interaction between above binary mixtures. Excess molar volume, excess free length, deviation in isentropic compressibility and deviation in kinematic viscosity are fitted to Redlich-Kister polynomial equation of fourth order. An attempt is made to express the molecular interaction based on Partial molar volumes. In this study correlate the viscosities of binary liquid mixture of benzyl benzoate with 2-alkaxyethanols using equations Grunberg-Nissan (GN), Katti-Chowdary (KC), Tamura-Kurata (TK), Hind et al.(Hind), Auslander (Aus) and Jouyban–Acree (JA). The ultrasonic study reveals that the strength of molecular interactions at all the temperature follows the order BB+BE>BB+EE> BB+ME.

Key words:

Molecular interactions, alkoxyethanols, Binary mixtures and isentropic compressibility

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1.Introduction

Thermodynamic and physiochemical investigations play an important means and tools in understanding molecular interactions in liquids and liquid mixtures. These techniques are comparable to other techniques like FTIR, NMR and dielectric relaxation etc. Often liquid mixtures are used as channel for industrial and chemical process, because they provide wide range of properties. The knowledge of thermodynamic, excess thermodynamic and allied parameters play an essential role in understanding the nature and molecular interactions in between like and unlike molecules of liquid mixtures. The physical properties like ultrasonic velocity, density, viscosity, molar volume, isentropic compressibility, free length and their excess or deviation values gives an important information regarding the interactions in liquid mixtures.

In the present investigation an attempt is made to ultrasonic study of the benzyl benzoate in 2-alkaxyetahnols (2-methoxyethanol, 2-ethaxyethanol and 2-butoxyethanol) at three constant temperatures 303.15, 313.15 and 323.15 K. Benzyl benzoate is a corboxylate ester, which is used as to treat scabies and lice. It is used in widening of blood vessels, which decreases blood pleasure and spasmolytic effects (able to relieve spasm of smooth muscle) and present in many asthma and whooping cough drugs. Benzyl benzoate is used as a topical acaricide, scabicide and pediculicide inventory hospitals. It is also used as repellant of chiggers[1] and mosquitoes. All 2-alkaxyethanols are used as a solvent to varnishes, dyes, resins, greases, waxes, nitrocellulose and lacquers[2,3]. 2-methoxyethanol is used as a deicing solution to remove snow and frost from surfaces. 2-ethoxyethanol is useful property to dissolve chemical diverse compounds. 2-butoxyethanol is employed as ingredient in paint thinners, varnish removers, herbicides, cleaning products and inks.[4]Fire fighting foam, leather protectors and degreasers contain 2-butoxyethanol.

A survey of literature shows that behavior of benzyl benzoate has been studied ultrasonically with ethyl acetate[5], 1-butanol[6], dimethyl corbonate[7]etc. Rajalakshmi et al.[8], Jos Carlos et al.[9], Vankataramana et al.[10], Kemea Khega and team[11], Roy et al[12], Awasthi and Awasthi[13], Zareena Begam and her coworkers[14], Hui Guo et al.[15], Guganathan and Kumar[16], Sarkar & Roy[17] and Kinart and his team[18] studied molecular

interactions containing 2-alkoxyethanols (either 2-methoxy or 2-ethoxy or 2-butoxy) as one of the component in a binary mixture. But to the best of my knowledge there is no literature report on ultrasonic study of benzyl benzoate with 2-alakxyethanols.

In the present investigation is to study ultrasonically, experimentally measured ultrasonic velocity (u), density (ρ) and kinematic viscosity (η).Thermo dynamic parameters such as molar volume, free length, isentropic compressibility, specific acoustic impedance and their excess/deviation parameters are calculated using experimental measured parameters at three constant temperatures 303.15, 313.15 and 323.15 K of three binary mixtures. The excess/deviation parameters of all the binary mixtures are fitted with Redlich-Kister polynomial equation of 4th order.

2. Experimental

2.1 Materials

Benzyl benzoate, 2-methoxyethanol, 2-ethoxyethanol and 2-butoxyethanol are supplied by Loba Chemie Private Limited, Mumbai with purity 99%. These liquids are further purified up to 99.9% using distillation method and presented in Table 1 along with molecular formula, molecular weight, molecular structure and CAS number for comparing the purity of liquids.

2.2. Apparatus and procedure

Binary mixtures of Benzyl benzoate with 2-methoxyethanol (BB+ME), 2-ethoxyethanol (BB+EE) and 2-butoxyethanol (BB+BE) have been prepared and stored in air tight glass bottles as a precaution to minimize the loss of evaporation. The ultrasonic velocity in pure and binary liquid mixtures measured experimentally using single crystal ultrasonic interferometer for liquids with frequency 2 MHz supplied by Mittal Enterprises, New Delhi, Model F-81. It is connected to circulating water bath with temperature controller (Thermtech –TH-012 Model) supplied by Mittal enterprises, New Delhi. This can maintain temperature of water in the bath any desired temperature with accuracy of ±0.01 K. The accuracy of the velocity measured by ultrasonic interferometer is ±0.01 ms^{-1}. The viscosity of pure and liquid mixtures is measured using Ostwald viscometer with an accuracy of ±0.1 %. The density has been measured using double stem pyknometer and introduces an error of 2 in 10^6 in the measurement of density and is negligible when compared with the overall accuracy of the method of pyknometer. The weight of the liquids has been taken using digital weight meter having an accuracy of one milligram. The experimental measured values of ultrasonic velocity, density and viscosity of pure components are presented in Table 2 and checked with the literature[19-23] available and found good agreement.

3. Theory

Experimentally measured values of ultrasonic velocity (u), density (ρ) and kinematic viscosity (η) are used to determine thermodynamic and acoustic parameters and their excess and deviation parameters using following formulas

An ideal value of the isentropic compressibility suggested by Benson and Keohara[24] is

$$K_s^{id} = \sum \varphi_i \left[K_{s,i}^o + \frac{TV_i^o(\alpha_i^o)^2}{C_{p,i}^o} \right] - T \sum X_i V_i^o \left(\frac{\sum \varphi_i \alpha_i^{o2}}{\sum X_i C_{p,i}^o} \right) \quad \text{---- (1)}$$

In which φ_i and X_i are volume fraction and mole fraction of the ith component in the combination of liquids. $K_s^{i,o}$, V_i^o, α_i^o and $C_p^{i,o}$ are isentropic compressibility, molar volume, coefficient of thermal expansion and isobaric heat capacity per mole of the ith component in the given mixture.

