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Data Article

Thermodynamic study of Butylamine + Propanone, + Methyl Isobutyl Ketone (MIK) at (288.15 to 318.15) K temperature range

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ABSTRACT

Experimental determination of density and viscosity of the pure components and [Butylamine (1) + Propanone (2)] and [Butylamine (1) + MIK (2)] binary mixtures at (288.15 to 318.15) K are performed using an Anton Paar SVM 3000/G2 Stabinger Viscometer. The excess molar volume and viscosity deviation are calculated. Correlation equations for the experimental data and calculated functions are obtained. For [Butylamine + Propanone] binary system, the excess molar volume is negative and the viscosity deviation is positive for all temperatures. The values of excess volumes become more negative and the deviations of viscosity more positive with increasing temperature. For [Butylamine + MIK] binary system, the excess molar volume and the viscosity deviation are sigmoid. The excess molar volume is negative and the viscosity deviation is positive until next molar fractions $x_1 \approx 0.7$.

1. Rationale

The thermodynamic study of binary liquid systems is relevant because, through it, it is possible to know what the mixing process involved, and this information is essential to both the design of sep-

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aration equipment, reactors, etc., and for the development and / or verification of molecular models (both of academic and technological interest [1–3]).

The amines are derived from ammonia, a nitrogen atom that contains a free electron pair. They are found in plants and animals and are used in solvents and emulsifiers for the manufacture of herbicides, pesticides, dyes, etc. Amines have polar nature and H-bonding with other amines (having at least one NH bond important to maintain intermolecular cohesion) and form hydrogen bonds with any compound either donor or acceptor of protons.

In this paper we reported the density and viscosity of the pure components and mixtures over the entire range for the: [Butylamine (1) + propanone (2)] and [Butylamine (1) + MIK (2)] binary systems in the temperature range of (288.15 to 318.15) K. Density and viscosity were simultaneously measured with an Anton PaarStabinger viscometer (SVM 3000/G2) calibrated by the manufacturer and the temperature is kept constant within ± 0.02 K. Total uncertainties in this work are ± 0.35% of measured value for viscosity value, ± 0.5 kg.m^{-3} for density, and ± 0.02 K for temperature. The apparatus was checked periodically using standard oils provided by the manufacturer. At least three determinations, for each temperature and for each solution or pure component were performed.

Excess molar volume (V^E) and the viscosity deviation ($\Delta\eta$) of the system were calculated. Empiric equations for the excess molar volumes $\boldsymbol{V^E}$ and viscosity deviation $\boldsymbol{\Delta\eta}$ of the binary system as a function of composition and temperature were developed. These equations were fitted using least squares with all points equally weighted and the values obtained compared well within experimental error. The appropriate number of constants and significant digits were obtained by comparing them with the experimental errors. The excess molar volume and viscosity deviation for binary system were fitted to a Redlich–Kister [4] type equation using least squares in order to find the dependence on concentration and temperature. In all cases OriginPro 8.5 was used.

This work is part of an ongoing research program in which the group studies thermodynamic, transport, and spectroscopic properties of binary mixtures containing Butylamine as one of their components.

There have been various studies on the pure components [5–8] but there are very few thermodynamic studies of binary mixtures with butylamine [9]. No data density and viscosity, or excess molar volume values and viscosity deviation for [Butylamine (1) + propanone (2)] and [Butylamine (1) + MIK (2)] binary mixtures at (288.15 to 318.15) K have been published, to our knowledge.

Subject area	*Physical Chemistry*
Compounds	*n-Butylamine; propanone; methyl isobutyl ketone (MIK)*
Data category	*Physicochemical*
Data acquisition format	*Physical properties*
Data type	*Raw and calculated.*
Procedure	*Determination: density with vibrating tube densimeter viscosity with concentric cylinder viscometer, Hall effect Excess Molar and viscosity deviation are calculated with the general expressions*
Data accessibility	*In this article*

2. Procedure

2.1. Materials

Propanone (p.a.) and Methil-isobutyl-ketone (MIK) (p.a.) were supplied by Dorwill, while Butylamine (p.a.) was supplied by MERK (Germany).

