

EXPERIMENTAL DYNAMIC VISCOSITIES OF BINARY MIXTURES: ACETIC ACID + WATER, BENZENE, TOLUENE, n – HEXANE, n – HEPTANE AT 296.15, 302.15, 308.15, 314.15 AND 319.15 K

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Abstract: This paper reports the dynamic viscosities of acetic acid + water, benzene, toluene, n-hexane and n-heptane at five temperatures in the range of 23⁰ C to 46⁰ C throughout the whole concentration range. The viscosity deviations were calculated from experimental data and fitted to a Redlich-Kister polynomial function. Results were analyzed in terms of molecular interactions.

Keywords: *dynamic viscosities, viscosity deviations, binary mixtures*

INTRODUCTION

This paper, as part of a continuing study in our laboratory [1–3] presents experimental viscosities for the binary mixtures. It is known that binary liquid mixtures are frequently met in mass transfer processes (extraction, absorption, distillation, etc.) at both industrial scale and pilot scale, and for this reason, properties like density, viscosity, refraction index, etc, were determined by numerous researchers [4–8] with the object of improving the respective processes and designing.

The viscosity of binary liquid mixtures often represented the subject of many studies [9–11]. The theoretical studies were focused on the possibilities of determining the

viscosity of liquid mixtures beginning from the component properties and some molecular models, which can represent the variety of existent mixtures in practice. The viscous flow is considered as a phenomenon of transition of molecule from an equilibrium state to another state, over a barrier of potential energy. This mechanism has been treated by Eyring [12] by similitude with the theory of absolute-reaction rates. Many researches [13–17] have studied the viscosity of binary liquid mixtures establishing intrinsic parameters of viscous flow. For the dependence of liquid viscosity on temperature there are known, particularly, Guzman-Andrade and Walther-Ubbelohde equations, which requires verification for each class of pure liquids, with close molecular structure and so much more for solutions.

For binary liquid mixtures, if the components mixture develops without volume and enthalpy variation, then they have an ideal behavior. For the mixture behave ideally must that the two molecular species to differ as little as possible one to the other, and the interaction forces between the different molecules to be equal to the interaction forces between the identical molecules. The deviations from the ideality of solutions are determined by the solute distribution between the two solvents [18]. It is possible to be explained the nature of the deviations from the ideality of solutions on the basis of hydrogen bond potential and internal pressure. The emphasizing of deviations from ideality is made by introduction of excess magnitudes.

Excess magnitudes (excess volume, excess enthalpy, excess viscosity, etc.) can be correlated with many empirical models, but the most used by researchers at the present is the model proposed by Redlich-Kister (1948) [19] and improved by McAllister, respectively, Lobe.

Postigo and other [20] present the experimental data of viscosity for the following binary systems: 1-decanol with hexane, 1-decanol with diethylamine, and hexane with diethyl-amine at 10, 25 and 40°C and barometric pressure for molar fractions in the range 0 – 0.5. Then the authors used these data in order to calculate the excess viscosity. Oswal and Desai [21–23] have also investigated the excess viscosity corresponding to the binary mixtures of dipropyl-amine and dibutyl-amine with ethanol, propanol, butanol, pentanol, heptanol and decanol for the entire range of molar fractions, at 303.15 and 313.15 K.

The viscosity measurement for the systems: water-1,4-dioxan, water-propionic acid, toluene-propionic acid, has been studied by Ionescu, Lisa and other [24-25] in order to determine the intrinsic parameters of viscous flow.

The purpose of this work is to report dynamic viscosities of the acetic acid + water, benzene, toluene, n-hexane and n-heptane binary mixtures at temperatures 296.15, 302.15, 308.15, 314.15 and 319.15 K at atmospheric pressure for the whole range of compositions.

No literature data on density or dynamic viscosities are available for these mixtures.

EXPERIMENTAL

The liquids involved in the experiments, benzene, toluene, n-hexane, n-heptane, and acetic acid, were of analytical purity. Ubbelohde viscosimeters with capillaries, thermostated with a precision of 0.01 °C, were used. Preparation of the solutions was performed through weighing. This operation employed for solutions synthesizing determining was performed with accuracy of ± 0.0001 g.

For acetic acid – water, acetic acid – benzene, acetic acid – toluene, acetic acid – n-hexane, acetic acid – n-heptane solutions, an experimental determination of viscosity at nine values of concentration have been made, and were expressed in molar fractions and five values of temperatures.

For accurate values, a great attention was accorded in maintaining of a constant value of temperature by using an ultrathermostate.