Excess molar volume $V_m = \frac{x_1M_1+x_2M_2}{\rho} - \left(\frac{x_1M_1}{\rho_1} + \frac{x_2M_2}{\rho_2}\right)$ ---- (2)

The excess parameter fitted to Redlich-Kister equation using general formula

$Y_{cal}^E = x_1x_2 \sum A_i (x_2 - x_1)^I$ ---- (3)

The standard deviation $\sigma = \frac{Y_{obs}^E - Y_{cal}^E}{(m-n)^{\frac{1}{2}}}$ ---- (4)

Grunberg- Nissan empirical relation $\ln \eta = x_1\ln\eta_1 + x_2\ln\eta_2 + x_1x_2G_{12}$ ---- (5)

Where G_{12} is an interaction parameter, which is a function of viscosity of components (1 and 2) of the mixture and temperature

Katti-Chowdary equation for viscosity of the liquid mixture is

$\ln (\eta V) = x_1\ln(\eta_1V_1) + x_2\ln(\eta_2V_2) + x_1x_2W_{vis}/RT$ ---- (6)

Where W_{vis} is interaction parameter

The expression for viscosity of binary mixture of Hind et al. is

$\eta = x_1^2\eta_1+x_2^2\eta_2+2x_1x_2H_{12}$ ---- (7)

Where H_{12} is interaction term

Specific acoustic impedance $Z = \rho u$ ---- (8)

The intermolecular free length was calculated using Newton-Laplace equation

Inter molecular free length $L_f = \frac{K}{u\rho^{\frac{1}{2}}}$ ---- (9)

Where K is the temperature dependant Jacobson's constant, and $K= (93.875+0.375T) \times 10^{-8}$

Excess free length $L_f^E = L_f-(x_1L_{f,1}+x_2L_{f,2})$ ---- (10)

Excess Gibb's activation energy $G^E = RT [\ln(\eta V)-(x_1\ln(\eta_1V_1)+ x_2\ln(\eta_2V_2)]$ ---- (11)

Where R is the universal gas constant and T is the absolute temperature

Deviation in kinematic viscosity $\Delta\eta = \eta_{mix}-(x_1\eta_1+x_2\eta_2)$ ---- (12)

The partial molar volumes $V_{m,1}$ and $V_{m,2}$ for the binary mixture over the entire composition range have been calculated by using the relation

$V_{m,1} = V_m^E+V_1+x_2 (\frac{\partial V_m^E}{\partial x_1})$ ---- (13)

$V_{m,2} = V_m^E+V_2-x_1 (\frac{\partial V_m^E}{\partial x_1})$ ---- (14)

Where V_1 and V_2 are molar volumes of components of the mixture

The excess parameters of molar volume, free length and deviation in isentropic compressibility, kinematic viscosity for each mixture fitted to the Redlich-Kister polynomial equation of the order 4 using the formula $Y_{cal}^E = x_1x_2\Sigma A_j(x_2-x_1)^j$ ---- (15)

Where Y_{cal}^E is excess parameter and A_j are adjustable coefficients and also calculated standard deviation σ in each excess parameter at all temperatures.

4. Results and discussion

4.1Exprimental measurements

The measured values of ultrasonic velocity (u), density(ρ) and kinematic viscosity (η) of liquid mixtures as a function of mole fraction of benzyl benzoate is presented in table 3 and figures 1,2 and 3 at three temperatures 303.15, 313.15 and 323.15 K over the whole concentration range. The trend observed in the experimental values u, ρ and η are increased with mole fraction of benzyl benzoate in all three mixtures at three temperatures, but decreases with increase in temperature. It is evident that velocity and density increases non-linearly with the composition of benzyl benzoate. The non linear variation of u and ρ indicates the deviation of ideal nature of molecular interactions. This study projects the existence of interactions between unlike molecules in the binary mixtures at all temperatures.

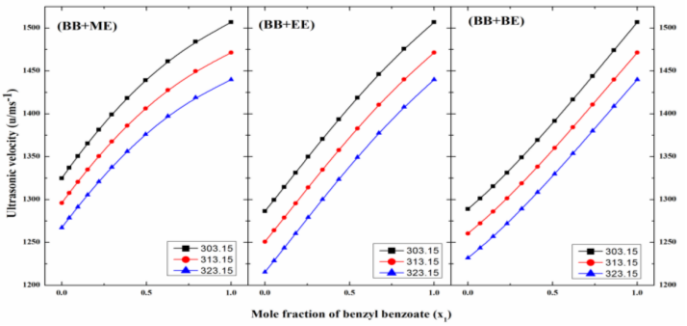


Figure 1. Ultrasonic velocity of binary mixtures of the 2-methoxyethanol (ME), 2-ethoxyethanol (EE) and 2-butoxyethanol (BE) with benzyl benzoate (BB) as common component

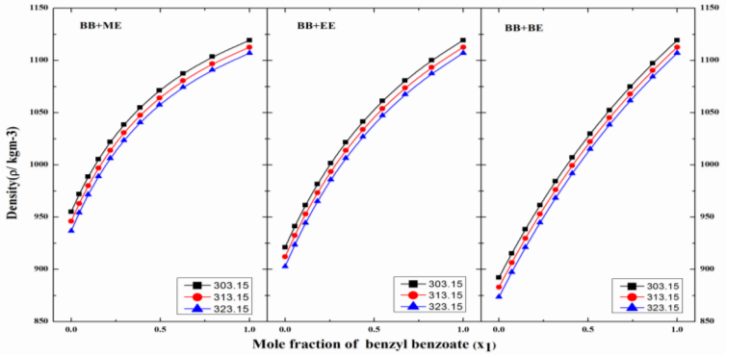


Figure 2. Density (ρ/kgm^{-3}) of binary mixtures of the 2-methoxyethanol (ME), 2-ethoxyethanol (EE) and 2-butoxyethanol (BE) with benzyl benzoate (BB) as common component

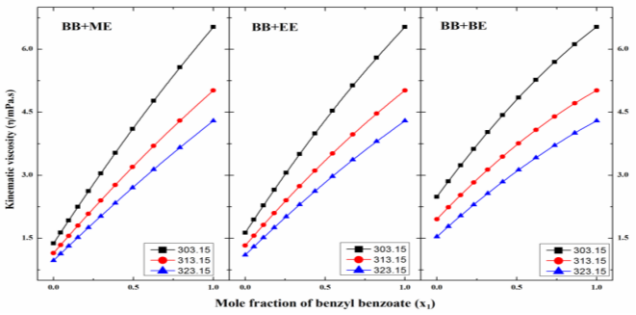


Figure3. Kinematic viscosity (η/mPa.s) of binary mixtures of the 2-methoxyethanol (ME), 2-ethoxyethanol (EE) and 2-butoxyethanol (BE) with benzyl benzoate (BB) as common component

4.2. Volumetric Studies

The interaction of constituent molecules in a binary mixture can be explained in light of excess/deviation parameters.

The excess molar volumes of all three binary mixtures BB+ME, BB+EE and BB+BE over the whole composition range is negative and presented in Table 4 and Fig.4.

The values of excess molar volumes depend on the structural changes of the components of liquid mixtures. The values of excess molar volume depends on the following three factors

1. Chemical association between unlike molecules of binary mixture by formation of hydrogen bond and this is strong interaction.
2. Accommodation of molecules of one component into interstitial position of molecule of another component.
3. Due to addition of dipolar molecules with the second type of molecule and association through weaker physical forces like Vander wall forces.

The first and second factors contribute to the negative excess molar volume, which reflects the presence of strong interactions in liquid mixtures.

The third factor contributes the positive excess molar volume due to the expansion of volume, which reflects the weak interactions and dispersion forces in between unlike molecules.

