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Viscosity and Excess Viscosity for Binary Mixtures at Different Temperatures

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Abstract:

The calculated viscosities and excess viscosities for three binary systems (2-propanol + 2-phenylethanol) were compared to the results of Ching-Ta et al.'s experimental study at T= (298.15, 308.15, and 318.15) K over the concentration range of 0.05-0.95.   The behaviour of the examined liquids, which would generally exhibit significant interactions, was predicted using a variety of theoretical models that assumed association and non-association of the components of the mixes. The Redlich-Kister polynomial equation was fitted with the characteristics to estimate the binary coefficients and standard errors. The molecular interactions in the binary mixes were investigated using the excess viscosities. The parameters of the binary liquid mixes were also correlated using the McAllister multi-body interaction model. Testing of the models for the different systems showed that, compared with the non-association model theoretical results, the association model theoretical results were more consistent with the experimental results.

Keywords: **Viscosity, Excess viscosity, Binary systems, Molecular interaction, Theoretical models**

I. INTRODUCTION

Viscosities are crucial fundamental information utilised in molecular dynamics, solution theory, equipment design, and process simulation [1-2]. A deeper comprehension of viscosity is crucial for constructing computations involving heat transfer, mass transfer, and fluid movement and is of great physico-chemical importance. Viscosity is a concept that is frequently employed in product compositions and processing [3] in many industrial applications. The mixing qualities of two different flavour alcohols, such as 2-phenylethanol and 2-propanol, are the focus of this article. These alcoholic beverages play a crucial role in our everyday lives. In artificial essence and as a basic solvent for some flavour molecules, 2-phenylethanol is utilised. The protic and self-associated features of 2-propanol make it a useful solvent for studying hydrophobic effects. Theoretical findings on viscosity and excess viscosity for the binary system 2-propanol + 2-phenylethanol at T= (298.15,308.15, and 318.15) K across the concentration range of 0.05-0.95 at atmospheric pressure are presented in this paper. Due to the flavouring properties of 2-phenylethanol and its propensity to establish associations in the form of hydrogen bonds, several research for binary combinations using this compound have been conducted in recent years [4–7]. The Ramaswamy and Anbananthan (RA) model [8], a model proposed by Glinski [9], the McAllister multi body interaction model [10], and the Flory model [11–12] were used to analyse the data in order to assess the advantages of various models. The association constant is a variable parameter in the first two of these models, which presume association between the mixture's constituent parts. The Flory model, in contrast, presupposes that the constituents do

not associate (non-association) and that the behaviour of each liquid in the mixture merely adds to the total qualities. We selected liquids in this work that typically exhibit significant interactions. To determine the binary coefficients and standard errors for changes in viscosity, the Redlich-Kister polynomial [13] was assessed and fitted. The McAllister multi body interaction model [10], which is based on Eyring's theory of absolute response rates [14], was attempted to be correlated with the experimental results. Using the various liquid state models, the association behaviour of the liquids was connected with molecular interactions. The findings of all the theoretical models utilized were used to determine excess viscosities for all three systems, which is highly important in understanding the kind and degree of molecular interactions present in liquid mixtures. Our research's major goal was to simulate several liquid state models that could accurately capture the thermo-physical characteristics of all liquid varieties. We chose a small number of binary liquids with significant association qualities over the whole range of composition at different temperatures for that aim, and we simultaneously deployed associated and non-associated models to explore various thermo-physical features. In the present work, the measured values of density and dynamic viscosity for these binary systems were taken from the work of ching-ta et al [15] and utilized for calculations.

II. MODELLING

RA Model:

Ramswamy and Anbananthan [8] proposed the model based on the assumption of linearity of acoustic impedance with the mole fraction of components. Assuming that when solute is added to solvent the molecules interact according to the equilibrium as:

$$A + B \leftrightarrow AB \tag{1}$$

and the association constant K_{as} can be defined as;

$$K_{as} = \frac{[A\ B\ ]}{[A\ ][B\ ]} \tag{2}$$

where [A] is amount of solvent and [B] is amount of solute in the liquid mixture.
By applying the condition of linearity in viscosity with composition

$$u_{obs} = x_A\, \eta_A + x_{AB}\, \eta_{AB} \tag{3}$$

where x_A, x_{AB}, η_A and η_{AB} and η_{obs} are the mole fraction of A, mole fraction of associate AB, viscosity of A, viscosity of associate AB and observed viscosity respectively. The equilibrium reaction in the eq (3) is not complete by definition as there are molecules of non-associated component present in the liquid mixture prevailing in the high solute content. Considering the non-associated component present in the liquid mixture eq takes the fo