Viscometric behavior

Experimental dynamic viscosities η of the pure acetic acid, water, acetic acid – water solutions are shown in Table 1.

Table 1. Experimental data for dynamic viscosity η [mPa·s]

$X_{\text{acetic acid}}$	T, K				
	296.15	302.15	308.15	314.15	318.15
0.0000	0.9426	0.8413	0.7399	0.6386	0.5542
0.1252	1.1767	0.9942	0.8116	0.6291	0.4769
0.2439	1.2822	1.1467	1.0113	0.8759	0.7629
0.3728	1.4250	1.2832	1.1414	0.9997	0.8816
0.4960	1.5821	1.4097	1.2373	1.0649	0.9213
0.6279	1.5571	1.3948	1.2324	1.0700	0.9348
0.7476	1.4204	1.2469	1.0735	0.9000	0.7555
0.8774	1.1006	1.0037	0.9067	0.8097	0.7289
1.0000	1.1549	1.0564	0.9697	0.8931	0.8358

Experimental dynamic viscosities η of the pure acetic acid, benzene, acetic acid – benzene solutions are shown in Table 2.

Table 2. Experimental data for dynamic viscosity η [mPa·s]

$X_{\text{acetic acid}}$	T, K				
	296.15	302.15	308.15	314.15	318.15
0.0000	0.6277	0.5756	0.5297	0.4889	0.4584
0.1244	0.6282	0.5821	0.5360	0.4899	0.4515
0.2504	0.6122	0.5707	0.5291	0.4876	0.4530
0.3730	0.6537	0.6053	0.5568	0.5084	0.4680
0.4990	0.6899	0.6378	0.5858	0.5338	0.4904
0.6245	0.6848	0.6280	0.5712	0.5144	0.4670
0.7505	0.7924	0.7334	0.6744	0.6154	0.5663
0.8757	0.9044	0.8424	0.7804	0.7183	0.6666
1.0000	1.1549	1.0564	0.9697	0.8931	0.8358

Experimental dynamic viscosities η of the pure acetic acid, toluene, acetic acid – toluene solutions are shown in Table 3.

Table 3. Experimental data for dynamic viscosity η [mPa·s]

$X_{\text{acetic acid}}$	T, K				
	296.15	302.15	308.15	314.15	318.15
0.0000	0.5665	0.5276	0.4927	0.4614	0.4376
0.1264	0.3677	0.3488	0.3299	0.3110	0.2953
0.2514	0.3683	0.3508	0.3334	0.3159	0.3014
0.3976	0.3808	0.3622	0.3436	0.3250	0.3095
0.4992	0.4798	0.4316	0.3833	0.3351	0.2949
0.6279	0.4265	0.4039	0.3813	0.3587	0.3399
0.7476	0.4770	0.4515	0.4260	0.4005	0.3792
0.8770	0.4776	0.4518	0.4261	0.4004	0.3789
1.0000	1.1549	1.0564	0.9697	0.8931	0.8358

Experimental dynamic viscosities η of the pure acetic acid, n-hexane, acetic acid – n-hexane solutions are shown in Table 4.

Table 4. Experimental data for dynamic viscosity η [mPa·s]

$X_{\text{acetic acid}}$	T, K				
	296.15	302.15	308.15	314.15	318.15
0.0000	0.3124	0.2956	0.2804	0.2664	0.2557
0.1237	0.6449	0.5952	0.5455	0.4957	0.4544
0.2486	0.6586	0.6045	0.5505	0.4965	0.4514
0.3751	0.7019	0.6440	0.5862	0.5282	0.4799
0.5012	0.7899	0.7269	0.6641	0.6007	0.5482
0.6360	1.0235	0.9280	0.8327	0.7373	0.6578
0.7508	1.1557	1.0620	0.9684	0.8748	0.7968
0.8693	1.5609	1.4264	1.2917	1.1571	1.0450
1.0000	1.1549	1.0564	0.9697	0.8931	0.8358

Experimental dynamic viscosities η of the pure acetic acid, n-heptane, acetic acid – n-heptane solutions are shown in Table 5.