Molar volume is equal to the volume per one mole of the liquid at a given temperature and pressure. The maximum values of the excess molar volume at 303.15, 313.15 and 323.15 K are -0.156, -0.204 and -0.251 ($V_m^E/10^{-6}$ m^3mol^{-1}) in BB+2-methoxyethanol mixture, -0.189, -0.232 and -0.280 ($V_m^E/10^{-6}$ m^3mol^{-1}) in BB+2-ethoxyethanol mixture and -0.217, -0.279 and -0.337 ($V_m^E/10^{-6}$ m^3mol^{-1}) in BB+2-butoxyethanol mixture respectively. Table 4 and Fig. 4 show the negative values of molar volume and indicate the reduction in volume. It predicts the strong dipole –dipole interactions in the three binary mixtures BB+ME, BB+EE and BB+BE.

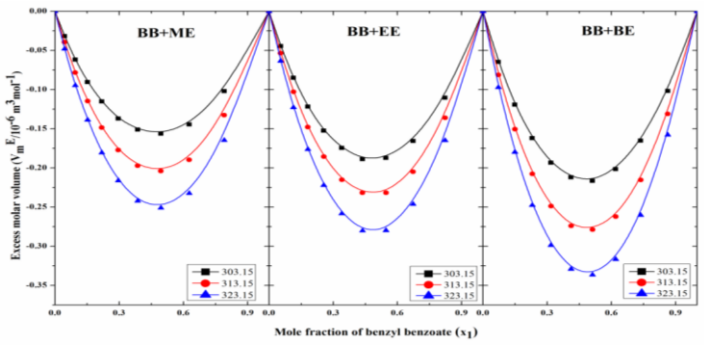


Figure 5.10. Excess molar volume with mole fraction of benzyl benzoate in the binary mixtures of 2-methoxyethanol (ME), 2-ethoxyethanol (EE) and 2-butoxyethanol (BE) with benzyl benzoate (BB) as common component

4.3. Thermo Acoustic Studies

The deviation in isentropic compressibility also predicts the interactions between liquid mixtures. The charge transfer, formation of hydrogen bonding between unlike molecules and the packing is highly efficient than the pure components, which indicate the negative deviation in isentropic compressibility and shows strong interactions in the liquid mixtures. The positive deviation indicates the weak interaction and is attributed to dispersion forces[6]. Table 4 and fig.5 indicates the deviation of isentropic compressibility is negative and predicts the strong dipole -dipole interactions in between binary mixtures of BB+ME, BB+EE and BB+BE.

The negative values of deviation in isentropic compressibility is maximum at 0.4950M in BB+2-methoxyethanol, at 0.4363M and 0.5463M in BB+2-ethoxyethanol and at 0.5116M in BB+ 2-butoxyethanol. The maximum values of isentropic compressibility are -0.037, -0.042 and -0.051 (Δk_s $/10^{-10}$ Pa^{-1}) in BB+2-methoxyethanol mixture, -0.040, -0.047 and -0.054 (Δk_s $/10^{-10}$ Pa^{-1}) in BB+2-ethoxyethanol mixture and -0.046, -0.055 and -0.062 (Δk_s $/10^{-10}$ Pa^{-1}) in BB+2-butoxythanol mixture at 303.15, 313.15 and 323.15 K respectively. The maximum values of isentropic compressibility increases with increase in temperature.

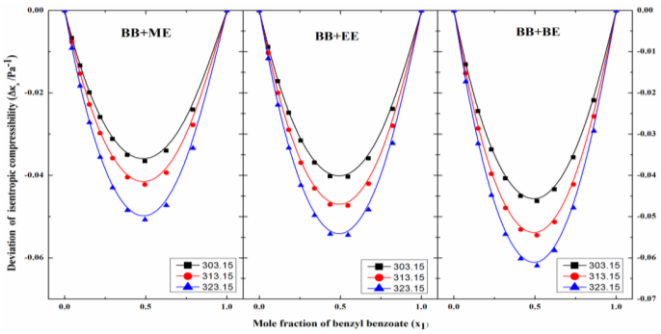


Figure 5. Deviation of isentropic compressibility with mole fraction of benzyl benzoate in the binary mixtures of 2-methoxyethanol (ME), 2-ethoxyethanol (EE) and 2-butoxyethanol (BE) with benzyl benzoate (BB) as common component

Due to the increase of molecular association, free length decreases with mole fraction of one of the components in binary mixtures, while free length falls down due to the molecular dissociation. The free length followed the similar behavior of isentropic compressibility, but reciprocal to the sound velocity. The maximum values of excess free length are -0.178, -0.204 and -0.244 (L_f^E/ 10^{-12}m) in BB+2-methoxyethanol mixture, -0.193, -0.224 and -0.255 (L_f^E/ 10^{-12}m) in BB+2-ethoxyethanol mixture and -0.214, -0.250 and -0.281 (L_f^E/ 10^{-12}m) in BB+2-butoxyethanol mixture at 303.15, 313.15 and 323.15 K respectively.

As shown in Tables from 4, the free length decreases from 2-methoxyethanol to benzyl benzoate, 2-ethoxethanol to benzyl benzoate and 2-butoxyethanol to benzyl benzoate and increases with temperature. The variation of intermolecular free length is shown pictorially in Figure 6 with mole fraction of benzyl benzoate and with temperature.

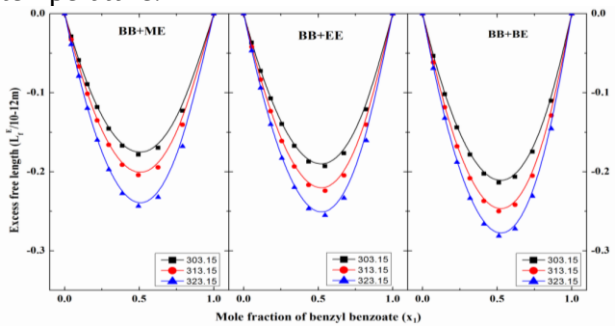


Figure 6. Excess free length with mole fraction of benzyl benzoate in the binary mixtures of 2-methoxyethanol (ME), 2-ethoxyethanol (EE) and 2-butoxyethanol (BE) with benzyl benzoate (BB) as common component

Reed et.al[25] predicted that the deviation in Gibb's activation energy explains the interaction between unlike molecules. According to them positive value of excess Gibb's activation energy indicates the strong interactions , while negative value of excess Gibb's activation energy indicates the weak interactions and dispersion forces in liquid mixtures.

The maximum values of excess Gibbs activation energies are 1.088, 1.010 and 0.990 (10^3G^E/ J mol^{-1}) at 0.3866M, 0.865, 0.816 and 0.815 (10^3G^E/ J mol^{-1}) at0.4363M and 0.492, 0.485 and 0.518 (10^3G^E/ J mol^{-1}) at 0.4112 M in three binary mixtures of 2-alkoxyethonals (methoxy-, ethoxy- and butoxy-) with benzyl benzoate at 303.15, 313.15 and 323.15K respectively.

As shown in Table 5 and Figure 7, the deviation in Gibbs's activation energy is positive in all three systems studied predicts the strong interactions between unlike molecules of binary mixtures.