$$\eta_{RA} = [x_A\, \eta_A + x_B\, \eta_B + x_{AB}\, \eta_{AB}] \tag{4}$$

where x_B and η_B are the mole fraction of B and viscosity of B (non-associated component).
The general idea of this model for predicting the values of pure associate AB can be, however, exploited as;

$$K_{as} = \frac{[AB\ ]}{(C_A - [AB\ ])(C_B - [AB\ ])} \tag{5}$$

where C_A and C_B are initial molar concentrations of the components. One can take any value of K_{as} and calculate the equilibrium value of [AB] for every composition of the mixture as well as [A] = C_A-[AB] and [B] = C_B-[AB]. Replacing molar concentration by activities for concentrated solution, eq (6) becomes,

$$K_{as} = \frac{a_{AB}}{(a_A - a_{AB})(a_B - a_{AB})} \tag{6}$$

where a_A, a_B and a_{AB} are the activity of component A, Component B and associate, AB respectively. Taking equimolar activities which are equal to; $a'_A = a_A - a_{AB}$ and $a'_B = a_B - a_A$
where a'_A and a'_B are the activities of [A] and [B] in equi molar quantities respectively.

From eq (6) one can obtain the value of K_{as} as;

$$K_{as} = \frac{a_{AB}}{a_A a_B - a_A a_{AB} - a_B a_{AB} + a_{AB}^2} \qquad (7)$$

Now, assuming any value of viscosity in the hypothetical pure component AB, η_{AB}, it is possible to compare the viscosity calculated using eq (4) with the experimental values. On changing both the adjustable parameters K_{as} and η_{AB} gradually, one can get different values of the sum of squares of deviations,

$$S = \Sigma (\eta_{obs} - \eta_{cal})^2 \qquad (8)$$

where η_{obs} and η_{cal} are the observed and calculated viscosity respectively.

The minimum value of S can be obtained theoretically by a pair of the fitted parameters, but we found that for some K_{as} and η_{AB}, the value of S is high and changes rapidly while for others, it is low and changes slowly when the fitted parameters are being changed. In such cases, the value of η_{AB} should not be much lower than the lowest observed acoustic velocity of the system or much higher than the highest one. Quantitatively, it should be reasonable to accept the pair of adjustable parameters K_{as} and η_{AB} which has the physical sense and reproduces the experimental physical property satisfactorily.

Model Suggested by Glinski:

On inspecting the results obtained from RA model, Glisnki [9] suggested the equation assuming additivity with the volume fraction, ϕ of the components, the refined version of Natta and Baccaredda model [16] as,

$$\eta_{Glinski} = \frac{\eta_A \eta_B \eta_{AB}}{\phi_A \eta_B \eta_{AB} + \phi_B \eta_A \eta_{AB} + \phi_{AB} \eta_A \eta_B} \qquad (9)$$

where η_{cal} is the theoretical acoustic velocity of binary liquid mixture, ϕ_A, ϕ_B are the volume fractions of component A and B and η_A, η_B and η_{AB} are the acoustic velocity of components A, B and AB. The numerical procedure and determination of association constant, K_{as}, was similar to that described before and the advantage of this method as compared with the earlier one was that the data on densities of liquid mixture are not necessary except those of pure components needed to calculate the volume fractions. In this context the importance of models assuming associated liquids already mentioned and was further developed and elaborated by Reis et al [17].

Flory model:

Theories relate the viscosities of liquids either to the activation energy required for the molecule to overcome the attraction forces of its neighbors and flow to a new position absolute rate theory) or the probability that an empty site exists near a molecule (free volume theory). Mecedo and Litovitz [18] made the hypothesis that the two effects are combined so that the probabilities for viscous flow is taken as the product of the probabilities for acquiring sufficient activation energy and of the occurrence of an empty site. Similar assumptions are made for solutions. A bridge can be formed to the thermodynamic functions of mixing by assuming a simple relationship between solution activation energy $\Delta G^{\neq}$, the pure liquid activation energy $\Delta G_1^{\neq}$, and the residual Gibbs free energy of mixing

ΔG_M^R.

$$\Delta G^{\neq} = X_1 \Delta G_1^{\neq} + X_2 \Delta G_2^{\neq} - \Delta G_M^R \qquad (10)$$

For pure components and the solution the viscosities η_i are described as:

$$\eta_i = A \exp\left[\Delta G_1^{\#} / RT + (\tilde{V}_1 - 1)^{-1}\right] \qquad (11)$$

where $\tilde{v}_1$ is the reduced volume, Taking logarithms,

$$\ln \eta_i = \ln A + \frac{\Delta G_1^{\#}}{RT} + (\tilde{V}_1 - 1)^{-1} \qquad (12)$$

