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Assessing How Thermodynamic Properties Varies for Ethyl Acetate and N-Pentanol System at Dualistic Temperatures

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ABSTRACT: For any liquid mixtures, the study of thermodynamic properties is very crucial as they provide a valuable source of information. The data of these binary mixtures for the chemical industries have to be very reliable as they provide a continuous feed that helps in the design process for chemical separation heat transfer, mass transfer, fluid flow, and many others. In this process, the present study is focused on thermodynamic and excess thermodynamic properties for a binary mixture of n-Pentanol with ethyl acetate. After calculating all the thermodynamic properties, excess parameters were also calculated to test the system's reliability and the values thus obtained are fitted into the Redlich – Kister equation. Moreover to compare Ultrasonic velocities theoretical relations of Nomoto and Van Dael Vangeel were used. These properties can be commendably utilized as a qualitative study to predict the extent of molecular interactions between the components.

Keywords: Adiabatic Compressibility, Intermolecular forces, Nomoto, Ultrasonic Velocity, Viscosity, Van Dael and Vangeel.

I.INTRODUCTION

From the past few years, examining and assessing the thermodynamic properties of liquid mixtures has been ever increasing .The thermodynamic properties of liquids in any binary mixture depict substantial weight on the physical and chemical properties [1-5]. These properties provide better information necessary for understanding the non –ideal behavior of complex systems, which are caused by molecular interactions, dipole-dipole interactions etc., of different molecules. In the practical world, these properties are very much looked-for the diverse areas like bio-chemical, Food industry, metallurgy, molecular dynamics studies and what not. It is the year of 1931 which paved a new path that. Till 1931 no one knows how can solutions deviates from its ideal behavior, but in the same year Scatchard proposed an equation which solved afore mentioned problem with the excess thermo dynamic parameters which are shown below, where excess thermodynamic parameters denoted by super script E.

$$Y^E = Y^M_{real} - Y^M_{ideal}$$

Initially Vander Waals and Van Laar [6] proposed the theories for binary liquid mixtures which successfully explained many properties to the certain extent. To further improve Van Laar's theory, Hildebrand and Scott [7] and Scatchard [8-11] used Hildebrand's [12] developed a concept of regular solutions and there by correlated with excess volume.

Redlich and Kister [13] derived an experimental equation to predict Y^E values for binary liquid mixtures.

$$Y^E = X_1X_2[A_0 + A_1(X_1-X_2) + A_2(X_1-X_2)^2$$

Where A_0, A_1 and A_2 are constants X_1, X_2 are the mole fractions of the two different components.

Rao [14] found that the thermal coefficient of ultrasonic velocity in organic liquids is about three times the thermal coefficient of density.

$$R = U^{1/3} V,$$

Where *R* is known as molar sound velocity constant.

Jacobson [15] derived an empirical relation between three thermodynamic parameters (ultrasonic velocity, density, and intermolecular free length). Survey on literature reveals the great volume of work has been carried out in binary and ternary systems for weak and strongly interacting systems but only a few studies are reported with Ethyl acetate as the main component, and no thermodynamic studies were conducted at 303.15K and 313.15K. To have a piece of precise knowledge about the molecular interactions; ultrasonic velocities, densities, viscosities and theoretical relations of Nomoto; Van Dael and Vangeel of Ethyl acetate +n-pentanol at two temperatures have been studied.

II. METHODOLOGY

The ultrasonic velocity measurements are made with the help of a single crystal ultrasonic pulse echo-interferometer. The densities of the liquid mixture (Ethyl Acetate + n-Pentanol) have been determined by using a single pan electrical balance for the determination of mass of a given volume of the liquid. The coefficient of viscosity has been determined as a function of composition and temperature, using the Oswald's viscometer. The temperature of the mixture is maintained at the required constant value by using constant temperature bath, controlled by thermostat with an accuracy of ± 0.01K. All the excess parameters are fitted into the Redlich – Kister equation. The values of parameters obtained by Cramer's rule are included with the standard deviation(σ). The excess volumes of mixing have been evaluated both as a formation of composition and temperature to examine the possibility of structural adjustment. To have a clear knowledge the Present Study has been divided into 3 parts. An attempt has been made to compare the merits of the relations for the binary liquid mixtures investigated at different temperatures. The deviation in the variation of U^2_{exp} / U^2_{imx} from unity has also been evaluated for explaining the non-ideality in the mixture.

III. RESULTS AND DISCUSSION

All the measured values like, ultrasonic velocity (U) density (ρ), viscosity(η), molar volume (V_m), adiabatic compressibility (β_{ad}), intermolecular free length (L_f), Rao's Constant(R) and Wada's Constant (W) along with excess molar volume (V_m^E), excess intermolecular free length (L_f^E), deviations in adiabatic compressibility ($\Delta\beta_{ad}$) and deviations in viscosity (Δη) of the binary mixture and had been measured for the chosen two temperatures. All the calculated parameters were presented from tables 1 to 3. The results are interpreted in terms of intermolecular interactions between the components of the mixtures.

Ultrasonic velocity (U) in this system is plotted with respect to mole fraction of ethyl acetate in Fig. 1(A) for different temperatures which represents that the velocity decreases non-linearly and the decrease in ultrasonic velocity in any solution indicates the maximum association among the molecules of the solution. Density variation, dependence of viscosity (η), and deviation in viscosity(Δη) had shown in Fig. 1(B), 2(A) and 6(C) respectively. The viscosity curves show positive deviations maximum at about 0.52 mole fraction and is favoring the dipole-dipole interactions. The variation of molar volume (V) and excess molar volume (V^E) is shown in Figs. 2(D) and 5(A) respectively.

Table 1: Variation of U,ρ,η, $V_m$at temperatures 303.15K AND 313.15K.