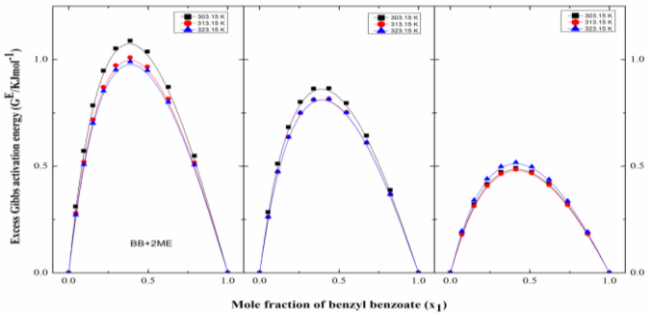


Figure 7. Excess Gibb's activation energy with mole fraction of benzyl benzoate in the binary mixtures of 2-methoxtethanol, 2-ethoxyethanol and 2-butoxyethanol with benzyl benzoate (BB) as common component

4.4. Viscometric Studies

The viscosity of liquid mixtures strongly depends on the entropy of the mixture and related to the structure and consequently molecular interactions in liquid mixtures. According to Vogel and Weisss[25] the strong interactions between unlike molecules present positive deviation in viscosity, where as for weak interactions the deviation in viscosity is negative. Fort and Moore[26] predicts that deviation in viscosity is positive as the strength of the interaction increases. The deviation in viscosity explains the qualitative estimation of the intermolecular interactions in liquid mixtures. The factors influence the deviation in viscosity as follows

1. The negative deviation in viscosity causes the difference in size and shape of the individual

molecules and loss of dipolar association in pure components of the liquid mixtures.

2. The positive deviation in viscosity causes the hydrogen bond formation and dipole –dipole interactions or charge transfer complex in the binary mixtures.

The deviation in kinematic viscosity is positive in the whole concentration range in all the three systems studied at three temperatures. The deviation in kinematic viscosity maximum values are 0.174, 0.133 and 0.088 (Δη/ mPa.s) in BB+2-methoxyethanol mixture, 0.229, 0.177 and 0.128 (Δη/ mPa.s) in BB+2-methoxyethanol mixture and 0.293, 0.238 and 0.179 (Δη/ mPa.s) in BB+2-butoxyethanol mixture at 303.15, 313.15 and 323.15 K respectively. It shows that, the deviation in kinematic viscosity decreases with rise in temperature in three liquid combinations under investigation.

Table 4 and Figure 8 shows the deviation in kinematic viscosity is positive over the entire composition range in all the three system studied at three temperatures. The deviation in viscosity decreases with increase in temperature in all three systems. It shows that strong molecular interactions are present in all the three systems BB+ME, BB+EE and BB+BE.

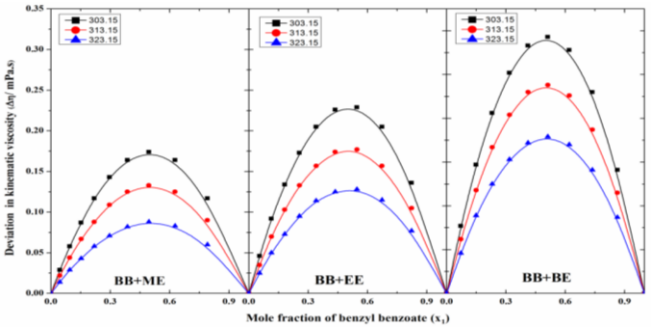


Figure 8. Deviation in kinematic viscosity with mole fraction of benzyl benzoate in the binary mixtures of ME,EE and BE with benzyl benzoate (BB) as common component

4.5. Partial Molar Volumes

D.Krishna Rao et al[20] predicts the molecular interactions in terms of Partial molar volumes. The partial molar volumes $V_{m,1}$ and $V_{m,2}$ for both the components presented in table 6 and Figure 10 of the binary mixture are smaller than their individual molar volumes in the pure state. This indicates that the decreases in volume takes place on preparing of binary mixture of benzyl benzoate and 2-alkaxyethanols. The study of these values of partial molar volumes reveals the existence of strong interactions between unlike molecules in three binary mixtures BB+ME,BB+EE and BB+BE at three constant temperatures 303.15, 313.15 and 323.15 K.

The values of excess parameters and deviation parameters reveal that the strength of the molecular interactions is BB+BE>BB+EE>BB+ME.

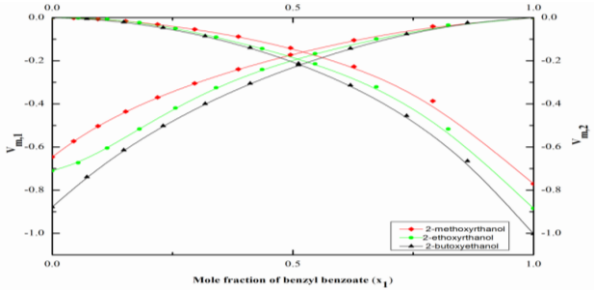


Figure 10. Excess partial molar volumes in the binary mixtures of *2*-methoxyethanol, 2-ethoxyethanol and 2-butoxyethanol with benzyl benzoate (BB) as common component at 303.15 K

4.6. Theoretical computations of viscosities

Several empirical and semi empirical equations have been designed for correlating the viscosity of liquid mixtures to interpret the molecular interaction between them. In this study correlate the viscosities of binary liquid mixture of benzyl benzoate with 2-alkaxyethanols using equations Grunberg and Nissan (GN), Katti and Chowdary (KC), Tamura-Kurata (TK), Hind et al(Hind), Auslaender (Aus) and Jouyban–Acree (JA) and presented in table 7 and Figure 9. In which Hind et al. (Hind), Auslander (Aus) and Jouyban–Acree (JA) are well correlated to experimental values.

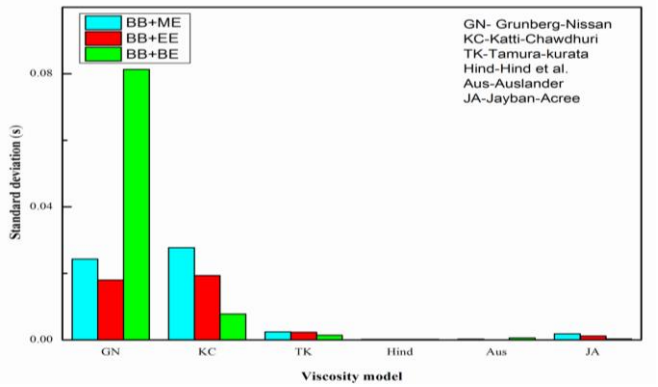


Figure 9. Standard deviation of viscosity models in the binary mixtures of 2-methoxyethanol, 2-ethoxyethanol and 2-butoxyethanol with benzyl benzoate as common component at 303.15 K.