Applying eq. (12) to the solution and pure component, one obtains

$$\Delta \ln \eta = \ln \eta_{sol} - (X_1 \ln \eta_1 + X_2 \ln \eta_2) \tag{13}$$

By utilizing eqs. (10) (11) and (13),the values of ΔG_M^R was evaluated from consideration of Flory theory and may be expressed as follows,

$$\Delta G_M^R = X_1 P_1^* V_1^* \left[\left(\frac{1}{\tilde{V}_1} - \frac{1}{\tilde{V}} \right) + 3\tilde{T}_1 \ln \frac{(\tilde{V}_1^{1/3} - 1)}{(\tilde{V}^{1/3} - 1)} \right] + \frac{X_1 P_1^* V_1^* \theta_2 X_{12}}{V_1^*} \tag{14}$$

By combining the Eyring [14] relation for the residual Gibbs free energy of mixing, ΔG_M^R and $\Delta G^{\#}$, we have obtained the following expression for the viscosity η of a binary liquid system:

$$R T \ln \eta = \sum_{i=}^{2} x_i \ln \eta_i - \left[\sum_{i=1}^{2} x_i P_i^* v_i^* \left\{ (1/\tilde{v}_i - 1/\tilde{v}) + 3\tilde{T}_i \ln \frac{(\tilde{v}^{1/3} - 1)}{(\tilde{v} - 1)} \right) \right.$$

$$= \sum_{i=1}^{2} \sum_{j=1}^{2} (x_i v_i^* \theta_j x_{ij} / \tilde{v}_i) / RT \left(\frac{1}{\tilde{v} - 1} \right) - \left(\sum_{i=1}^{2} \frac{x_i}{\tilde{v} - 1} \right) \tag{15}$$

Here, P^*, v^*, $\tilde{v}$, $\tilde{T}$, θ and X_{ij} are the characteristic pressure, characteristic volume, reduced volume, reduced temperature, site fraction and interaction parameter respectively. All the notations in the above equation have their usual significance as detailed out by Flory [13-14] and others [19-20].

McAllister – three body model:
Eyring [14] gave the following equation relating kinematic viscosity of a liquid with to temperature

$$\partial = \frac{hN}{M} e^{\Delta G^*/RT} \#\tag{16}$$

The movement of the molecule between two layers of liquid may be regarded as the passage of the system over a potential energy burrier, related to ΔG^* .McAllister considered a number of different three bodied planar encounters in the study of the viscosity of a mixture of molecules type (1) and (2). He proposed that the total free energy of activation will be dependent on thefree energy of activation (ΔG_i, ΔG_{ij} or Δs_{ijk}) of individual interactions and their fraction of total occurrences (x_i^3, $x_i^2 x_j$, x_j^2, $x_i x_j^2$ or $x_i x_j x_k$).Hence,

$$\Delta G^* = x_1^2 \Delta G_1^* + x_1^2 x_2 \Delta G_{121}^* + 2 x_1^2 x_2 \Delta G_{112}^* + x_1 x_2^2 \Delta G_{212}^* + 2 x_1 x_2^2 \Delta G_{123}^* + x_2^3 \Delta G_2^* \tag{17}$$

He made following additional assumptions as

$$\Delta G_{121}^* = \Delta G_{112}^* \equiv \Delta G_{12}^* \text{ and } \Delta G_{121}^* = \Delta G_{122}^* = \Delta G_{21}^*$$

Also, $\Delta G_{12}^* = \dfrac{\Delta G_{121}^* + 2\Delta G_{112}^*}{3}$ and $\Delta G_{21}^* = \dfrac{\Delta G_{212}^* + 2\Delta G_{122}^*}{3}$ (18)

Hence eq. (17) may written as

$$\Delta G^* = x_1^3 \Delta G_1^* + 3 x_1^2 x_2 \Delta G_{12}^* + 3 x_1 x_2^2 \Delta G_{21}^* + x_2^3 \Delta G_2^* \tag{19}$$

Now applying eq (17) for each set of interactions (i.e.*111,121,211, 112; 212, 122, 221; and 222*) and then taking logarithms of equations so obtained to eliminate free energy terms, following equation is obtained

$$\ln \eta = x_1^3 \ln \eta_1 + 3x_1^2 x_2 \ln \eta_{12} + 3x_1 x_2 \ln \eta_{21} + x_2^3 \ln \eta_2 - \ln[x_1 + x_2 M_2 / M_1] + 3x_1^2 x_2 \ln[(2 + M_2 / M_1)/3]$$

$$+ 3 x_1 x_2^2 \ln[(1 + 2 M_2 / M_1)/3] + x_2^3 \ln[M_2 / M_1] \tag{20}$$

Where

$$M_{12} = \frac{2 M_1 + M_2}{3} \text{ and } M_{21} = \frac{M_1 + 2 M_2}{3} \tag{21}$$