Table 5. Experimental data for dynamic viscosity η [mPa·s]

$X_{\text{acetic acid}}$	T, K				
	296.15	302.15	308.15	314.15	318.15
0.0000	0.6276	0.5756	0.5297	0.4889	0.4584
0.1273	0.6424	0.5948	0.5473	0.4997	0.4602
0.2566	0.6448	0.5954	0.5461	0.4967	0.4556
0.3784	0.6769	0.6259	0.5750	0.5240	0.4816
0.5029	0.7028	0.6519	0.6011	0.5502	0.5077
0.6283	1.1411	1.0026	0.8642	0.7258	0.6104
0.7523	1.2599	1.1442	1.0284	0.9126	0.8160
0.8768	1.3238	1.2036	1.0836	0.9635	0.8633
1.0000	1.1549	1.0564	0.9697	0.8931	0.8358

The dynamic viscosity deviations were evaluated for each composition and temperature using the following expression:

$$\Delta\eta = \eta - \sum_{i=1}^2 \eta_i X_i \quad (1)$$

where η_i and X_i represent the dynamic viscosity of the i pure component of the mixture and its molar fraction, respectively.

The dependence of the dynamic viscosity deviations on mole fraction is expressed in terms of the Redlich-Kister equation:

$$V_m^E = X_1 X_2 \sum_{k=0}^m A_k (2X_1 - 1)^k \quad (2)$$

where A_k represents the parameters.

The coefficients are included in Tables 6 - 10.

Table 6. Parameters of dynamic viscosity of acetic acid– water mixtures

	T, K				
	296.15	302.15	308.15	314.15	319.15
A₀	$2.06366 \cdot 10^{-3}$	$1.84634 \cdot 10^{-3}$	$1.55991 \cdot 10^{-3}$	$1.22344 \cdot 10^{-3}$	$9.10582 \cdot 10^{-4}$
A₁	$1.04242 \cdot 10^{-3}$	$5.65209 \cdot 10^{-4}$	$-1.82297 \cdot 10^{-5}$	$-5.9506 \cdot 10^{-4}$	$-1.07205 \cdot 10^{-3}$
A₂	$-1.41766 \cdot 10^{-3}$	$-1.6255 \cdot 10^{-3}$	$-1.58382 \cdot 10^{-3}$	$-1.5688 \cdot 10^{-3}$	$-1.57233 \cdot 10^{-3}$
A₃	$-3.99639 \cdot 10^{-3}$	$-2.76296 \cdot 10^{-3}$	$-9.3234 \cdot 10^{-4}$	$9.2429 \cdot 10^{-4}$	$2.48697 \cdot 10^{-3}$
A₄	$-1.7870 \cdot 10^{-3}$	$-1.20354 \cdot 10^{-3}$	$-1.7594 \cdot 10^{-3}$	$-2.4678 \cdot 10^{-3}$	$-3.1587 \cdot 10^{-3}$

Table 7. Parameters of dynamic viscosity of acetic acid– benzene mixtures

	T, K				
	296.15	302.15	308.15	314.15	319.15
A₀	$-8.58695 \cdot 10^{-4}$	$-7.69717 \cdot 10^{-4}$	$-7.16935 \cdot 10^{-4}$	$-6.94997 \cdot 10^{-4}$	$-6.97166 \cdot 10^{-4}$
A₁	$-4.88599 \cdot 10^{-4}$	$-5.03270 \cdot 10^{-4}$	$-5.25917 \cdot 10^{-4}$	$-5.55330 \cdot 10^{-4}$	$-5.84358 \cdot 10^{-4}$
A₂	$-7.84487 \cdot 10^{-4}$	$-6.24280 \cdot 10^{-4}$	$-4.82113 \cdot 10^{-4}$	$-3.56456 \cdot 10^{-4}$	$-2.61976 \cdot 10^{-4}$
A₃	$-3.92563 \cdot 10^{-4}$	$-1.65091 \cdot 10^{-4}$	$3.07379 \cdot 10^{-5}$	$1.99745 \cdot 10^{-4}$	$3.22888 \cdot 10^{-4}$
A₄	$4.91271 \cdot 10^{-4}$	$5.39117 \cdot 10^{-4}$	$4.75049 \cdot 10^{-4}$	$3.17446 \cdot 10^{-3}$	$1.23320 \cdot 10^{-3}$