5. Conclusion

The ultrasonic velocity, density and kinematic viscosity have been measured experimentally of the three binary mixtures of benzyl benzoate with 2-methioxyethanol, 2-ethoxyethanol and 2-butoxyethanol as a function of mole fraction of benzyl benzoate at three temperatures 303.15, 313.15 and 323.15 K at atmospheric pressure. Computed excess molar volume (V_m^E), excess free length (L_f^E), excess internal pressure (π^E), excess Gibb's activation energy (G^E), deviation in isentropic compressibility ($\Delta\kappa_s$) and deviation in kinematic viscosity ($\Delta\eta$). The values of V_m^E, L_f^E, $\Delta\kappa_s$ and $\Delta\eta$ are correlated using the Redlich-Kister polynomial equation of the order4. The observed thermodynamic and acoustic parameters suggested the strong interactions are present in all three binary systems studied. The magnitude of interactions is in the order BB+BE>BB+EE>BB+ME. The studied parameters provide a comprehensive investigation of intermolecular association arising from the hydrogen bond between benzyl benzoate and 2-alkaxyethanols.

Table1.Molecular formula, molecular weight and molecular structure, CAS number, supplier and purity of Benzyl benzoate, 2-methoxy ethanol, 2-ethoxy ethanol and 2-butoxy ethanol

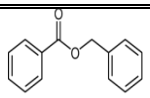
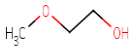
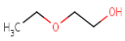
S.No	Name of the Chemical	Molecular formula	Molecular weight	Molecular structure	CAS number	Supplier	Purity	Further purity
1	Benzyl benzoate	$C_{14}H_{12}O_2$	212.24		120-51-4	Loba Chemie Pvt.Ltd., Mumbai.	99%	99.9%
2	2-Methoxyethanol	$C_3H_8O_2$	76.09		109-86-4	Loba Chemie Pvt.Ltd., Mumbai.	99%	99.9%
3	2-Ethoxyethanol	$C_4H_{10}O_2$	90.12		110-80-5	Loba Chemie Pvt.Ltd., Mumbai.	99%	99.9%
4	2-Butoxyethanol	$C_6H_{14}O_2$	118.17		111-76-2	Loba Chemie Pvt.Ltd., Mumbai.	99%	99.9%

Table 2.Experimental and literature values of benzyl benzoate, 2-methoxyethanol, 2-ethoxyethanol and 2-butoxyethanol

Component	Temperature (T/K)	Ultrasonic velocity (u/ms^{-1})		Density (ρ/kgm^{-3})		Viscosity (ρ/mPa.s)	
		Exp	Lit	Exp	lit	Exp	lit
Benzyl benzoate	303.15 K	1506.9	1506.00(21)	1119.35	1119.30(21)	6.532	6.532 (21)
			1506.00(19)				6.536(19)
	313.15 K	1471.44	1471.40(21)	1112.75	1109.70(20)	5.021	5.021(21)
			1471.42(20)		1109.70(19)		5.021(19)
			1471.20(19)				

	323.15 K	1440	1440.00(21)	1107.09		4.298	4.298(21)
2-methoxy ethanol	303.15 K	1324.91	1324.50(23)	955.22	955.76(22)	1.378	
					955.64(23)		
	313.15 K	1296.08	1299.60(23)	946.06	946.28(22)	1.147	
					945.31(23)		
	323.15 K	1267.25		936.85		0.971	
2-ethoxy ethanol	303.15 K	1286.45	1287.10(23)	921.15	921.21(23)	1.632	
	313.15 K	1250.98	1252.00(23)	912.06	911.88(23)	1.328	
	323.15 K	1215.56		902.85		1.103	
2-butoxy ethanol	303.15 K	1289.05	1288.50(23)	892.23	892.28(23)	2.489	
	313.15 K	1260.57	1259.00(23)	883	884.17(23)	1.956	
	323.15 K	1232.02		873.71		1.539	

Table 3. Experimental values of ultrasonic velocity (u), density (ρ), kinematic viscosity (η) and thermal expansion coefficient (α) in the binary mixtures of benzyl benzoate with ME,EE and BE at 303.15, 313.15 and 323.15 K

Mole fraction of BB(x_1)	Ultrasonic Velocity (u/ms^{-1})			Density (ρ/kg.m^{-3})			Kinematic Viscosity (η/mPa.s)		
	303.15 K	313.15 K	323.15 K	303.15 K	313.15 K	323.15 K	303.15 K	313.15 K	323.15 K
	Benzyl benzoate+ 2-methoxyethanol								
0.0000	1324.91	1296.08	1267.25	955.22	946.06	936.85	1.378	1.147	0.971
0.0446	1337.14	1307.81	1278.75	972.00	963.12	954.28	1.637	1.342	1.133
0.0950	1350.60	1320.75	1291.47	988.71	980.13	971.66	1.926	1.559	1.316
0.1526	1365.41	1335.02	1305.53	1005.41	997.12	989.03	2.252	1.805	1.522
0.2188	1381.59	1350.64	1320.96	1022.01	1014.03	1006.33	2.623	2.083	1.757
0.2958	1399.25	1367.71	1337.86	1038.55	1030.86	1023.55	3.046	2.402	2.026
0.3866	1418.46	1386.31	1356.28	1055.01	1047.61	1040.69	3.535	2.770	2.339
0.4950	1439.16	1406.35	1376.15	1071.36	1064.22	1057.67	4.104	3.198	2.706
0.6269	1461.24	1427.70	1397.28	1087.58	1080.68	1074.47	4.774	3.701	3.140
0.7908	1484.23	1449.83	1419.05	1103.61	1096.89	1091.00	5.572	4.301	3.662
1.0000	1506.90	1471.44	1440.00	1119.35	1112.75	1107.09	6.533	5.021	4.298
x_1	Benzyl benzoate+ 2-ethoxyethanol								
0.0000	1286.45	1250.98	1215.56	921.15	912.06	902.85	1.632	1.328	1.103
0.0542	1299.72	1264.14	1228.77	941.37	932.53	923.66	1.944	1.563	1.301
0.1143	1314.66	1278.99	1243.72	961.56	952.98	944.47	2.284	1.820	1.518
0.1811	1331.35	1295.61	1260.51	981.66	973.35	965.20	2.654	2.100	1.755

0.2559	1349.96	1314.19	1279.30	1001.68	993.64	985.87	3.059	2.406	2.016
0.3403	1370.65	1334.86	1300.28	1021.62	1013.87	1006.48	3.505	2.742	2.304
0.4363	1393.55	1357.80	1323.62	1041.50	1034.01	1027.01	3.996	3.113	2.622
0.5463	1418.74	1383.06	1349.39	1061.24	1054.02	1047.39	4.538	3.522	2.976
0.6736	1446.23	1410.64	1377.61	1080.83	1073.85	1067.57	5.138	3.973	3.37
0.8228	1475.83	1440.34	1408.07	1100.23	1093.46	1087.52	5.801	4.472	3.809
1.0000	1506.90	1471.44	1440.00	1119.35	1112.75	1107.09	6.533	5.021	4.298
x_1	Benzyl benzoate+ 2-butoxyethanol								
0.0000	1289.05	1260.57	1232.02	892.23	883.00	873.71	2.489	1.956	1.539
0.072	1301.34	1272.42	1243.60	915.37	906.41	897.46	2.857	2.239	1.784
0.1487	1315.41	1286.04	1256.94	938.46	929.78	921.18	3.237	2.530	2.038
0.2304	1331.35	1301.49	1272.12	961.44	953.06	944.82	3.627	2.829	2.300
0.3177	1349.30	1318.91	1289.27	984.34	976.25	968.39	4.026	3.134	2.569
0.4112	1369.40	1338.44	1308.53	1007.15	999.35	991.87	4.435	3.446	2.846
0.5116	1391.82	1360.21	1330.03	1029.87	1022.34	1015.25	4.851	3.762	3.130
0.6197	1416.68	1384.34	1353.88	1052.47	1045.22	1038.51	5.273	4.081	3.419
0.7364	1444.11	1410.92	1380.17	1074.94	1067.94	1061.60	5.697	4.400	3.712
0.8628	1474.21	1439.99	1408.93	1097.26	1090.47	1084.48	6.119	4.715	4.006
1.0000	1506.90	1471.44	1440.00	1119.35	1112.75	1107.09	6.533	5.021	4.298