McAllister –four body model:

If there is a much difference in size of two molecules, then a four body model approaches nearly a 3-dimensional treatment. Again considering different interactions and their fraction of total occurrences, energy of activation may be written as sum of energy of activations of various interaction

$$\Delta G^* = x_1^4 \Delta G_1^* + 4x_1^3 x_2 \Delta G_{1112}^* + 6x_1^2 x_2^2 \Delta G_{112}^* + 4x_1 x_2^3 \Delta G_{2221}^* + x_2^4 \Delta G_2^* \qquad (22)$$

by techniques entirely analogous to method given above, the following equation is derived;

$$\ln \eta_{mix} = x_1^4 \ln \eta_1 + 4x_1^3 x_2 \ln \eta_{1112} + 6x_1^2 x_2 \ln \eta_{1122} + 4x_1 x_2^2 \ln \eta_{222} + x_2^4 \ln \eta_2 - \ln(x_1 + x_2 M_2 / M_1)$$
$$+ 4x_1^3 x_2 \ln[(3 + M_2 / M_1)/4] + 6x_1^2 x_2^2 \ln[(1 + M_2 / M_1)/2]$$
$$+ 4x_1 x_2^3 \ln[(1 + 3M_2 / M_1)/4] + x_2^4 \ln(M_2 / M_1) \qquad (23)$$

e $\eta, x_1, \eta_1, M_1, x_2, \eta_2$ and M_2 are the viscosity of mixture, mole fraction, viscosity and molecular weight of pure component 1 and 2 respectively. McAllister coefficients are adjustable parameters that are characteristic of the system.

III. RESULTS AND DISCUSSION:

The divergence from the outcome that would be anticipated if the attributes of the components were treated additively is typically used to assess association properties. The behaviour of each mixture with association between the components was predicted using the RA model, which relies on the linearity of acoustic impedance with the amount-of-substance proportion of components. This model was adjusted [9] and tested [21] after being developed. The computations were done using a computer programme, and either manually or automatically changing the settings. The fitted parameters were the association constant (Kas) and A, B, where A, B is the acoustic velocity in a fictitious pure liquid containing only the species AB generated by association of the constituents A and B. The equilibrium concentrations of the species [A], [B], and [AB] will change when the parameters are modified, and this might have an impact on the viscosity. To calculate the sum of squares for the deviation, the discrepancies between experimental and theoretical viscosity values were employed. Because the AB species was formed by association following mixing, it was believed that three species—A, B, and AB—rather than just two—A and B—were present in solution. One may think of the acoustic velocity in the pure association as a fitting one with a value of Kas. An known equation that has been tried on any mixes was used to generate the Flory model's thermal expansion coefficient (α) and isothermal compressibility (β_T) values [22]. The mixing function *(Δσ)* can be represented mathematically by the Redlich-Kister polynomial [13] for correlating experimental data:

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$$y = x_i(1 - x_1) \sum_{i=0}^{p} A_i(2x_1 - 1)^i \qquad (24)$$

where y is the change in viscosity *(Δη)*, x_i is the amount-of-substance fraction, and A_i is the coefficient. The values of the coefficients are summarized along with the standard deviations between the experimental and fitted values of the respective function (Table 1). For the dynamic viscosity, the range was 0.005-0.011. McAllister coefficients a, b and c were calculated and standard deviations between the calculated and experimental values were determined (Table 2).

Excess viscosity was calculated by the following equation;

$$\eta E = \eta - \sum_{i=1}^{2} x_i \eta_i \qquad (25)$$

where η^E is excess viscosity is theoretical viscosity, η_i is viscosity for i^{th} component and x_i amount-of-substance fraction for i^{th} component.