Table 8. Parameters of dynamic viscosity of acetic acid– toluene mixtures

	T, K				
	296.15	302.15	308.15	314.15	319.15
A₀	$-1.7083 \cdot 10^{-3}$	$-1.5708 \cdot 10^{-3}$	$-1.4651 \cdot 10^{-3}$	$-1.3868 \cdot 10^{-3}$	$-1.3396 \cdot 10^{-3}$
A₁	$-3.7979 \cdot 10^{-4}$	$-3.3746 \cdot 10^{-4}$	$-3.0607 \cdot 10^{-4}$	$-2.8419 \cdot 10^{-4}$	$-2.7194 \cdot 10^{-4}$
A₂	$-1.6314 \cdot 10^{-3}$	$-1.1134 \cdot 10^{-3}$	$-6.1273 \cdot 10^{-4}$	$-1.2692 \cdot 10^{-4}$	$2.6799 \cdot 10^{-4}$
A₃	$-2.8875 \cdot 10^{-3}$	$-2.5543 \cdot 10^{-3}$	$-2.2642 \cdot 10^{-3}$	$-2.0098 \cdot 10^{-3}$	$-1.8217 \cdot 10^{-3}$
A₄	$-4.3254 \cdot 10^{-3}$	$-4.3507 \cdot 10^{-3}$	$-4.4726 \cdot 10^{-3}$	$-4.6769 \cdot 10^{-3}$	$-4.9019 \cdot 10^{-3}$

Table 9. Parameters of dynamic viscosity of acetic acid– n-hexane mixtures

	T, K				
	296.15	302.15	308.15	314.15	319.15
A ₀	2.86396·10 ⁻⁴	2.43870·10 ⁻⁴	1.80077·10 ⁻⁴	9.80543·10 ⁻⁵	1.76167·10 ⁻⁵
A ₁	2.10105·10 ⁻⁴	1.87354·10 ⁻⁴	1.80601·10 ⁻⁴	1.87461·10 ⁻⁴	2.02130·10 ⁻⁴
A ₂	2.35883·10 ⁻⁴	2.70746·10 ⁻⁴	2.90362·10 ⁻⁴	2.9695·10 ⁻⁴	2.93775·10 ⁻⁴
A ₃	3.98144·10 ⁻³	3.63287·10 ⁻³	3.23087·10 ⁻³	2.78336·10 ⁻³	2.38039·10 ⁻³
A ₄	6.84353·10 ⁻³	6.16382·10 ⁻³	5.42866·10 ⁻³	4.64610·10 ⁻³	3.9626·10 ⁻³

Table 10. Parameters of dynamic viscosity of acetic acid– n-heptane mixtures

	T, K				
	296.15	302.15	308.15	314.15	319.15
A ₀	1.39121·10 ⁻⁵	2.65948·10 ⁻⁴	-9.75766·10 ⁻⁵	-1.92847·10 ⁻⁴	-2.8879·10 ⁻⁴
A ₁	1.99972·10 ⁻³	1.64674·10 ⁻³	1.2252·10 ⁻³	8.20631·10 ⁻⁴	4.76363·10 ⁻⁴
A ₂	4.70966·10 ⁻³	2.03180·10 ⁻³	3.7699·10 ⁻³	3.2806·10 ⁻³	2.86482·10 ⁻³
A ₃	-2.3405·10 ⁻³	-1.90409·10 ⁻³	-1.38705·10 ⁻³	-9.7965·10 ⁻⁴	-6.68779·10 ⁻⁴
A ₄	-2.5009·10 ⁻³	8.86892·10 ⁻⁴	-1.91356·10 ⁻³	-1.7429·10 ⁻³	-1.65212·10 ⁻³

Figure 1 represents the dynamic viscosity deviations against the mole fraction and the Redlich – Kister fit, for the acetic acid – water binary systems.

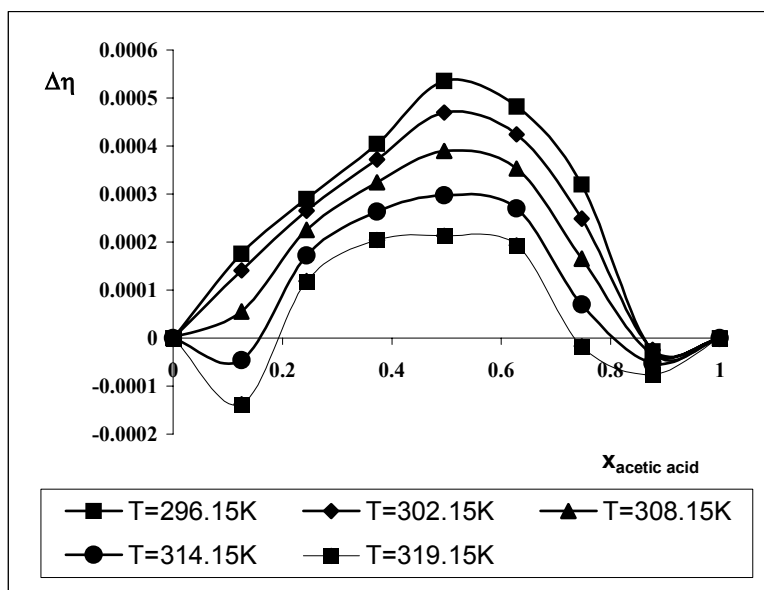


Figure 1. Viscosity deviation for acetic acid – water mixtures

Figure 2 represents the dynamic viscosity deviations against the mole fraction and the Redlich – Kister fit, for the acetic acid – benzene binary systems.