Table 4.Excess molar volume (V_m^E), excess free length (L_f^E), variation in isentropic compressibility (ΔK_s) and variation in viscosity ($\Delta\eta$) in binary mixtures of benzyl benzoate with ME,EE and BE at 303.15, 313.15 and 323.15 K

X_1	Excess molar volume ($Vm^E/10^{-6}$ m^3mol^{-1})			Excess free length ($L_f^E/10^{-12}$m)			Variation in isentropic compressibility ($\Delta k_s/10^{-10}$ Pa^{-1})			Variation in kinematic viscosity ($\Delta\eta$/ mPa.s)		
	303.15 K	313.15 K	323.15 K	303.15 K	313.15 K	323.15 K	303.15 K	313.15 K	323.15 K	303.15 K	313.15 K	323.15 K
	Benzyl benzoate+ 2-methoxyethanol											
0.0000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.0446	-0.032	-0.039	-0.048	-0.029	-0.033	-0.039	-0.007	-0.008	-0.009	0.029	0.022	0.014
0.095	-0.062	-0.078	-0.095	-0.059	-0.067	-0.079	-0.013	-0.015	-0.018	0.058	0.044	0.029
0.1526	-0.091	-0.115	-0.139	-0.089	-0.101	-0.12	-0.02	-0.023	-0.027	0.087	0.067	0.043
0.2188	-0.115	-0.149	-0.181	-0.118	-0.135	-0.16	-0.026	-0.03	-0.036	0.117	0.088	0.058
0.2958	-0.137	-0.177	-0.216	-0.146	-0.166	-0.197	-0.031	-0.036	-0.043	0.143	0.109	0.071
0.3866	-0.151	-0.197	-0.242	-0.167	-0.191	-0.228	-0.035	-0.04	-0.048	0.164	0.125	0.082
0.495	-0.156	-0.204	-0.251	-0.178	-0.204	-0.244	-0.037	-0.042	-0.051	0.174	0.133	0.088
0.6269	-0.145	-0.19	-0.232	-0.17	-0.195	-0.232	-0.034	-0.039	-0.047	0.164	0.125	0.083
0.7908	-0.102	-0.133	-0.165	-0.123	-0.141	-0.168	-0.024	-0.028	-0.033	0.117	0.09	0.060
1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00	0.000	0.000

0										0		
x_1	Benzyl benzoate+ 2-ethoxyethanol											
0.0000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.0542	-0.044	-0.053	-0.063	-0.037	-0.042	-0.047	-0.009	-0.01	-0.012	0.046	0.035	0.025
0.1143	-0.085	-0.103	-0.123	-0.073	-0.083	-0.094	-0.017	-0.02	-0.023	0.092	0.07	0.05
0.1811	-0.122	-0.148	-0.176	-0.107	-0.123	-0.14	-0.025	-0.029	-0.033	0.134	0.103	0.073
0.2559	-0.152	-0.185	-0.222	-0.14	-0.161	-0.183	-0.032	-0.037	-0.042	0.173	0.133	0.095
0.3403	-0.174	-0.215	-0.258	-0.167	-0.193	-0.22	-0.037	-0.043	-0.05	0.205	0.157	0.114
0.4363	-0.189	-0.232	-0.28	-0.187	-0.217	-0.247	-0.04	-0.047	-0.054	0.226	0.174	0.125
0.5463	-0.187	-0.232	-0.28	-0.193	-0.224	-0.255	-0.04	-0.047	-0.054	0.229	0.177	0.128
0.6736	-0.166	-0.205	-0.246	-0.177	-0.205	-0.233	-0.036	-0.042	-0.048	0.205	0.157	0.115
0.8228	-0.11	-0.136	-0.165	-0.121	-0.14	-0.161	-0.024	-0.028	-0.032	0.136	0.105	0.077
1.0000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
x_1	Benzyl benzoate+ 2-butoxyethanol											
0.0000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.072	-0.065	-0.081	-0.097	-0.054	-0.062	-0.069	-0.013	-0.015	-0.017	0.077	0.062	0.046
0.1487	-0.119	-0.15	-0.18	-0.102	-0.118	-0.132	-0.024	-0.029	-0.032	0.147	0.118	0.089
0.2304	-0.162	-0.208	-0.248	-0.144	-0.168	-0.188	-0.034	-0.04	-0.045	0.206	0.167	0.125
0.3177	-0.193	-0.249	-0.299	-0.179	-0.208	-0.234	-0.041	-0.048	-0.054	0.252	0.204	0.153
0.4112	-0.212	-0.274	-0.329	-0.203	-0.237	-0.266	-0.045	-0.053	-0.06	0.283	0.23	0.172
0.5116	-0.217	-0.279	-0.337	-0.214	-0.25	-0.281	-0.046	-0.055	-0.062	0.293	0.238	0.179
0.6197	-0.202	-0.262	-0.317	-0.207	-0.242	-0.272	-0.043	-0.051	-0.058	0.278	0.226	0.17
0.7364	-0.165	-0.215	-0.26	-0.175	-0.205	-0.231	-0.036	-0.042	-0.048	0.23	0.187	0.141
0.8628	-0.102	-0.131	-0.158	-0.11	-0.129	-0.146	-0.022	-0.026	-0.029	0.141	0.115	0.087
1.0000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table.5. Excess partial molar volumes of binary mixtures of benzyl benzoate with 2-methoxyethanol, 2-ethoxyethanol and 2-butoxyethanol at 303.15, 313.15 and 323.15 K