Tables 3–4 include data for the liquid mixes, which were assessed. With a few exceptions, the viscosity and excess viscosity decreased for all models at most temperatures as the amount-of-substance percentage grew. For each model, the absolute average percent variations in viscosity were computed (Table 4). Models based on association assumptions outperformed those based on non-association. Given that the Flory model was created for non-electrolyte -meric spherical chain molecules and that the system under research in the current study may exhibit contacts and association, a higher deviation for the values produced by the Flory model may be possible. Additionally, the equations used to calculate and T are of an empirical character. Strong interactions and associations lead to negative deviations. The relative potency of these two opposing forces determines the actual sign and size of the variances. The interaction between the constituent molecules is what causes the deviations to lack smoothness. The % deviations and excess viscosity values derived from the various models (Table 4) show that our theoretical conclusions are in agreement with the experimental data. Using several models, plots were made illustrating variations in viscosity, E with the amount-of-substance fraction at various temperatures (Figures 1). In each instance, the association models had less variation in the extra viscosity than the Flory model, which is a non-association model. Compared to the Glinski model, the RA model produced superior outcomes. At higher temperatures, there are stronger interactions between the liquid molecules, as evidenced by the patterns seen in all the figures, which were comparable and exhibited negative changes with rising temperature. For all three binary mixes, excess viscosity, E values are negative over the full mole fraction range. At various temperatures, the effects of excessive viscosity exhibit the same patterns. For all of these binary systems, E values rise from T= 298.15K to T= 318.15K. Standard deviations between the predicted and experimental values were derived for McAllister coefficients a, b, and c (Table 2).

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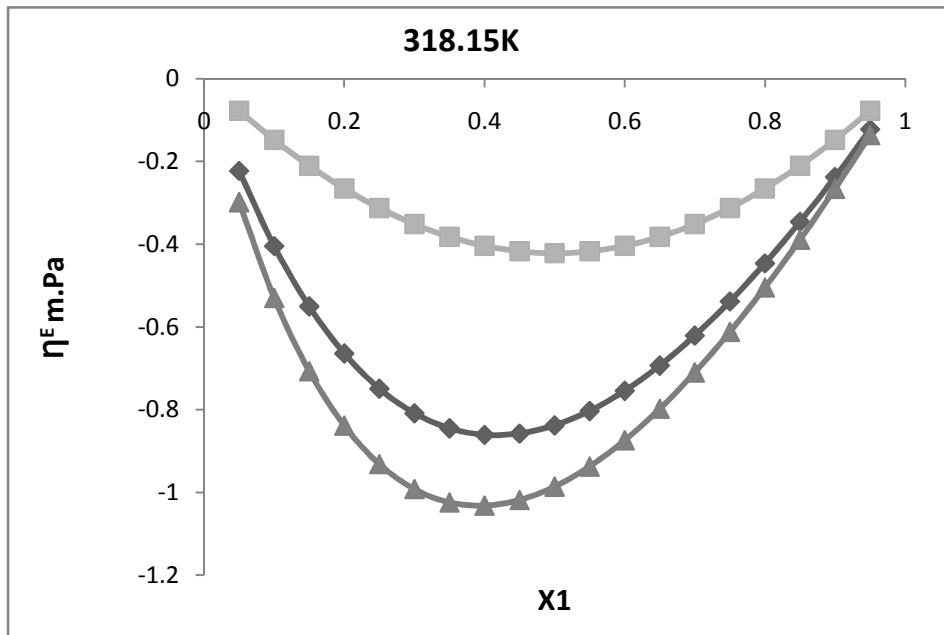
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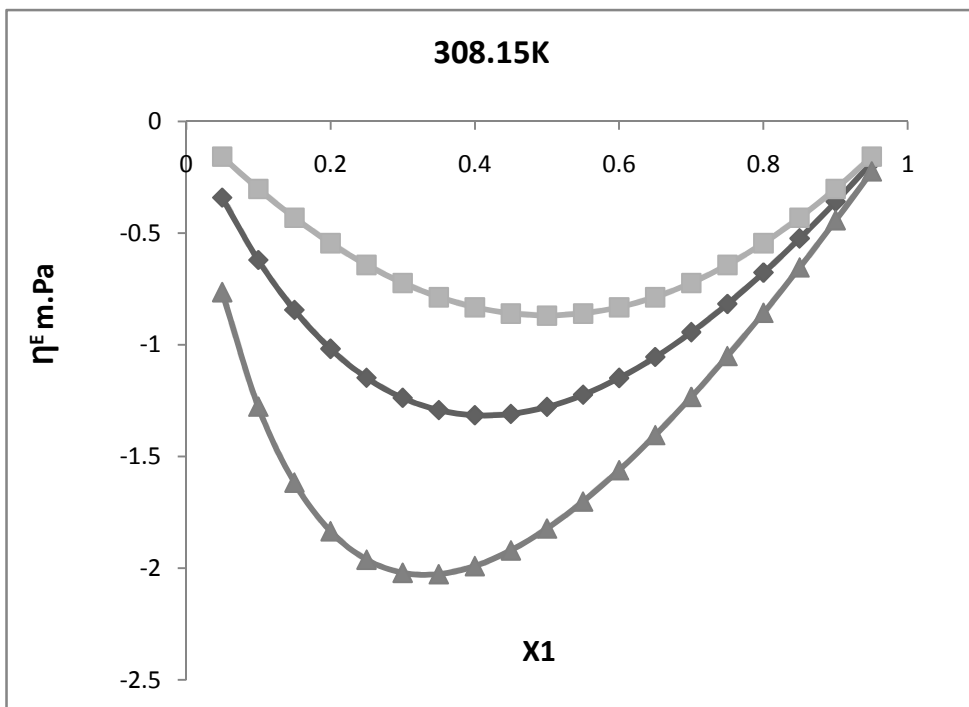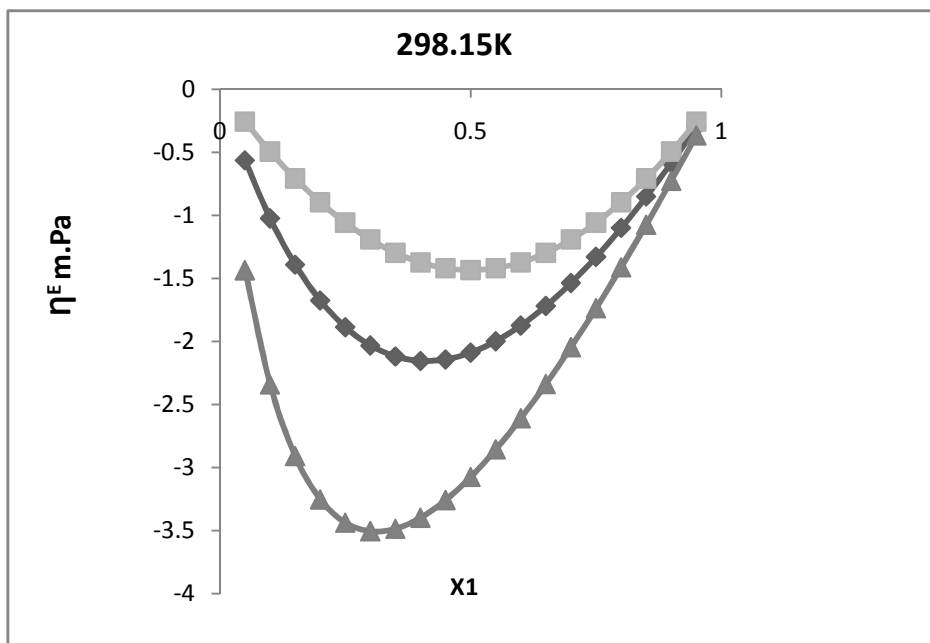
Figure 1 Changes in the excess viscosity (η^E) with the amount-of-substance fraction (x_1) for 2-propanol + $(1–x)$ 2-phenylethanol at 298.15, 308.15 and 318.15 K. Results were obtained using the following models: black diamond, Flory model, black square, Ramaswamy and Anbananthan model, and black triangle, model suggested by Glinski