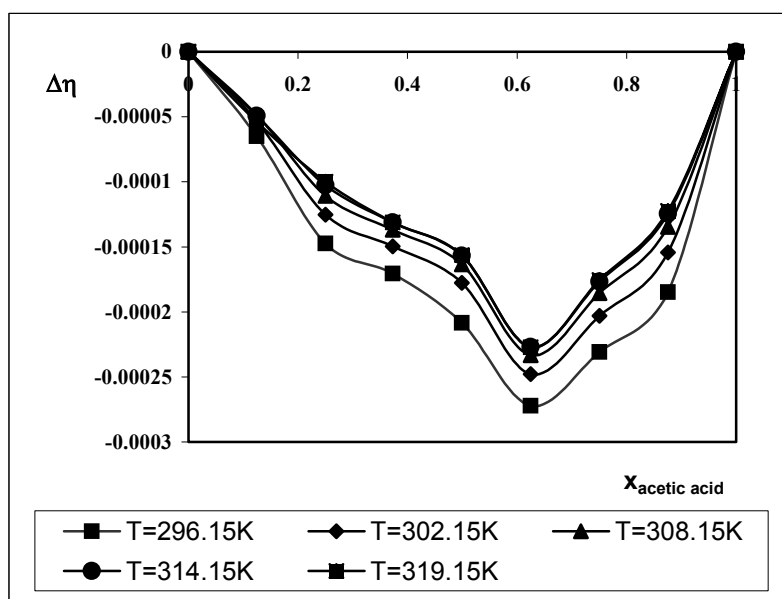


Figure 2. Viscosity deviation for acetic acid – benzene mixtures

Figure 3 represents the dynamic viscosity deviations against the mole fraction and the Redlich – Kister fit, for the acetic acid – toluene binary systems.

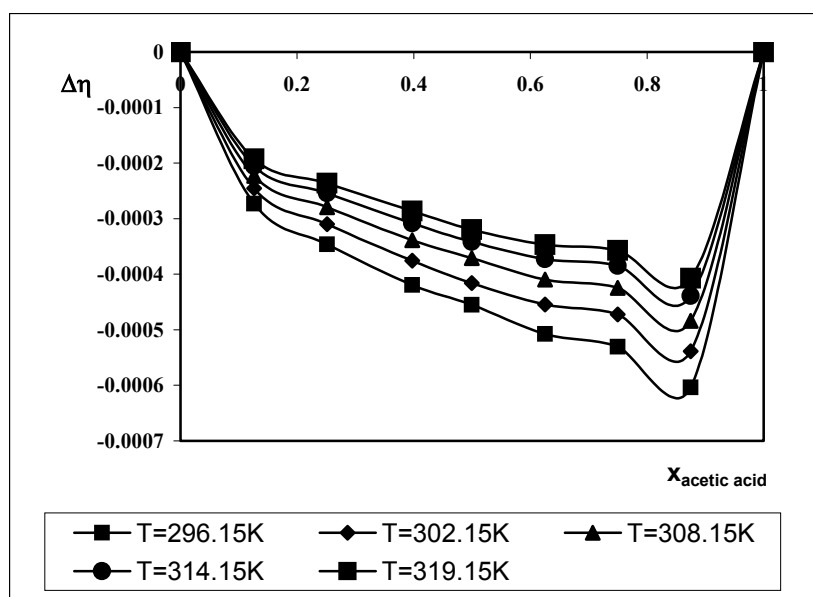


Figure 3. Viscosity deviation for acetic acid – toluene mixtures

Figure 4 represents the dynamic viscosity deviations against the mole fraction and the Redlich – Kister fit, for the acetic acid – n-hexane binary systems.