x_1	$V_{m,1}^E$	$V_{m,2}^E$	$V_{m,1}^E$	$V_{m,2}^E$	$V_{m,1}^E$	$V_{m,2}^E$
	303.15 K		313.15 K		323.15 K	
	Benzyl benzoate+ 2-methoxyethanol					
0.0000	-0.6458	0.0000	-0.8428	0.0000	-1.1783	0.0000
0.0446	-0.5727	-0.0016	-0.7444	-0.0022	-0.9651	-0.0046
0.0950	-0.5027	-0.0068	-0.6525	-0.0090	-0.7989	-0.0168
0.1526	-0.4354	-0.0163	-0.5657	-0.0212	-0.6719	-0.0345
0.2188	-0.3697	-0.0312	-0.4821	-0.0402	-0.5718	-0.0571
0.2958	-0.3046	-0.0538	-0.3989	-0.0690	-0.4825	-0.0880
0.3866	-0.2390	-0.0877	-0.3132	-0.1134	-0.3872	-0.1375
0.4950	-0.1721	-0.1405	-0.2235	-0.1843	-0.2763	-0.2254
0.6269	-0.1047	-0.2269	-0.1317	-0.3021	-0.1569	-0.3784
0.7908	-0.0403	-0.3863	-0.0472	-0.5099	-0.0552	-0.6265
1.0000	0.0000	-0.7703	0.0000	-0.9444	0.0000	-1.1649
	Benzyl benzoate+ 2-methoxyethanol					
0.0000	-0.7100	0.0000	-0.9319	0.0000	-1.1485	0.0000
0.0542	-0.6729	-0.0012	-0.8354	-0.0027	-1.0157	-0.0037
0.1143	-0.6046	-0.0076	-0.7319	-0.0122	-0.8832	-0.0158
0.1811	-0.5161	-0.0230	-0.6239	-0.0310	-0.7510	-0.0387
0.2559	-0.4191	-0.0502	-0.5144	-0.0615	-0.6197	-0.0754
0.3403	-0.3246	-0.0902	-0.4065	-0.1073	-0.4902	-0.1303
0.4363	-0.2402	-0.1436	-0.3030	-0.1729	-0.3643	-0.2102
0.5463	-0.1668	-0.2143	-0.2057	-0.2669	-0.2447	-0.3257
0.6736	-0.0990	-0.3210	-0.1161	-0.4076	-0.1358	-0.4965
0.8228	-0.0346	-0.5162	-0.0393	-0.6387	-0.0455	-0.7675
1.0000	0.0000	-0.8844	0.0000	-1.0649	0.0000	-1.2640
	Benzyl benzoate+ 2-methoxyethanol					
0.0000	-0.8780	0.0000	-1.0894	0.0000	-1.3146	0.0000
0.0720	-0.7386	-0.0051	-0.9546	-0.0052	-1.1501	-0.0063
0.1487	-0.6142	-0.0205	-0.8069	-0.0236	-0.9748	-0.0281
0.2304	-0.5018	-0.0467	-0.6589	-0.0582	-0.7983	-0.0694
0.3177	-0.3992	-0.0853	-0.5195	-0.1107	-0.6289	-0.1333
0.4112	-0.3053	-0.1392	-0.3932	-0.1831	-0.4724	-0.2230
0.5116	-0.2195	-0.2127	-0.2806	-0.2796	-0.3326	-0.3427
0.6197	-0.1424	-0.3134	-0.1804	-0.4103	-0.2111	-0.5011
0.7364	-0.0756	-0.4548	-0.0934	-0.5944	-0.1094	-0.7160
0.8628	-0.0236	-0.6648	-0.0273	-0.8608	-0.0331	-1.0235
1.0000	0.0000	-1.0025	0.0000	-1.2354	0.0000	-1.4904

Table 6. Excess Gibbs activation energy (G^E) for the binary mixtures of benzyl benzoate with 2-methoxyethanol, 2-ethoxyethanol and 2-butoxyethanol at 303.15, 313.15 and 323.15 K

	Excess Gibbs activation energy (G^E /KJ.mol^{-1})	Excess Gibbs activation energy (G^E /KJ.mol^{-1})	Excess Gibbs activation energy (G^E /KJ.mol^{-1})
		BB+2-ethoxyethanol	BB+2-butoxyethanol

BB+2-methoxyethanol

x_1	303.15 K	313.15 K	323.15 K	x_1	303.15 K	313.15 K	323.15 K	x_1	303.15 K	313.15 K	323.15 K
0.0000	0.000	0.000	0.000	0.0000	0.000	0.000	0.000	0.0000	0.000	0.000	0.000
0.0446	0.311	0.281	0.272	0.0542	0.285	0.262	0.262	0.0720	0.183	0.180	0.196
0.0950	0.572	0.520	0.508	0.1143	0.512	0.474	0.474	0.1487	0.321	0.314	0.341
0.1526	0.785	0.719	0.702	0.1811	0.683	0.637	0.637	0.2304	0.416	0.409	0.441
0.2188	0.948	0.871	0.853	0.2559	0.801	0.750	0.751	0.3177	0.473	0.465	0.499
0.2958	1.052	0.973	0.952	0.3403	0.864	0.812	0.812	0.4112	0.492	0.485	0.518
0.3866	1.088	1.010	0.990	0.4363	0.865	0.816	0.815	0.5116	0.474	0.468	0.498
0.4950	1.037	0.967	0.949	0.5463	0.796	0.753	0.752	0.6197	0.419	0.413	0.438
0.6269	0.871	0.816	0.801	0.6736	0.644	0.611	0.610	0.7364	0.323	0.319	0.337
0.7908	0.549	0.517	0.507	0.8228	0.388	0.369	0.368	0.8628	0.185	0.183	0.192
1.0000	0.000	0.000	0.000	1.0000	0.000	0.000	0.000	0.0000	0.000	0.000	0.000

Table 7. Experimental and calculated values of kinematic viscosity (Grunberg - Nissan (GN), Katti - Chowdary (KC), Tamura-Kurata (TK), Hind et al.(Hind), Auslaender (Aus) and Jouyban–Acree (JA)) for the binary mixtures of benzyl benzoate with 2-methoxyethanol, 2-ethoxyethanol and 2-butoxyethanol mixtures at 303.15, 313.15 and 323.15 K

x_1	η_{exp}	η_{GN}	η_{KC}	η_{TK}	η_{Hind}	η_{Aus}	η_{JA}
	Benzyl benzoate+ 2-methoxyethanol						
	303.15 K						
0.0000	1.378	1.378	1.378	1.378	1.378	1.378	1.378
0.0446	1.637	1.581	1.575	1.646	1.637	1.637	1.631
0.0950	1.926	1.832	1.822	1.940	1.927	1.927	1.923
0.1526	2.252	2.148	2.135	2.266	2.254	2.254	2.258
0.2188	2.623	2.544	2.533	2.631	2.624	2.623	2.635
0.2958	3.046	3.045	3.041	3.044	3.046	3.045	3.057
0.3866	3.535	3.672	3.686	3.518	3.534	3.533	3.530
0.4950	4.104	4.436	4.480	4.071	4.102	4.101	4.077
0.6269	4.774	5.309	5.389	4.729	4.771	4.772	4.751
0.7908	5.572	6.143	6.234	5.530	5.569	5.577	5.623
1.0000	6.533	6.533	6.533	6.533	6.533	6.533	6.533
	313.15 K						
0.0000	1.147	1.147	1.147	1.147	1.147	1.147	1.147
0.0446	1.342	1.306	1.301	1.349	1.342	1.342	1.339
0.0950	1.559	1.501	1.493	1.570	1.560	1.559	1.559
0.1526	1.805	1.743	1.735	1.816	1.806	1.805	1.809
0.2188	2.083	2.046	2.039	2.090	2.084	2.083	2.092