The butylamine was subjected to different purification processes, including fractional crystallization and fractional distillation. Finally, the product of higher purity (99.8%) was obtained placing the solvent over sodium hydroxide pellets and allowing it to stand several days, twice fractionally distilled and collecting the middle fraction (as suggested in the literature [10]).

The purity of the reagents was determined by gas chromatography and IR spectroscopy. Propanone and Methil-MIK were used without further purification because their purities were higher than 99.8%. Purity was checked periodically. The measured and literature values of density and viscosity in the temperature range of work are reported in Table 1.

Table 1
Densities and viscosities of the pure components.

Components	Temp/ K	ρ/kg·m^{-3}		η/mPa·s	
		Exp.	Lit.	Exp	Lit.
Butylamine	283.15	747.7		0.57690	
	288.15	743.0		0.53271	
	293.15	738.3	739.2 [5]	0.49628	
	298.15	733.5	733.0 [6]	0.46089	0.4689 [16]
					0.4700 [17]
	303.15	728.7	727.7 [7]	0.42939	
	308.15	723.8	722.8 [8]	0.40566	
	313.15	719.0		0.37628	0.3831 [16]
	318.15	714.1		0.35387	
	323.15	709.2		0.32916	
Propanone	283.15	800.9		0.32913	
	288.15	795.2		0.31313	0.3371 [5]
	293.15	789.6	789.98 [5]	0.29868	0.3180 [18]
			790.1 [18]		
	298.15	783.9	784.40 [5]	0.28624	0.3029 [5,18]
			784.4 [18]		
	303.15	778.1	780.33 [5]	0.27375	0.2954 [5]
	308.15	772.2	773.0 [18]	0.26042	0.2738 [18]
	313.15	766.4		0.24872	
MIK	288.15	804.4		0.60467	
	293.15	799.9	801.0 5	0.56784	0.5848 [5]
					0.575 [6]
	298.15	795.4	796.3 [5]	0.53407	0.5463 [5]
					0.543 [6]
	303.15	790.8	792.0 [6]	0.50299	0.49751 [5]
					0.518 [6]
	308.15	786.2	786.8 [6]		0.494 [6]
	313.15	781.6		0.44868	
	318.15	777.0		0.42453	
	323.15	772.3		0.40233	

2.2. Apparatus and methods

Liquid mixtures were prepared by weighing each component in airtight-stoppered bottles, keeping in mind the vapor pressures of the components when establishing the filling sequence using the same techniques described in previous publication [11] for the preparation of samples. The uncertainty in the mole fractions for these mixtures is estimated to be around than $\pm 1 \times 10^{-4}$. Each mixture was immediately used. The same instruments described in previous publications [12] were used.The uncertainty in the mole fractions for these mixtures is estimated to be around than $\pm 1 \times 10^{-4}$. Density and viscosity were measuredwith an Anton Paar Stabinger viscometer (SVM 3000/G2). The uncertainties were ± 0.5 kg m^{-3} for density, $\pm 0.35\%$ of the measured value for viscosity value. Infrared spectra of the pure components were recorded on a Perkin Elmer FT-IR Spectrometer - Spectrum RXI, using a cell with 0.5 mm optical path with KBr windows.

Figs. 1 and 2 show density and viscosity, respectively of pure butylamine as a function of temperature. Experimental errors are not observed in the graphic because its size is of the same order as the symbols. The other pure components show a similar behavior with temperature For all three components pure first-order polynomial equations for density are obtained. For viscosity, second-order polynomial equations are obtained:

$$\rho = B_0 + B_1 xT \tag{1}$$

$$\eta = A_0 + A_1 xT + A_2 xT^2 \tag{2}$$

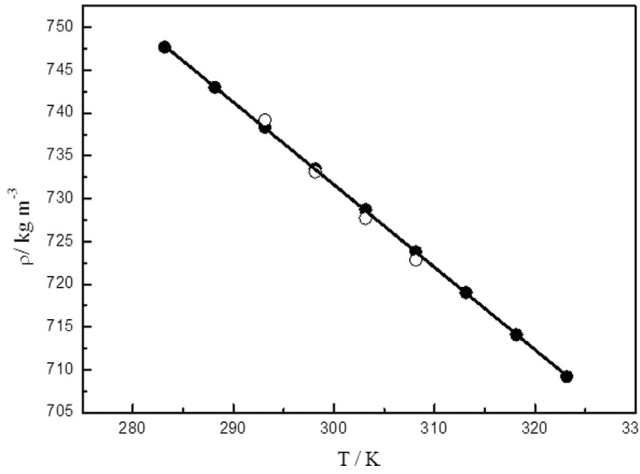

Fig. 1. Density versus temperature for Butylamine experimental (●); literature (○); The lines represent the adjustment.

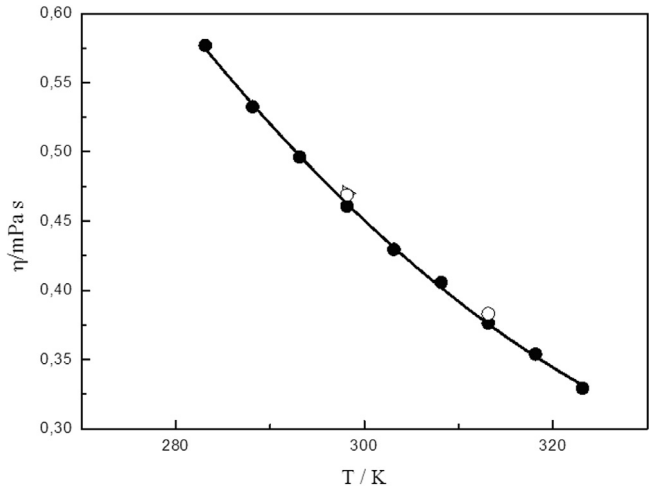

Fig. 2. Viscosity versus temperature for Butylamine experimental (●); literature (○); (▷). The lines represent the adjustment.

where A_i and B_i are constants and T is temperature. The appropriate number of constants and significant digits are obtained by comparison with the experimental errors mentioned above.

The standard deviation σ is calculated according to the following equation:

$$\sigma = \left[\frac{\sum (P_{\text{exp}} - P_{calc})^2}{n - m} \right]^{1/2} \tag{3}$$

where P represents the density (ρ) or viscosity (η), n is the number of experimental points and m the number of polynomial parameters.

Equations were fitted using the least squares method by assigning equal weight [13] to all points. These constants were evaluated by selecting the number of significant digits each factor has from experimental error. The final equations are shown in Table 2.

Using a similar methodology explained in previous work [12], the samples were prepared and the density and viscosity of each sample over (288.15 to 318.15) K range was determined.

Table 2
Equations for the density and viscosity as a function of temperature for pure components.

Equation	σ
Butylamine	
$\rho/kg.m^{-3} = 1020.67 - 0.96349 \times T$	0.1 $kg.m^{-3}$
$\eta/mPa.s = 7.3579 - 0.03962 \times T + 5.53289 \times 10^{-5} \times T^2$	0.002 *mPa.s*
Propanone	
$\rho/kg.m^{-3} = 1127.85 - 1.15417 \times T$	0.04 $kg.m^{-3}$
$\eta/mPa.s = 2.22335 - 0.01034 \times T + 1.2895 \times 10^{-5} \times T^2$	0.001 *mPa.s*
MIK	
$\rho/kg.m^{-3} = 1068.78 - 0.9171667 \times T$	0.07 $kg.m^{-3}$
$\eta/mPa.s = 6.80338 - 0.03556 \times T + 4.87625x10^{-5} \times T^2$	0.0005 *mPa.s*