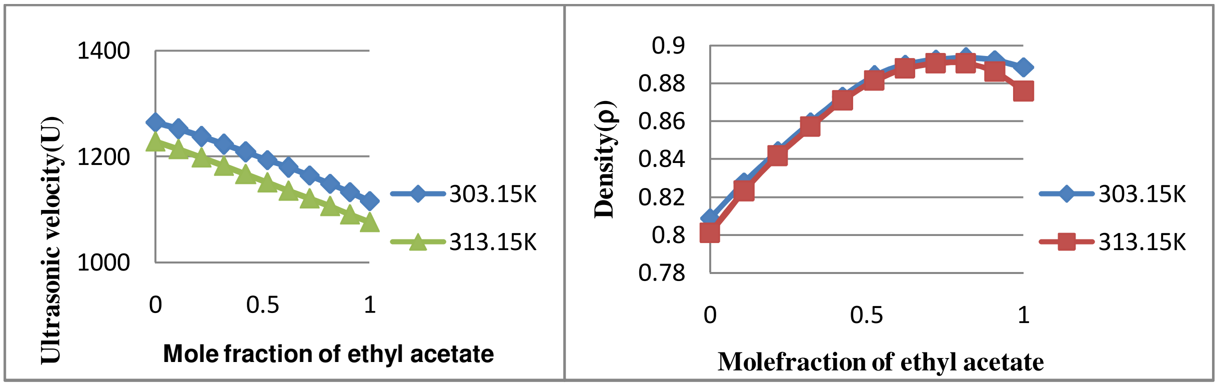
Mole Fraction X	Ultra sonic Velocity(U)m/s		ρ x 10^{-3}kg/m^3		ηCp		V_m cm^{-3} mol^{-1}	
	303.15K	313.15K	303.15K	313.15K	303.15K	313.15K	303.15K	313.15K
0.0000	1264.50	1228.50	0.8087	0.8009	3.7310	2.8906	109.0021	110.0637
0.1088	1251.94	1213.44	0.8276	0.8230	3.4031	2.6413	106.5104	107.1042
0.2156	1237.39	1197.99	0.8442	0.8416	3.0749	2.3993	104.4095	104.7247
0.3202	1222.85	1182.41	0.8595	0.8569	2.7527	2.1578	102.5389	102.8546
0.4229	1208.39	1166.26	0.8730	0.8708	2.4310	1.9164	100.9580	101.2135
0.5237	1193.37	1150.55	0.8839	0.8815	2.1051	1.6701	99.7062	99.9708
0.6225	1179.44	1134.85	0.8897	0.8878	1.7655	1.4111	99.0530	99.2659
0.7195	1163.94	1120.13	0.8925	0.8906	1.4235	1.1486	98.7379	98.9483
0.8147	1148.36	1105.89	0.8934	0.8906	1.0843	0.8875	98.6303	98.9377
0.9082	1132.90	1090.62	0.8921	0.8862	0.7456	0.6258	98.7698	99.4235
1.0000	1115.90	1076.00	0.8886	0.8758	0.4038	0.3652	99.1560	100.6052

Table 2: Variation of β_{ad}, L_f, R, W at Temperatures 303.15K and 313.15K.

Mole Fraction X	β_{ad} $10^{12}m^2N^{-2}$		L_f 10^{-10} m		R		W	
	303.15K	313.15K	303.15K	313.15K	303.15K	313.15K	303.15K	313.15K
0.0000	77.3348	82.7316	0.5514	0.5785	5471	5471	3034	3034
0.1088	77.0941	82.5212	0.5505	0.5777	5328	5302	2966	2953
0.2156	77.3657	82.7871	0.5515	0.5787	5203	5163	2906	2886
0.3202	77.8006	83.4703	0.5530	0.5811	5090	5048	2851	2831
0.4229	78.4493	84.4317	0.5553	0.5844	4991	4945	2804	2782
0.5237	79.4427	85.6923	0.5588	0.5887	4909	4862	2764	2742
0.6225	80.8015	87.4628	0.5636	0.5948	4858	4806	2739	2714
0.7195	82.7064	89.4942	0.5702	0.6017	4821	4770	2722	2697
0.8147	84.8780	91.8072	0.5777	0.6094	4794	4749	2709	2687
0.9082	87.3370	94.8627	0.5860	0.6194	4779	4750	2701	2687
1.0000	90.3739	98.6213	0.5961	0.6316	4774	4785	2699	2704

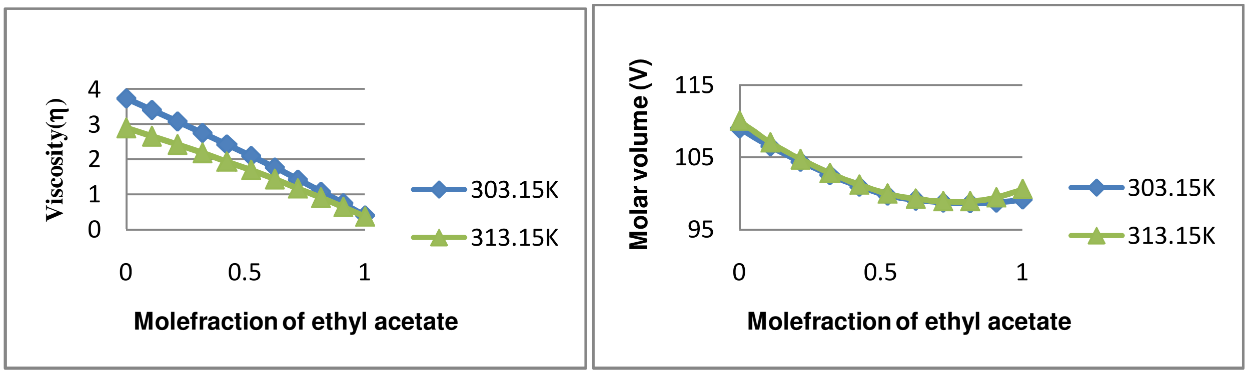
Table 3: Variation of V_m^E, $\Delta\beta_{ad}$, $\Delta\,\eta cp$, L_f^E Temperatures 303.15K & 313.15K.