0.2958	2.402	2.424	2.425	2.401	2.402	2.402	2.408
0.3866	2.770	2.894	2.910	2.757	2.769	2.770	2.764
0.4950	3.198	3.462	3.502	3.173	3.196	3.198	3.178
0.6269	3.701	4.107	4.173	3.667	3.698	3.701	3.687
0.7908	4.301	4.722	4.796	4.268	4.297	4.300	4.339
1.0000	5.021	5.021	5.021	5.021	5.021	5.021	5.021
	323.15 K						
0.0000	0.971	0.971	0.971	0.971	0.971	0.971	0.971
0.0446	1.133	1.110	1.107	1.139	1.134	1.133	1.132
0.0950	1.316	1.281	1.277	1.323	1.317	1.316	1.316
0.1526	1.522	1.495	1.491	1.530	1.523	1.522	1.527
0.2188	1.757	1.762	1.761	1.761	1.758	1.757	1.763
0.2958	2.026	2.096	2.103	2.026	2.027	2.026	2.029
0.3866	2.339	2.511	2.534	2.331	2.339	2.339	2.332
0.4950	2.706	3.011	3.056	2.689	2.704	2.706	2.686
0.6269	3.140	3.572	3.642	3.116	3.137	3.140	3.128
0.7908	3.662	4.090	4.164	3.640	3.659	3.662	3.702
1.0000	4.298	4.298	4.298	4.298	4.298	4.298	4.298
x_1	Benzyl benzoate+ 2-ethoxyethanol						
	303.15 K						
0.0000	1.632	1.632	1.632	1.632	1.632	1.632	1.632
0.0542	1.944	1.882	1.878	1.955	1.945	1.944	1.938
0.1143	2.284	2.184	2.178	2.300	2.285	2.284	2.282
0.1811	2.654	2.549	2.541	2.670	2.655	2.654	2.660
0.2559	3.059	2.988	2.982	3.068	3.060	3.059	3.070
0.3403	3.505	3.513	3.511	3.501	3.505	3.505	3.511
0.4363	3.996	4.128	4.135	3.977	3.995	3.996	3.989
0.5463	4.538	4.820	4.841	4.503	4.536	4.538	4.518
0.6736	5.138	5.544	5.577	5.093	5.134	5.138	5.128
0.8228	5.801	6.187	6.221	5.762	5.798	5.802	5.835
1.0000	6.533	6.533	6.533	6.533	6.533	6.533	6.533
	313.15 K						
0.0000	1.328	1.328	1.328	1.328	1.328	1.328	1.328
0.0542	1.563	1.521	1.519	1.573	1.564	1.563	1.559
0.1143	1.820	1.754	1.749	1.833	1.821	1.820	1.819
0.1811	2.100	2.033	2.028	2.112	2.101	2.100	2.104
0.2559	2.406	2.366	2.362	2.413	2.407	2.406	2.413
0.3403	2.742	2.762	2.762	2.740	2.742	2.742	2.748
0.4363	3.113	3.223	3.231	3.098	3.112	3.113	3.110
0.5463	3.522	3.740	3.758	3.495	3.520	3.522	3.509
0.6736	3.973	4.278	4.305	3.938	3.970	3.973	3.964
0.8228	4.472	4.757	4.785	4.442	4.469	4.472	4.487
1.0000	5.021	5.021	5.021	5.021	5.021	5.021	5.021
	323.15 K						
0.0000	1.103	1.103	1.103	1.103	1.103	1.103	1.103
0.0542	1.301	1.269	1.267	1.308	1.302	1.301	1.299
0.1143	1.518	1.470	1.467	1.528	1.519	1.518	1.518
0.1811	1.755	1.711	1.708	1.765	1.757	1.755	1.759
0.2559	2.016	2.001	1.999	2.021	2.017	2.016	2.021
0.3403	2.304	2.346	2.348	2.302	2.304	2.304	2.305
0.4363	2.622	2.749	2.757	2.611	2.621	2.623	2.616
0.5463	2.976	3.200	3.218	2.956	2.974	2.976	2.963

0.6736	3.370	3.669	3.695	3.343	3.366	3.370	3.365
0.8228	3.809	4.082	4.107	3.786	3.806	3.809	3.834
1.0000	4.298	4.298	4.298	4.298	4.298	4.298	4.298
x_1	Benzyl benzoate+ 2-butoxyethanol						
	303.15 K						
0.0000	2.489	2.489	2.489	2.489	2.489	2.489	2.489
0.0720	2.857	2.569	2.805	2.868	2.858	2.862	2.854
0.1487	3.237	2.674	3.160	3.252	3.238	3.243	3.236
0.2304	3.627	2.812	3.553	3.640	3.628	3.630	3.629
0.3177	4.026	2.992	3.983	4.033	4.027	4.026	4.030
0.4112	4.435	3.227	4.444	4.432	4.435	4.430	4.436
0.5116	4.851	3.540	4.927	4.837	4.850	4.843	4.848
0.6197	5.273	3.961	5.411	5.248	5.271	5.264	5.268
0.7364	5.697	4.539	5.870	5.668	5.694	5.694	5.696
0.8628	6.119	5.352	6.262	6.096	6.117	6.134	6.128
1.0000	6.533	6.533	6.533	6.533	6.533	6.533	6.533
	313.15 K						
0.0000	1.956	1.956	1.956	1.956	1.956	1.956	1.956
0.0720	2.239	2.201	2.201	2.248	2.240	2.239	2.237
0.1487	2.530	2.475	2.474	2.543	2.532	2.530	2.530
0.2304	2.829	2.777	2.776	2.840	2.830	2.829	2.831
0.3177	3.134	3.106	3.105	3.140	3.135	3.134	3.137
0.4112	3.446	3.457	3.457	3.443	3.446	3.446	3.446
0.5116	3.762	3.822	3.824	3.750	3.761	3.762	3.759
0.6197	4.081	4.188	4.190	4.061	4.079	4.081	4.077
0.7364	4.400	4.531	4.534	4.376	4.397	4.400	4.400
0.8628	4.715	4.822	4.825	4.696	4.713	4.715	4.722
1.0000	5.021	5.021	5.021	5.021	5.021	5.021	5.021
	323.15 K						
0.0000	1.539	1.539	1.539	1.539	1.539	1.539	1.539
0.0720	1.784	1.751	1.750	1.791	1.785	1.784	1.782
0.1487	2.038	1.990	1.989	2.048	2.039	2.038	2.038
0.2304	2.300	2.257	2.256	2.308	2.301	2.300	2.302
0.3177	2.569	2.550	2.549	2.573	2.570	2.569	2.572
0.4112	2.846	2.866	2.866	2.844	2.846	2.846	2.846
0.5116	3.130	3.198	3.199	3.120	3.129	3.130	3.127
0.6197	3.419	3.532	3.533	3.403	3.417	3.419	3.415
0.7364	3.712	3.847	3.850	3.693	3.709	3.712	3.712
0.8628	4.006	4.116	4.118	3.991	4.004	4.006	4.014
1.0000	4.298	4.298	4.298	4.298	4.298	4.298	4.298

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