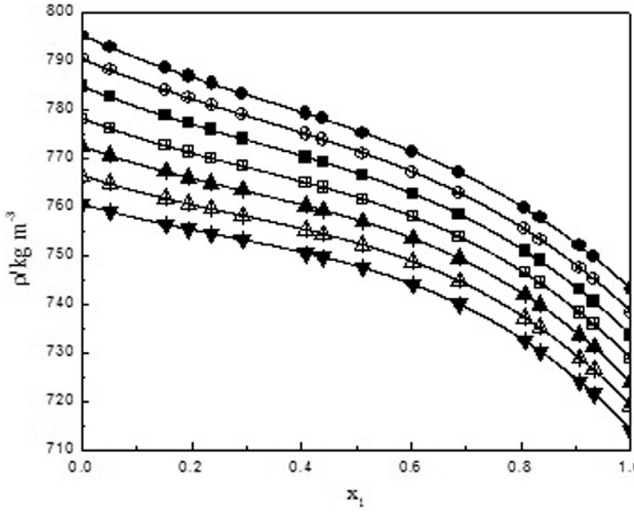

Fig. 3. Density versus concentration for [x_1Butylamine + (1-x_1) Propanone]: 288.15K (●); 293.15K (○); 298.15K (■); 303.15K (□); 308.15K (▲); 313.15K (△); 318.15K (▼). The lines represent the adjustment.

Density and viscosity were plotted as a function of concentration of butylamine (Figs. 3-6). In Tables 3 and 4 density and viscosity data of both systems for all temperatures are shown. With a similar previously cited methodology for the pure components, adjustmentequations are found. The equation used was

$$p = \sum_{i=0}^{n} A_i(T) x_1^i \tag{4}$$

where A_i are temperature dependent parameters and x_1 is the mole fraction of butylamine. The final equations are shown in Table 5.

The excess molar volumes V^E and viscosity deviation $\Delta\eta$ for binary systems were calculated from the following equations:

$$V^E = \sum_{i=1}^{n} x_i M_i \left[\left(\frac{1}{\rho} \right) - \left(\frac{1}{\rho_i} \right) \right] \tag{5}$$

$$\Delta\eta = \eta - \left(\sum_{i=1}^{n} \eta_i x_i \right) \tag{6}$$

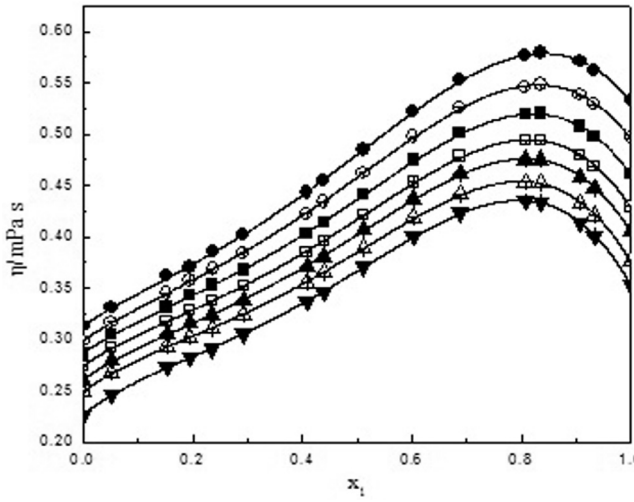

Fig. 4. Viscosity versus concentration for [x_1Butylamine + (1-x_1) Propanone]: 288.15K (●); 293.15K (○); 298.15K (■); 303.15K (□); 308.15K (▲); 313.15K (△); 318.15K (▼). The lines represent the adjustment.