Table 1 Coefficients of Redlich- Kister Polynomial and Standard Deviation (σ) for Viscosity of Binary Liquid Mixtures at Various Temperatures

2-Propenol+2-Phenylethnol

T/K	A_0	A_1	A_2	A_3	Std dev. (σ)
298.15	-5.35	0.81	-0.44	-0.81	0.008
308.15	-3.49	0.34	0.02	-0.19	0.009
318.15	-2.00	0.09	0.17	-0.19	0.011

Table 2 Parameters of McAllister three body and four Body Interaction Models and Standard Deviation (δ) for Viscosity of Binary Liquid Mixtures at Various Temperatures

2-Propenol+2-Phenylethanol

Mc Allister Three Body				Mc Allister 4 body			
T/K	a	b	Std dev	a	b	c	Std dev
298.15	4.90	**7.84**	0.084	4.05	6.31	8.29	0.038
308.15	3.29	5.25	0.029	2.75	4.29	5.45	0.029
318.15	2.52	3.83	0.014	2.09	3.23	3.91	0.040

Table 3 Comparison of Absolute Average Percent Deviation of Viscosity obtained from Various Theoretical Models for Binary Liquid mixtures at (T=298.15, 308.15 and 318.15) K

2-Propenol+2-Phenyl ethanol

				Absolute Average % deviation			
T/K	K_{as}	η_{ab}/mPa.s	η Flory /mPa.s	η RS/mPa.s	$\eta_{Glinski}$ /mPa.s	η McA-3body /mPa.s	η McA-4body /mPa.s
298.15	0.90	2.10	9.53	1.23	23.84	1.23	0.51
308.15	0.80	1.65	7.75	0.47	19.17	0.59	0.56
318.15	0.70	2.50	8.93	2.06	12.96	0.39	1.08

CONCLUSION:

Models assuming association give more reliable results than those assuming non-association. Association models can be helpful for determining how components in a mixture associate. This can be achieved using the viscosity in a hypothetical pure component and the observed dependence of concentration on the composition of a mixture.