Mole Fraction X	$V_m^E Cm^3 mol^{-1}$		$\Delta\beta_{ad}\ 10^{10} m^2\ N^{-1}$		$\Delta\,\eta cp$		$L_f^E 10^{-10} m$	
	303.15K	313.15K	303.15K	313.15K	303.15K	313.15K	303.15K	313.15K
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.1088	-1.4200	-1.9300	-1.6600	-1.9400	0.0343	0.0256	-0.0057	-0.0065
0.2156	-2.4700	-3.3000	-2.7800	-3.3700	0.0612	0.0531	-0.0095	-0.0113
0.3202	-3.3100	-4.1800	-3.7100	-4.3500	0.0872	0.0760	-0.0127	-0.0144
0.4229	-3.8800	-4.8500	-4.4000	-5.0200	0.1071	0.0938	-0.0150	-0.0166
0.5237	-4.1400	-5.1400	-4.7200	-5.3600	0.1164	0.1019	-0.0160	-0.0176
0.6225	-3.8200	-4.9100	-4.6500	-5.1600	0.1057	0.0925	-0.0156	-0.0168
0.7195	-3.1800	-4.3100	-4.0100	-4.6700	0.0864	0.0750	-0.0133	-0.0150
0.8147	-2.3500	-3.4200	-3.0800	-3.8700	0.0640	0.0544	-0.0102	-0.0124
0.9082	-1.2900	-2.0500	-1.8400	-2.3000	0.0364	0.0288	-0.0060	-0.0073
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000



(A) **(B)**

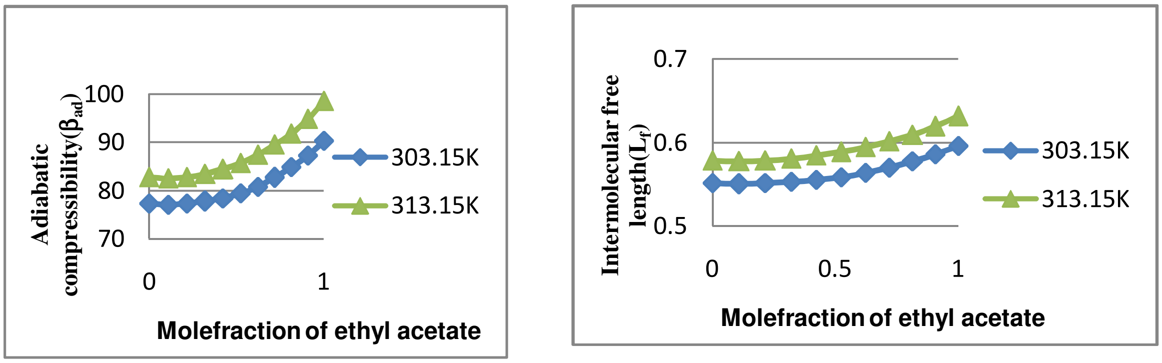
Fig.1. A. Variation of ultrasonic velocity with mole fraction of ethyl acetate for ethyl acetate + n-pentanol system. **B.** Variation of Density with mole fraction of ethyl acetate + n-Pentanol system.



(C) **(D)**

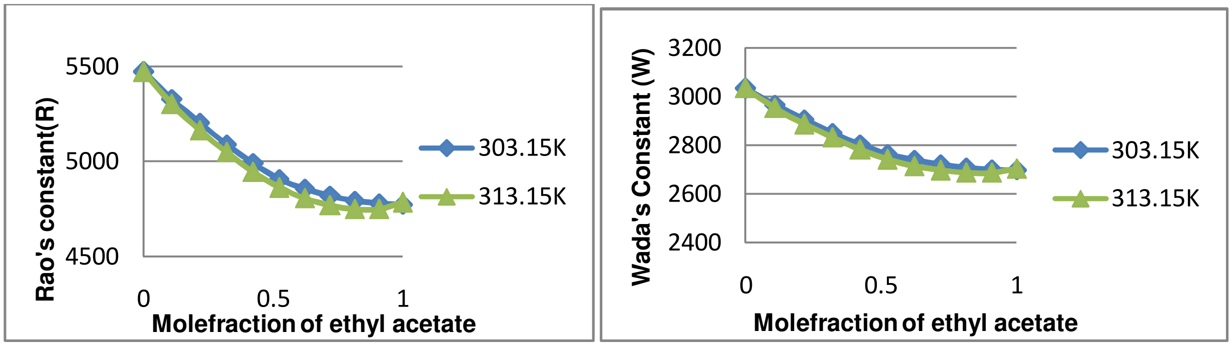
Fig. 2.(C) Variation of viscosity with mole fraction of ethyl acetate for ethyl acetate + n-pentanol system.**(D)**Variation of molar volume with mole fraction of ethyl acetate for ethyl acetate + n-pentanol system.

The results indicate that there is a volume contraction in mixing. The V^E values become more and more negative as the temperature is increased. The broad negative V^E is observed at about 0.52 mole fraction of ethyl acetate. Plotting of Variation of adiabatic compressibility (β_{ad}) and the deviation in adiabatic compressibility($\Delta\beta_{ad}$) are shown in Fig. 3(A) and Fig. 5(B). It can be seen that the deviation in adiabatic compressibility ($\Delta\beta_{ad}$) is negative over the entire composition range reaching broad minimum at about 0.52 mole fractions. Variation of intermolecular free length (L_f) and excess intermolecular free length (L_f^E) is shown in Fig. 3(B) and Fig. 6(D). These curves indicated that the intermolecular free length varies non-linearly with mole fraction and increases slightly with increase in temperature. The variation of Rao's constant(R) and Wada's Constant (W)[18-20] is depicted in Figs. 4(C) and 4(D).