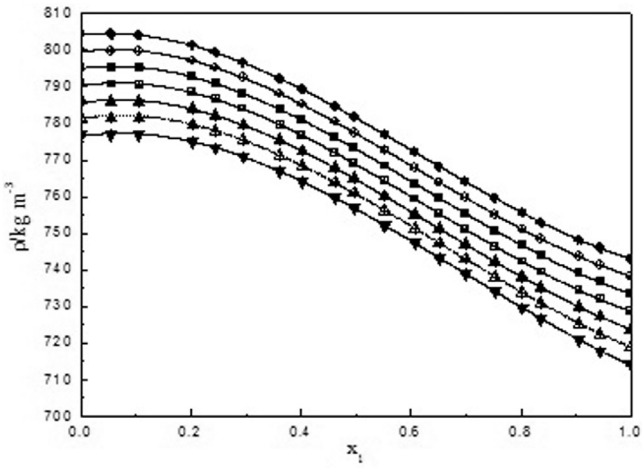

Fig. 5. Density versus concentration for [x_1Butylamine + (1-x_1) MIK]: 288.15K (●); 293.15K (○); 298.15K (■); 303.15K (□); 308.15K (▲); 313.15K (△); 318.15K (▼). The lines represent the adjustment.

where n is the number of components, x_i the mole fraction of component i in the mixture, M_i its molecular weight, ρ, η, the density and viscosity of the mixture and η_i, ρ_i the measured viscosities and densities of the pure component, respectively.

Excess molar Volume and Viscosity Deviation are plotted as a function of concentration of butylamine (Figs. 7-10). The uncertainties for Excess Molar Volume and Viscosity Deviation are 10^{-8} m^3 mol^{-1}, and 10^{-3} mPas, respectively. Excess molar Volume and Viscosity Deviation of binary systems were fitted using the Redlich-Kister[4] polynomial equation of the type:

$$Y_{ij} = x_i x_j \sum_{p=0}^{k} a_p (1 - 2x_i)^p \tag{7}$$

where Y_{ij} is the excess property of the *ij* binary system and a_p are adjustable parameters. These equations were fitted using least squares [14] with all points equally weighed. The appropriate number of

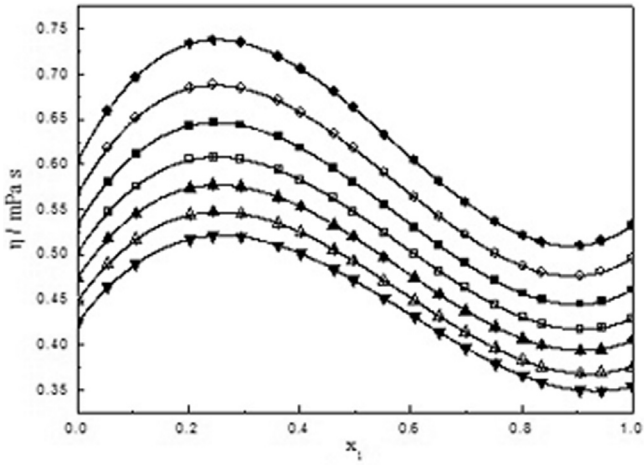

Fig. 6. Viscosity versus concentration for [x_1Butylamine + (1-x_1) MIK]: 288.15K (●); 293.15K (○); 298.15K (■); 303.15K (□); 308.15K (▲); 313.15K (△); 318.15K (▼). The lines represent the adjustment.

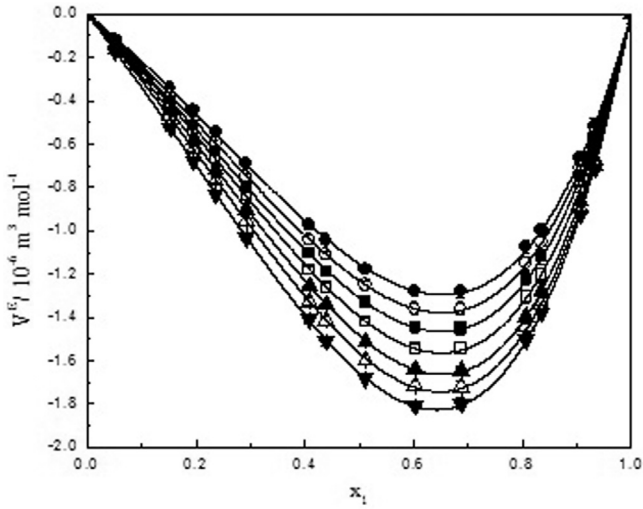

Fig. 7. Excess molar volume versus concentration for [x_1Butylamine + (1-x_1) Propanone]: 288.15K (●); 293.15K (○); 298.15K (■); 303.15K (□); 308.15K (▲); 313.15K (△); 318.15K (▼). The lines represent the adjustment.

constants and significant digits were obtained by comparison with the experimental errors mentioned above.