Table 4 Experimental Density, Experimental Viscosity, Theoretical Viscosity from Flory Model, Ramaswami and Anbananthan Model (RS),Model Devised by Glinski, McAllister 3 body (McA-3) and McAllister 4 body (McA-4) models and their Percent deviations for Binary Liquid Systems at various temperatures

2-Propenol+2-Phenyl ethanol

X1	ρ_{mix} g/cc	η_{exp} /mPa.s	ηFlory /mPa.s	η_{RS} / mPa.s	$\eta_{Glinski}$/ mPa.s	McA-3body/ mPa.s/	McA-4body/ mPa.s	%ΔFlory/ mPa.s	%Δ$_{RS/}$ mPa.s	%Δ$_{Glinski/}$ mPa.s	%ΔMcA-3body/ mPa.s	%ΔMcA-4body/ mPa.s
T=298.15K												
0.05	1.0094	10.67	10.37	10.68	9.50	10.60	10.55	2.73	-0.14	10.90	0.60	1.08
0.10	1.0021	9.93	9.45	9.98	8.13	10.00	9.92	4.88	-0.44	18.13	-0.64	0.14
0.15	0.9944	9.26	8.61	9.30	7.10	9.41	9.33	6.93	-0.45	23.32	-1.67	-0.75
0.20	0.9864	8.62	7.86	8.64	6.29	8.84	8.76	8.74	-0.30	27.03	-2.63	-1.67
0.25	0.9780	8.00	7.19	8.02	5.64	8.30	8.22	10.16	-0.20	29.52	-3.73	-2.80
0.30	0.9691	7.41	6.58	7.42	5.10	7.77	7.71	11.22	-0.12	31.09	-4.94	-4.08
0.35	0.9599	6.86	6.02	6.84	4.66	7.27	7.22	12.18	0.19	32.08	-5.98	-5.21
0.40	0.9502	6.35	5.52	6.30	4.28	6.79	6.74	13.05	0.75	32.62	-6.86	-6.16
0.45	0.9400	5.86	5.07	5.79	3.95	6.32	6.29	13.56	1.22	32.57	-7.89	-7.25
0.50	0.9293	5.41	4.65	5.31	3.67	5.89	5.85	14.00	1.90	32.19	-8.75	-8.12
0.55	0.9180	4.98	4.28	4.86	3.42	5.47	5.44	14.05	2.40	31.26	-9.86	-9.20
0.60	0.9062	4.57	3.94	4.44	3.20	5.07	5.04	13.86	2.91	29.94	-11.00	-10.28
0.65	0.8936	4.17	3.63	4.05	3.01	4.70	4.67	13.11	3.00	27.93	-12.65	-11.83
0.70	0.8804	3.79	3.34	3.69	2.83	4.35	4.31	11.89	2.80	25.30	-14.66	-13.73
0.75	0.8663	3.44	3.08	3.35	2.68	4.02	3.98	10.33	2.42	22.16	-16.89	-15.84
0.80	0.8513	3.10	2.85	3.05	2.53	3.71	3.67	8.22	1.64	18.28	-19.60	-18.48
0.85	0.8355	2.81	2.63	2.77	2.41	3.42	3.39	6.36	1.29	14.34	-21.76	-20.66
0.90	0.8186	2.54	2.43	2.52	2.29	3.15	3.12	4.34	0.88	9.96	-23.93	-22.97
0.95	0.8005	2.28	2.25	2.29	2.18	2.90	2.88	1.41	-0.36	4.40	-27.05	-26.43
T=308.15K												
0.05	1.0023	7.05	6.88	7.06	6.47	7.05	7.00	2.45	-0.16	8.44	0.01	0.76
0.10	0.9949	6.59	6.30	6.62	5.66	6.66	6.58	4.46	-0.38	14.40	-0.93	0.26
0.15	0.9868	6.15	5.78	6.19	5.02	6.27	6.19	6.02	-0.71	18.57	-2.04	-0.62
0.20	0.9787	5.73	5.31	5.78	4.51	5.90	5.82	7.34	-0.93	21.57	-3.12	-1.65
0.25	0.9702	5.34	4.88	5.38	4.08	5.55	5.47	8.67	-0.79	23.89	-3.90	-2.49
0.30	0.9613	4.97	4.49	5.00	3.72	5.21	5.14	9.65	-0.71	25.39	-4.83	-3.53