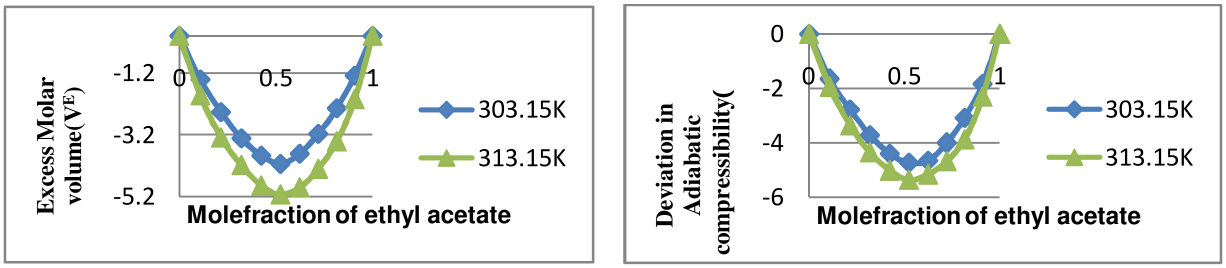
(A) **(B)**

Fig. 3 (A) Variation of adiabatic compressibility with mole fraction of ethyl acetate for ethyl acetate + n-pentanol system, **(B)** Variation of intermolecular free length with mole fraction of ethyl acetate for ethyl acetate + n-pentanol system.



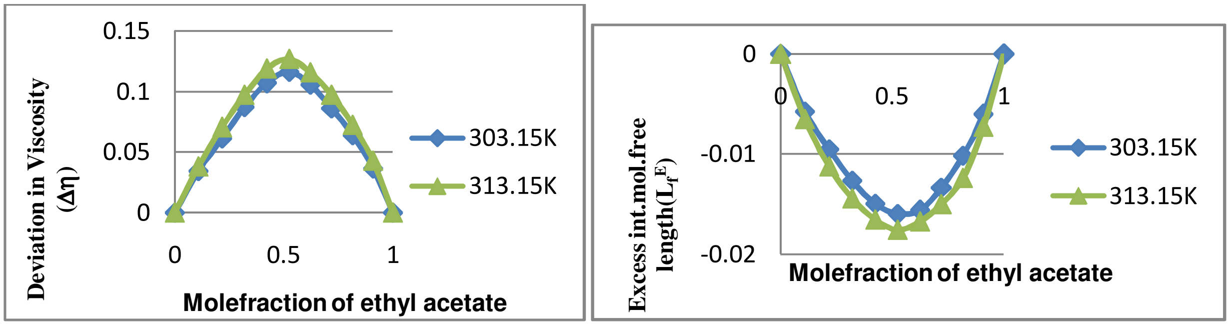
(A) **(B)**

Fig. 4 (A) Variation of Rao's constant with mole fraction of ethyl acetate for ethyl acetate + n-pentanol system, **(B)** Variation of Wada's constant with mole fraction of ethyl acetate for ethyl acetate + n-pentanol system.



(A) **(B)**

Fig. 5 (A) Variation of excess molar volume with mole fraction of ethyl acetate for ethyl acetate + n-pentanol system **(B)** Variation of deviation in adiabatic compressibility with mole fraction of ethyl acetate for ethyl acetate + n-pentanol system.



(C) **(D)**

Fig.6 (C) Variation of deviation in viscosity with mole fraction of ethyl acetate for ethyl acetate + n-pentanol system**(D)**Variation of excess inter molecular free length with mole fraction of ethyl acetate for ethyl acetate + n-pentanol system.

From the Figs, there is a linearity of these constants at all the temperatures. These results are favoring the dipole-dipole interactions between unlike molecules in binary mixtures.

The excess values (V^E,L_f^E,$\Delta\beta_{ad}$ and $\Delta\eta$)are fitted in to an empirical equation of the form

$$A^E = X_1 X_2[A+B(X_1-X_2) + C(X_1-X_2)^2]$$

Where A^E is the excess parameter, X_1 and X_2 is the mole fraction of the two components. The coefficients A, B and C evaluated form linear least square method are given in tables. The standard deviations σ of (A^E) are evaluated by the following relation.

$$\sigma (A^E) = \Sigma(A_{exp}{}^E - A_{eq}{}^E) / (m-n)^{1/2}$$

Where m is number of experimental data and n is the number of coefficients.

The results of the excess values indicate that the experimental and theoretical values are in good correlation (Tables 4-7).

Table 4: Variation of molar volumes at 303.15K AND 313.15K.

Mole fraction X	Temperature 303.15K A =0.1115 B =-1.0615 C=-1.1985 σ = 0.1325		Temperature 313.15K A=- 0.3320 B= 1.1215 C= -2.1125 σ = 0.1115	
	$(V_M{}^E)$	$(V_m{}^E)_{cal}$	$V_m{}^E$	$(V_m{}^E)_{cal}$
0.0000	0.0000	0.0000	0.0000	0.0000
0.1088	-1.4200	-1.4200	-1.9300	-1.9300
0.2156	-2.4700	-2.4755	-3.3000	-3.3150
0.3202	-3.3100	-3.3155	-4.1800	-4.1855
0.4229	-3.8800	-3.8750	-4.8500	-4.8525
0.5237	-4.1400	-4.1400	-5.1400	-5.1400
0.6225	-3.8200	-3.8225	-4.9100	-4.9120
0.7195	-3.1800	-3.1835	-4.3100	-4.3250
0.8147	-2.3500	-2.3400	-3.4200	-3.4160
0.9082	-1.2900	-1.2900	-2.0500	-2.0500
1.0000	0.0000	0.0000	0.0000	0.0000

Table 5: Deviation in adiabatic compressibility, a, b, c and σ values.