It should be noted that experimental errors are not observed in the graphs because their size is of the order of the symbols. Table 5 shows the equations for the functions and the standard deviation (σ). Equations cited in Table 5 make it possible to predict the density, and viscosity of the binary system at any concentration and over the temperature range (288.15 to 318.15) K for butylamine and MIK and (288.15 to 318.15) K for butylamine and propanone, within its respective standard deviation σ. Values calculated with these equations compare well with experimental data.

For adjustment equations and all figures, the OriginPro 8.5 software was used.

Table 3
Experimental density ρ/kg·m^{-3}at the (288.15 to 318.15) K range for [Butylamine (1) + propanone (2)] and [Butylamine (1) + MIK (2)] binary systems.

x_1	288.15 K	293.15 K	298.15 K	303.15 K	308.15 K	313.15 K	318.15 K
[Butylamine 1) + propanone ((2)]							
0.00000	795.2	790.4	784.7	778.1	772.4	766.4	760.5
0.05099	792.9	788.2	782.6	776.2	770.6	764.8	759.0
0.15227	788.5	784.0	778.7	772.6	767.3	761.7	756.4
0.1949	786.8	782.4	777.2	771.2	766.0	760.6	755.4
0.23602	785.3	780.9	775.8	770.0	764.9	759.6	754.5
0.29267	783.2	779.0	773.9	768.3	763.4	758.2	753.2
0.40794	779.2	774.9	770.1	764.9	760.2	755.2	750.4
0.43878	778.1	773.8	769.2	764.0	759.3	754.4	749.7
0.51183	775.2	771.0	766.4	761.5	756.9	752.2	747.4
0.60249	771.3	767.2	762.7	758.0	753.4	749.7	744.0
0.68702	767.1	762.9	758.4	753.8	749.4	744.7	740.0
0.80699	759.6	755.4	750.9	746.4	741.9	737.2	732.4
0.83473	757.7	753.3	748.9	744.4	739.8	735.2	730.3
0.90686	751.9	747.5	742.9	738.2	733.6	728.9	724.1
0.93212	749.7	745.2	740.6	735.9	731.2	726.5	721.6
1.00000	743.0	738.3	733.5	728.7	723.8	719.0	714.1
[Butylamine 1) + MIK ((2)]							
0.00000	804.4	799.9	795.4	790.8	786.2	781.6	777.0
0.05566	804.3	799.8	795.3	790.7	786.1	781.5	776.9
0.10576	804	799.8	795.1	790.4	785.9	781.4	776.8
0.20304	801.3	797.2	792.8	788.5	784.0	779.6	775.0
0.24525	799.4	795.3	790.9	786.7	782.2	777.9	773.4
0.29486	796.6	792.6	788.2	784.0	779.7	775.4	771.0
0.36288	792.2	788.1	783.8	779.7	775.4	771.3	767.0
0.40260	789.3	785.2	780.9	776.8	772.5	768.5	764.2
0.46199	784.6	780.5	776.2	772.1	767.9	763.9	759.8
0.49714	781.7	777.5	773.3	769.1	765.0	761.0	756.9
0.55333	776.9	772.6	768.4	764.2	760.1	756.1	752.1
0.60706	772.2	767.9	763.6	759.4	755.3	751.3	747.4
0.65193	768.2	763.9	759.6	755.3	751.2	747.2	743.3
0.69910	764.1	759.7	755.4	751.1	747.0	742.9	739.0
0.75279	759.6	755.1	750.8	746.4	742.2	738.1	734.1
0.80253	755.6	751.1	746.7	742.2	737.9	733.7	729.6
0.83723	753.0	748.4	743.9	739.5	735.1	730.8	726.6
0.90604	748.3	743.7	739.0	734.4	729.9	725.3	720.8
0.94493	745.9	741.3	736.6	731.9	727.2	722.5	717.8
1.00000	743.0	738.3	733.5	728.7	723.8	719.0	714.1

3. Data, value and validation

Binary systems presented in this paper are part of the studies conducted in the research group on the intermolecular hydrogen bonds, how they affect the thermophysical properties of the systems where they are present.