0.35	0.9520	4.62	4.14	4.64	3.42	4.88	4.83	10.49	-0.46	26.35	-5.68	-4.51
0.40	0.9423	4.29	3.82	4.30	3.16	4.57	4.53	10.98	-0.29	26.72	-6.71	-5.65
0.45	0.9321	3.96	3.52	3.97	2.93	4.28	4.24	11.14	-0.22	26.53	-7.94	-6.95
0.50	0.9213	3.67	3.26	3.66	2.72	4.00	3.96	11.30	0.14	26.11	-8.98	-8.01
0.55	0.9100	3.39	3.01	3.38	2.54	3.74	3.70	11.15	0.39	25.22	-10.23	-9.23
0.60	0.8981	3.12	2.79	3.10	2.38	3.49	3.45	10.76	0.61	23.93	-11.63	-10.52
0.65	0.8855	2.88	2.58	2.85	2.24	3.25	3.22	10.17	0.83	22.30	-13.13	-11.88
0.70	0.8721	2.63	2.40	2.62	2.11	3.03	3.00	9.03	0.64	20.00	-15.22	-13.79
0.75	0.8580	2.41	2.22	2.40	2.00	2.83	2.79	7.60	0.32	17.25	-17.59	-15.99
0.80	0.8430	2.20	2.07	2.20	1.89	2.64	2.60	6.13	0.11	14.27	-19.93	-18.22
0.85	0.8270	2.01	1.92	2.01	1.79	2.46	2.43	4.39	-0.25	10.83	-22.57	-20.88
0.90	0.8101	1.86	1.79	1.84	1.71	2.30	2.27	3.87	0.77	8.34	-23.62	-22.16
0.95	0.7920	1.69	1.66	1.69	1.62	2.15	2.13	1.73	0.15	4.09	-26.78	-25.83
T=318.15K												
0.05	0.9942	4.95	4.81	4.95	6.45	4.97	4.93	2.94	0.01	4.46	-0.40	0.48
0.10	0.9868	4.65	4.42	4.68	5.64	4.72	4.66	4.78	-0.75	7.48	-1.69	-0.28
0.15	0.9790	4.37	4.07	4.41	5.01	4.48	4.41	6.68	-1.11	10.26	-2.61	-0.94
0.20	0.9708	4.10	3.76	4.16	4.49	4.24	4.17	8.41	-1.31	12.65	-3.40	-1.67
0.25	0.9623	3.85	3.47	3.91	4.06	4.01	3.95	9.86	-1.48	14.59	-4.21	-2.55
0.30	0.9534	3.60	3.21	3.67	3.71	3.79	3.73	10.88	-1.82	15.96	-5.25	-3.72
0.35	0.9440	3.36	2.97	3.43	3.40	3.57	3.53	11.68	-2.09	16.99	-6.30	-4.91
0.40	0.9342	3.13	2.75	3.21	3.14	3.37	3.33	12.16	-2.42	17.61	-7.49	-6.24
0.45	0.9239	2.91	2.55	2.99	2.91	3.17	3.13	12.37	-2.75	17.88	-8.78	-7.62
0.50	0.9131	2.71	2.37	2.78	2.71	2.98	2.95	12.68	-2.65	18.13	-9.74	-8.60
0.55	0.9017	2.52	2.20	2.59	2.53	2.80	2.77	12.79	-2.49	18.09	-10.76	-9.58
0.60	0.8897	2.34	2.05	2.40	2.38	2.62	2.59	12.58	-2.37	17.68	-11.98	-10.68
0.65	0.8770	2.16	1.91	2.22	2.23	2.46	2.43	11.84	-2.54	16.66	-13.71	-12.23
0.70	0.8636	1.99	1.78	2.04	2.11	2.30	2.27	10.72	-2.81	15.19	-15.78	-14.09
0.75	0.8494	1.82	1.66	1.88	1.99	2.16	2.12	9.16	-3.20	13.19	-18.27	-16.38
0.80	0.8343	1.67	1.55	1.73	1.89	2.02	1.98	7.18	-3.66	10.68	-21.19	-19.16
0.85	0.8183	1.53	1.44	1.58	1.79	1.89	1.86	5.42	-3.45	8.24	-23.71	-21.70
0.90	0.8013	1.42	1.35	1.44	1.70	1.77	1.74	4.66	-1.68	6.66	-24.82	-23.09
0.95	0.7831	1.30	1.26	1.31	1.62	1.65	1.64	2.79	-0.65	3.86	-27.31	-26.20

CONCLUSION:

Models assuming association give more reliable results than those assuming non-association. Association models can be helpful for determining how components in a mixture associate. This can be achieved using the viscosity in a hypothetical pure component and the observed dependence of concentration on the composition of a mixture.

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