Mole fraction X	Temperature 303.15K A = -5.3541 B = 1.5236 C = -1.6584 σ = 0.0256		Temperature 313.15K A = -2.1625 B = 0.2514 C = -3.254 σ = 0.15001	
	$\Delta\beta_{ad}$	$(\Delta\beta_{ad})_{cal}$	$\Delta\beta_{ad}$	$(\Delta\beta_{ad})_{cal}$
0.0000	0.0000	0.0000	0.0000	0.0000
0.1088	-1.6600	-1.6600	-1.9400	-1.9400
0.2156	-2.7800	-2.7825	-3.3700	-3.3790
0.3202	-3.7100	-3.7280	-4.3500	-4.3580
0.4229	-4.4000	-4.4150	-5.0200	-5.0150
0.5237	-4.7200	-4.7200	-5.3600	-5.3600
0.6225	-4.6500	-4.6585	-5.1600	-5.1810
0.7195	-4.0100	-4.0190	-4.6700	-4.6690
0.8147	-3.0800	-3.0885	-3.8700	-3.8650
0.9082	-1.8400	-1.8400	-2.3000	-2.3000
1.0000	0.0000	0.0000	0.0000	0.0000

To further substantiate the presence of interactions it is pivotal to examine the excess parameters like free volume, internal pressure and enthalpy [18]. Variation of free Volume (V_f), Internal pressure(π) and Enthalpy shown in Fig 7(A),(B) & (C) respectively. The decrease in free volume, Enthalpy and increase in internal pressure suggests the close packing of the molecules inside which was suggested by Jacobson [19-22].

Excess values of Internal Pressure and Enthalpy (π^E & H^E) are shown in Figs. 8(B) and 9(D) shows that first the graph increase, attain maximum value at 0.5 and 0.6 mole fraction of ethyl acetate respectively. Data presented in Tables [from 8 to 13] as well as Figs. 7(B) & (C) also indicate clearly that increase in temperature cause variation in the experimental values of all the excess thermodynamic.

Table 6: Deviation in Viscosity at 303.15K & 313.15K.

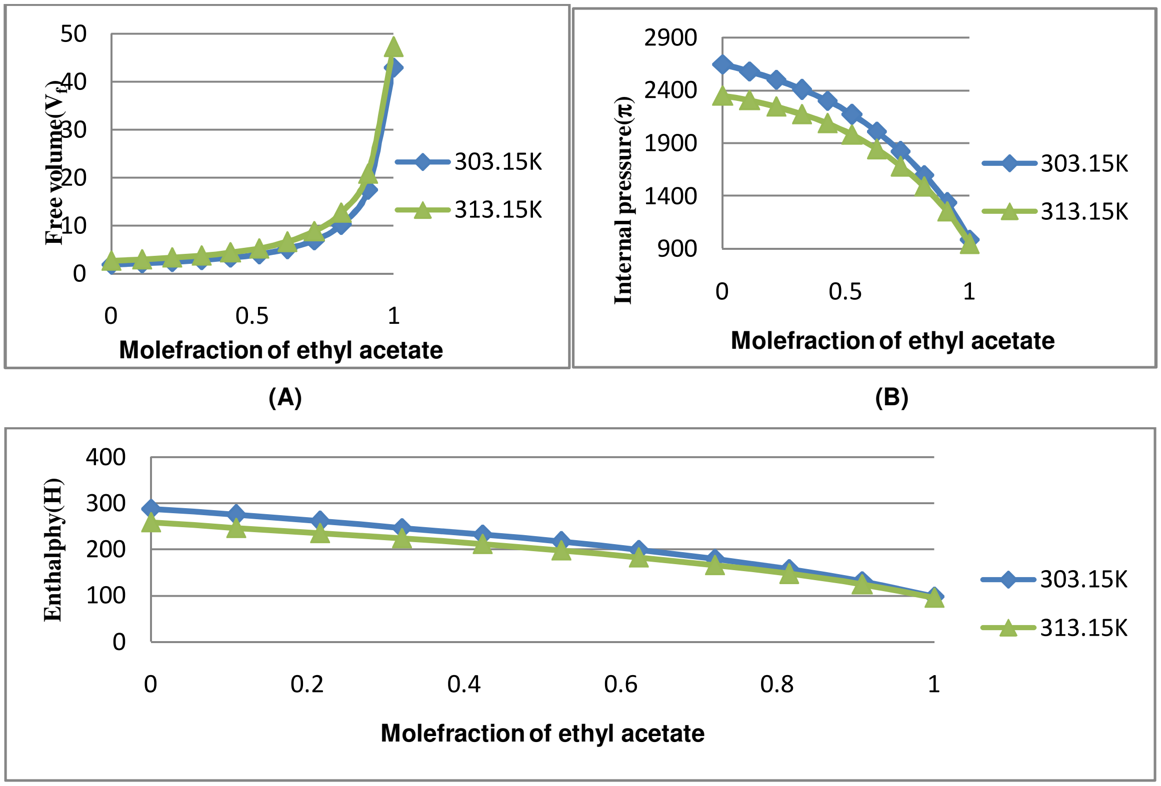
Mole fraction X	Temperature 303.15K A = 0.2299 B = - 0.2272 C = - 0.0547 σ =0.0521		Temperature 313.15K A = 0.1229 B = -0.3783 C = -0.1367 σ = 0.0021	
	$\Delta\eta$	$(\Delta\eta)_{cal}$	$\Delta\eta$	$(\Delta\eta)_{cal}$
0.0000	0.0000	0.0000	0.0000	0.0000
0.1088	0.0343	0.0343	0.0256	0.0256
0.2156	0.0612	0.0619	0.0531	0.0522
0.3202	0.0872	0.0873	0.0760	0.0772
0.4229	0.1071	0.1080	0.0938	0.0945
0.5237	0.1164	0.1164	0.1019	0.1019
0.6225	0.1057	0.1059	0.0925	0.0932
0.7195	0.0864	0.0855	0.0750	0.0762
0.8147	0.0640	0.0655	0.0544	0.0556
0.9082	0.0364	0.0364	0.0288	0.0288
1.0000	0.0000	0.0000	0.0000	0.0000

Table 7: Excess Intermolecular Free Length at 303.15K and 313.15K.