The binary systems were not studied, as far as could be found. Thus these data are very useful for scientific and technological community. The amines are used in solvents, emulsifiers, for the manufacture of herbicides, pesticides, dyes, etc. and form hydrogen bonds with any compound either donor or acceptor of protons.

The purity of the reagents used was controlled by chromatography and IR spectroscopy which guarantees its purity.

The instruments used are certified by the manufacturer and monitored regularly, each time a series of measurements starts.

Experimental determinations were repeated at least three times. Mixtures of any composition are also prepared and their properties are determined experimentally to obtain the total uncertainty of the proposed relationship. Additionally, residual analysis is performed in each case.

Table 4
Experimental viscosity η/mPa.s at the (288.15 to 318.15) K range for [Butylamine (1) + propanone (2)] and [Butylamine (1) + MIK (2)] binary systems.

x_1	288.15 K	293.15 K	298.15 K	303.15 K	308.15 K	313.15 K	318.15 K
[Butylamine (1) + propanone (2)]							
0.00000	0.31313	0.29868	0.28624	0.27375	0.26042	0.24872	0.22641
0.05099	0.33109	0.31711	0.30483	0.29206	0.27937	0.26794	0.24673
0.15227	0.36148	0.34483	0.33127	0.31777	0.30515	0.29387	0.27384
0.19490	0.37057	0.35792	0.34289	0.32866	0.31601	0.30275	0.28312
0.23602	0.38502	0.36834	0.35278	0.33736	0.32428	0.31111	0.29107
0.29267	0.40180	0.38448	0.36766	0.35169	0.33837	0.32439	0.30519
0.40794	0.44284	0.42253	0.40309	0.38526	0.37090	0.35548	0.33683
0.43878	0.45511	0.43406	0.41397	0.39569	0.38104	0.36507	0.34657
0.51183	0.48483	0.46257	0.44109	0.42117	0.40644	0.38914	0.37063
0.60249	0.52245	0.49762	0.47453	0.45314	0.43687	0.41867	0.40063
0.68702	0.55283	0.52594	0.50084	0.47834	0.46129	0.44176	0.42371
0.80699	0.57600	0.54638	0.51886	0.49373	0.47553	0.45300	0.43487
0.83473	0.57926	0.54856	0.52004	0.49428	0.47536	0.45237	0.43367
0.90686	0.57059	0.53788	0.50706	0.47911	0.45839	0.43312	0.41324
0.93212	0.56253	0.52909	0.49715	0.46840	0.44721	0.42095	0.40054
1.00000	0.53271	0.49628	0.46089	0.42939	0.40566	0.37628	0.35387
[Butylamine (1) + MIK (2)]							
0.00000	0.60467	0.56784	0.53407	0.50299	0.47466	0.44868	0.42453
0.05566	0.65974	0.61782	0.58103	0.54698	0.51811	0.49020	0.46424
0.10576	0.69654	0.65090	0.61188	0.57578	0.54586	0.51688	0.49016
0.20304	0.73391	0.68418	0.64298	0.60505	0.57417	0.54429	0.51744
0.24525	0.73809	0.68770	0.64631	0.60831	0.57738	0.54751	0.52107
0.29486	0.73520	0.68476	0.64362	0.60600	0.57527	0.54565	0.51997
0.36288	0.71982	0.67036	0.63023	0.59378	0.56366	0.53475	0.51045
0.40260	0.70591	0.65748	0.61822	0.58271	0.55310	0.52473	0.50138
0.46199	0.68008	0.63366	0.59595	0.56210	0.53338	0.50595	0.48408
0.49714	0.66274	0.61770	0.58100	0.54820	0.52007	0.49322	0.47224
0.55333	0.63321	0.59054	0.55550	0.52442	0.49725	0.47134	0.45171
0.60706	0.60442	0.56408	0.53055	0.50104	0.47479	0.44970	0.43121
0.65193	0.58115	0.54268	0.51029	0.48195	0.45641	0.43192	0.41420
0.69910	0.55858	0.52191	0.49051	0.46317	0.43831	0.41430	0.39715
0.75279	0.53664	0.50167	0.47105	0.44448	0.42022	0.39653	0.37967
0.80253	0.52124	0.48741	0.45706	0.43076	0.40687	0.38320	0.36619
0.83723	0.51402	0.48065	0.45020	0.42378	0.40002	0.37618	0.35877
0.90604	0.51020	0.47679	0.44527	0.41773	0.39383	0.36912	0.35016
0.94493	0.51526	0.48116	0.44846	0.41970	0.39546	0.36990	0.34954
1.00000	0.53271	0.49628	0.46089	0.42939	0.40566	0.37628	0.35387