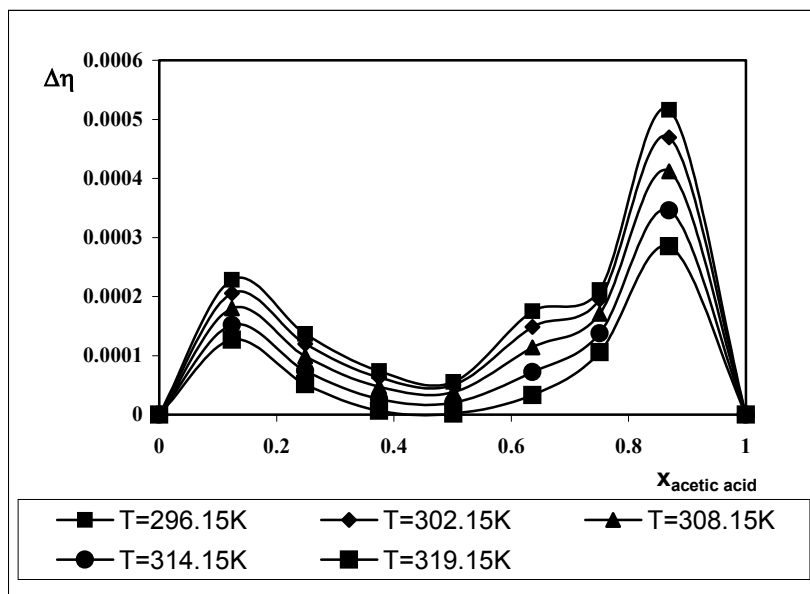


Figure 4. Viscosity deviation for acetic acid – n-hexane mixtures

Figure 5 represents the dynamic viscosity deviations against the mole fraction and the Redlich – Kister fit, for the acetic acid – n-heptane binary systems.

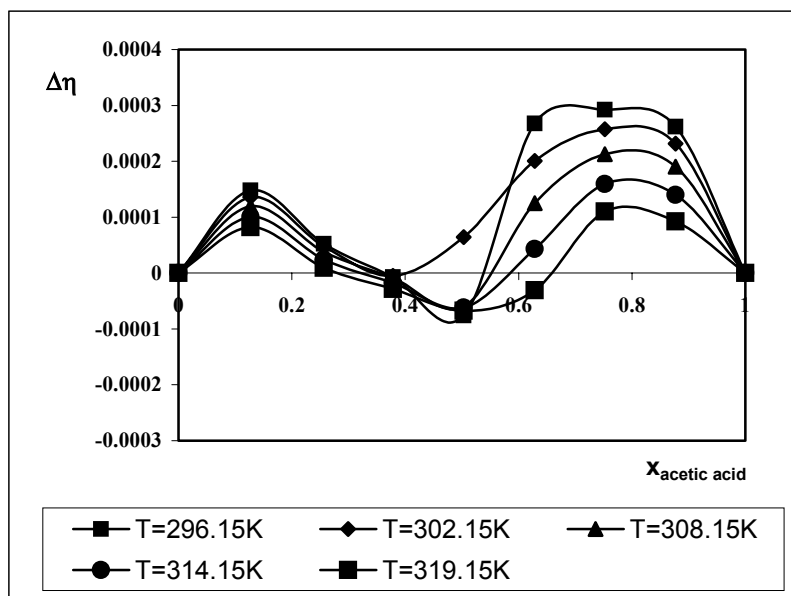


Figure 5. Viscosity deviation for acetic acid – n-heptane mixtures

The viscosity deviation is related to the molecular interactions between the components of the mixture. So, the dynamic viscosity deviations are function of the molecular interactions as well as of the size and shape of molecules. Fort and Moore [26] state that a negative dynamic viscosity deviation is characteristic of systems where dispersion

forces are predominant whereas mixtures with strong interactions between unlike molecules present positive dynamic viscosity deviations. In case of systems acetic acid and benzene, toluene excess viscosity gives negative deviations; instead for systems acetic acid-water, n-hexane and n-heptane there are both negative and positive deviations. Analyzing the results obtained we can affirm that for extraction of acetic acid from water can be used toluene and benzene.

CONCLUSIONS

Viscosities (η) for acetic acid + water, benzene, toluene, n-hexane and n-heptane, have been measured over the whole composition range at atmospheric pressure and 296.15, 302.15, 308.15, 314.15 and 319.15 K. The viscosity deviation ($\Delta\eta$) were calculated. The viscosity deviation $\Delta\eta$ are fitted to the Redlich-Kister equation. The viscosity deviations are negative over whole composition range and increase with decreasing temperature for acetic acid – toluene and acetic acid – benzene; from here we can affirm that for the extraction of acetic acid from water can be used toluene and benzene.

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