Mole fraction X	TEMPERATURE 303.15K A= 0.1847 B= - 0.2125 C= - 0.0312 σ = 0.0015		TEMPERATURE 313.15K A= 0.0545 B= -0.0401 C= 0.0755 σ = 0.0013	
	L_f^E	$(L_f^E)_{cal}$	L_f^E	$(L_f^E)_{cal}$
0.0000	0.0000	0.0000	0.0000	0.0000
0.1088	-0.0057	-0.0057	-0.0065	-0.0065
0.2156	-0.0095	-0.0086	-0.0113	-0.0118
0.3202	-0.0127	-0.0119	-0.0144	-0.0139
0.4229	-0.0150	-0.0158	-0.0166	-0.0162
0.5237	-0.0160	-0.0160	-0.0176	-0.0176
0.6225	-0.0156	-0.0166	-0.0168	-0.0164
0.7195	-0.0133	-0.0139	-0.0150	-0.0152
0.8147	-0.0102	-0.0111	-0.0124	-0.0128
0.9082	-0.0060	-0.0060	-0.0073	-0.0073
1.0000	0.0000	0.0000	0.0000	0.0000

Table 8: Free Volume, Internal Pressure and Enthalpy at 303.15k and 313.15k.

Mole Fraction X	Temperature 303.15K			Temperature 313.15K		
	V_f Cm^3 mol^{-1}	π N/m^2	H J/mole	V_f Cm^3 mol^{-1}	π N/m^2	H J/mole
0.0000	1.8442	2644.16	288.22	2.5897	2346.03	258.21
0.1088	2.0854	2577.43	274.52	2.9103	2297.90	246.11
0.2156	2.3857	2497.37	260.75	3.2973	2237.48	234.32
0.3202	2.7670	2405.76	246.68	3.7905	2161.72	222.34
0.4229	3.2748	2298.04	232.01	4.4363	2073.38	209.85
0.5237	3.9881	2169.92	216.35	5.3428	1964.91	196.43
0.6225	5.1013	2007.75	198.87	6.7387	1827.21	181.38
0.7195	6.9075	1818.65	179.57	8.9973	1662.92	164.54
0.8147	10.1821	1599.17	157.73	12.9938	1471.27	145.56
0.9082	17.4947	1333.92	131.75	21.4900	1240.06	123.29
1.0000	42.9102	986.54	97.82	47.2383	946.24	95.20



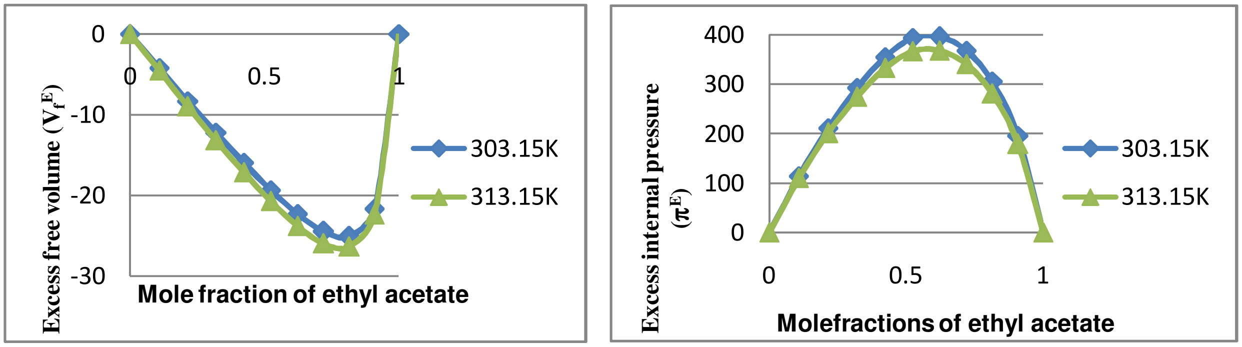
(A) **(B)**

(C)

Fig. 7. (A) Variation of free volume with mole fraction of ethyl acetate for ethyl acetate + n-pentanol system, **(B)** Variation of internal pressure with mole fraction of ethyl acetate for ethyl acetate + n-pentanol system **(C)** Variation of enthalpy with mole fraction of ethyl acetate for ethyl acetate + n-pentanol system.

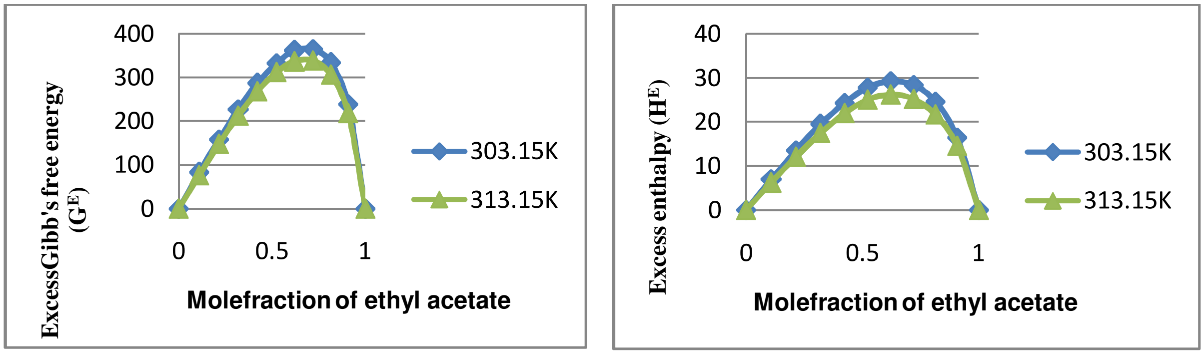
The excess values of π^E and H^E show positive, thus suggesting strong interaction between the mixing components of molecules. The variation of excess internal pressure (π^E) is entirely positive. The positive values of the excess enthalpies (H^E) indicate that the breaking of the interactions existing in the pure compounds, especially the strong interactions which is the main source of the energetic behavior. Variations in Excess free volume and Excess Gibbs free energy shown in Fig. 8(A) & 9(C) respectively. We observed that G^E is positive which indicates of strong molecular interaction [23]. Several attempts have been made by various workers [24-28] relate G^E to chemical interaction. Hence a conclusion can be drawn that chemical forces are dominating over the physical forces in the above system [29].

The ΔG^E have local maxima at mole fraction about 0.5 for the system due to the interactions of the alcohol molecules. The negative values of excess free volume, excess molar volume, excess intermolecular free length, deviation in adiabatic compressibility and positive values of excess internal pressure, excess enthalpy excess,



(A) **(B)**

Fig. 8 (A) Variation of excess free volume with mole fraction of ethyl acetate for ethyl acetate + n-pentanol system **(B)** Variation of excess internal pressure with mole fraction of ethyl acetate for ethyl acetate + n-pentanol system.



(C) (D)

Fig. 9 (C) Variation of excess Gibb's free energy with mole fraction of ethyl acetate for ethyl acetate + n-pentanol system **(D)** Variation of excess enthalpy with mole fraction of ethyl acetate for ethyl acetate + n-pentanol system.

Gibbs free energy of activation and deviation in viscosity hint to the presence of strong dipole - dipole interactions between the component molecules in the liquid mixture studied and the inherent nature of ethyl acetate predominant the existing strong interactions. The results of the values indicate that the experimental and theoretical values are in good correlation (Tables 8-13).

Table 9: Variation of excess free volume, excess internal pressure excess enthalpy and excess Gibb's free energy at 303.15K AND 313.15K.

Mole Fraction X	TEMPERATURE – 303.15K				TEMPERATURE 313.15K			
	V_f^E $Cm^3\ mol^{-1}$	π^E N/m^2	H^E J/mole	G^E Cal/mol	V_f^E $Cm^3\ mol^{-1}$	π^E N/m^2	H^E J/mole	G^E Cal/mol
0.0000	0.0000	0.00	0.00	0.00	0.0000	0.00	0.00	0.00
0.1088	-4.2288	113.70	7.03	82.66	-4.5394	104.23	5.65	73.12
0.2156	-8.3115	210.56	13.58	158.61	-8.9176	193.22	11.25	142.70
0.3202	-12.2286	292.46	19.44	227.19	-13.0979	263.97	16.34	206.08
0.4229	-15.9371	354.92	24.31	286.33	-17.0362	319.35	20.58	260.13
0.5237	-19.3604	393.78	27.84	332.79	-20.6272	351.88	23.58	302.15
0.6225	-22.3062	395.44	29.18	360.89	-23.6444	352.54	24.64	325.64
0.7195	-24.4836	367.15	28.34	364.71	-25.7170	324.03	23.62	325.88
0.8147	-25.1193	305.50	24.63	333.05	-25.9720	265.68	20.16	293.26
0.9082	-21.6458	195.21	16.45	238.90	-21.6498	165.32	13.13	204.50
1.0000	0.0000	0.00	0.00	0.00	0.0000	0.00	0.00	0.00

Table 10: Excess free volumes at 303.15K & 313.15K.

Mole fraction X	Temperature 303.15K A = -10.4425 B = -10.4125 C = -71235 σ = 0.4356		Temperature 313.15K A = -18.4253 B = -16.5266 C = -6.1256 σ = 0.7856	
	V_f^E	$(V_f^E)_{cal}$	V_f^E	$(V_f^E)_{cal}$
0.0000	0.0000	0.0000	0.0000	0.0000
0.1088	-4.2288	-4.2288	-4.5394	-4.5394
0.2156	-8.3115	-8.3563	-8.9176	-8.9456
0.3202	-12.2286	-12.2458	-13.0979	-13.1245
0.4229	-15.9371	-15.9758	-17.0362	-17.1236
0.5237	-19.3604	-19.3604	-20.6272	-20.6272
0.6225	-22.3062	-22.3785	-23.6444	-23.6231
0.7195	-24.4836	-24.4012	-25.7170	-25.7125
0.8147	-25.1193	-25.4521	-25.9720	-25.9452
0.9082	-21.6458	-21.6458	-21.6498	-21.6498
1.0000	0.0000	0.0000	0.0000	0.0000

The experimental and theoretical values using the relations of Nomoto and Van Dael ideal mixing for Ethyl acetate + n-Pentanol are given in Tables 14 and Fig 10. The table and graph replicates that there is good agreement between experimental and theoretical values calculated by VanDael ideal mixing and Nomoto relations. Here Nomoto's relation provides the best result than the result of ideal mixing relation which is in good agreement with the conclusions drawn by others [29-32]. The ratio U^2_{exp}/U^2_{imx} is used as an important tool to measure the non-ideality in the mixtures, especially in these cases where the properties other than sound velocity are not known.

Table 11: Excess Internal Pressures at 303.15K & 313.15K.

Mole fraction X	Temperature 303.15K A = -11.2356 B = -30.7896 C = 10.8532 σ = 0.6856		Temperature 313.15K A = 12.5632 B = 21.7562 C = -32.4523 σ = 0.7856	
	π^E	$(\pi^E)_{cal}$	π^E	$(\pi^E)_{cal}$
0.0000	0.00	0.00	0.00	0.00
0.1088	113.70	113.70	104.23	104.23
0.2156	210.56	210.33	193.22	193.56
0.3202	292.46	292.52	263.97	263.24
0.4229	354.92	354.45	319.35	319.87
0.5237	393.78	393.78	351.88	351.88
0.6225	395.44	395.24	352.54	352.65
0.7195	367.15	367.02	324.03	324.56
0.8147	305.50	305.75	265.68	265.35
0.9082	195.21	195.21	165.32	165.32
1.0000	0.00	0.00	0.00	0.00

Table 12: Excess Enthalpy at 303.15K &313.15K.

Mole fraction X	Temperature 303.15K A = -1.9856 B = 12.4563 C = -8.4523 σ = 0.9965		Temperature 313.15K A = -2.0012 B = -13.1235 C = 6.3652 σ = 0.8998	
	H^E	$(H^E)_{cal}$	H^E	$(H^E)_{cal}$
0.0000	0.00	0.00	0.00	0.00
0.1088	7.03	7.03	5.65	5.65
0.2156	13.58	13.35	11.25	11.65
0.3202	19.44	19.56	16.34	16.55
0.4229	24.31	24.27	20.58	20.96
0.5237	27.84	27.84	23.58	23.58
0.6225	29.18	29.38	24.64	24.87
0.7195	28.34	28.75	23.62	23.45
0.8147	24.63	24.46	20.16	20.38
0.9082	16.45	16.45	13.13	13.13
1.0000	0.00	0.00	0.00	0.00

Table 13: Excess Gibb's Free Energy at 303.15K &313.15K.

Mole fraction X	TEMPERATURE 303.15K A = - 40.2006 B = -20.3126 C = 10.4123 σ = 3.4525		TEMPERATURE 313.15K A = -24.3568 B =-14.1425 C = -36.7423 σ = 2.0102	
	G^E	$(G^E)_{cal}$	G^E	$(G^E)_{cal}$
0.0000	0.00	0.00	0.00	0.00
0.1088	82.66	82.66	73.12	73.12
0.2156	158.61	158.45	142.70	142.58
0.3202	227.19	227.05	206.08	206.26
0.4229	286.33	286.88	260.13	260.24
0.5237	332.79	332.79	302.15	302.15
0.6225	360.89	360.586	325.64	325.38
0.7195	364.71	364.25	325.88	325.27
0.8147	333.05	333.45	293.26	293.55
0.9082	238.90	238.90	204.50	204.50
1.0000	0.00	0.00	0.00	0.00

Table 14: Nomoto Relation (NOM) & Vandael Vangeel Ideal Mixing Relation (VAN) at Two Temperature 303.15K AND 313.15K.

Mole fraction X	Temperature – 303.15K						Temperature – 313.15K					
	U_{exp} m/s	U_{Nomoto}	U_{idmx}	% U_{No}	% U_{imx}	U^2_{exp}/U^2_{imx}	U_{exp} m/s	U_{Nomoto}	U_{idmx}	% U_{No}	% U_{imx}	U^2_{exp}/U^2_{imx}
0.0000	1264.50	1264.50	1264.50	0.0000	0.0000	1.0000	1228.50	1228.50	1228.50	0.0000	0.0000	1.0000
0.1088	1251.94	1249.04	1245.39	-0.2322	-0.5239	1.0106	1213.44	1212.29	1208.69	-0.0949	-0.3921	1.0079
0.2156	1237.39	1233.77	1227.46	-0.2925	-0.8022	1.0162	1197.99	1196.54	1190.16	-0.1208	-0.6534	1.0132
0.3202	1222.85	1218.62	1210.62	-0.3457	-1.0005	1.0203	1182.41	1180.95	1172.80	-0.1235	-0.8123	1.0164
0.4229	1208.39	1203.60	1194.75	-0.3959	-1.1286	1.0230	1166.26	1165.50	1156.49	-0.0657	-0.8381	1.0170
0.5237	1193.37	1188.71	1179.78	-0.3906	-1.1389	1.0232	1150.55	1150.20	1141.13	-0.0304	-0.8187	1.0166
0.6225	1179.44	1173.93	1165.62	-0.4664	-1.1714	1.0238	1134.85	1135.05	1126.64	0.0179	-0.7231	1.0146
0.7195	1163.94	1159.28	1152.21	-0.4003	-1.0081	1.0205	1120.13	1120.05	1112.95	-0.0064	-0.6406	1.0129
0.8147	1148.36	1144.76	1139.49	-0.3135	-0.7722	1.0156	1105.89	1105.20	1099.98	-0.0623	-0.5342	1.0108
0.9082	1132.90	1130.35	1127.40	-0.2250	-0.4853	1.0098	1090.62	1090.49	1087.68	-0.0120	-0.2697	1.0054
1.0000	1115.90	1115.90	1115.90	0.0000	0.0000	1.0000	1076.00	1076.00	1076.00	0.0000	0.0000	1.0000

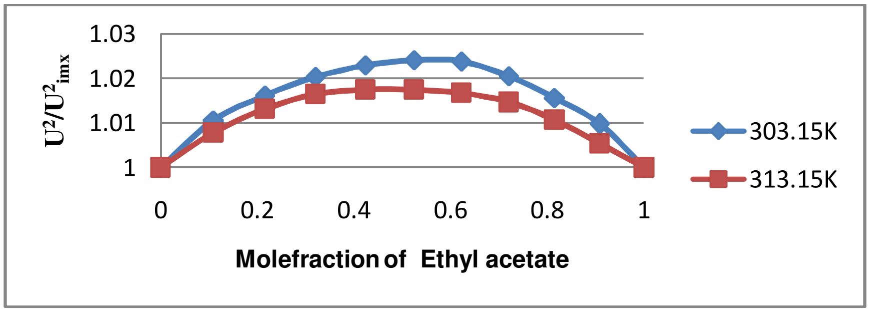


Fig. 10. Variation of U^2/U^2_{imx} with mole fraction of ethyl acetate for ethyl acetate + n-pentanol system.

CONCLUSIONS

The present study provides a comprehensive understanding of dipole-dipole interactions in binary liquid mixture taken. Data on the excess parameters has been used for understanding the structural deviations and molecular interactions between unlike molecules and they are fitted into Redlich – Kister equation to test the quality of the experimental values. Estimated coefficients and standard deviation values are also presented for better understanding the nature of the binary system.

FUTURE SCOPE

Taking this study as a reference, thermodynamic properties of many other binary mixtures can be studied at different temperatures that can help in developing new theoretical models which can help many industries in big way.

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