Excess thermodynamic functions and deviations of nonthermodynamic ones of binary liquid mixtures are very important for the design of industrial equipment and for the interpretation of the liquid state, particularly when polar components are involved because there exists a possibility of drawing conclusions about the interactions between the components of the mixture.

4. Discussion and conclusions

From the results it can be seen that for both systems:

1. The equations for setting the density and viscosity are polynomial functions of the mole fraction of butylamine
2. For the [Butylamine (1) ± propanone (2)] binary system :
   (a) The excess molar volume is negative throughout the concentration range and all temperatures in the temperature range studied, with a minimum approximately $x_1 = 0.7$. It becomes more negative with increasing temperature. This is significant evidence that the dominant process is the formation of a hetero hydrogen bond [9] (**2 B:1 P**) and-or interstitial accommodation of one molecule of propanone in the n-mer butylamine structure.

Table 5
Equations for the density, viscosity, excess molar volume and viscosity deviation as a function of composition and temperature for [Butylamine (1) + propanone (2)] and [Butylamine (1) + MIK (2)] binary systems at (288.15 to 318.15) K range.

Equations	σ
[Butylamine (1) + propanone (2)]	
$\rho/kg.m^{-3} = 1132.94157 - 1.1698 \times T + (-221.72202 + 0.58837 \times T)X_1 + (75.60279 - 0.08769 \times T)X_1^2 + (33.97185 - 0.2942 \times T)X_1^3$	*0.3 kg.m^{-3}*
$\eta/mPa.s = 1.10537 - 0.00274 \times T + (-0.06144 + 0.00138 \times T)X_1 + (3.81654 - 0.01483 \times T)X_1^2 + (-5.03554 - 0.02235 \times T)X_1^3 + (2.38176 - 0.01199 \times T)X_1^4$	*0.006 mPa.s*
$V^E/10^{-6}m^3\ mol^{-1} = (14.86101 - 0.0675 \times T)X_1(1 - X_1) + (-8.36303 + 0.04068 \times T)X_1(1 - X_1) \times (1 - 2X_1) + (1.30579 - 0.00742 \times T)X_1(1 - X_1)(1 - 2X_1)^2$	*1 × 10^{-8} m^3 mol^{-1}*
$\Delta\eta/mPa.s = (-0.49775 + 0.00252 \times T)X_1(1 - X_1) + (-0.11788 - 8.51261 \times 10^{-4} \times T)X_1 \times (1 - X_1)(1 - 2X_1) + (-0.58596 - 0.00292 \times T)X_1(1 - X_1)(1 - 2X_1)^2$	*0.002 mPa.s*
[Butylamine (1) + MIK (2)]	
$\rho/kg.m^{-3} = 1070.22 - 0.9232 \times T + (-1143.4657 + 7.47586 \times T - 0.01197 \times T^2)X_1 + (3884.01479 - 26.94885 \times T + 0.00447 \times T^2)X_1^2 + (-2996.992 + 20.8203 \times T - 0.03505 \times T^2)X_1^3$	0.3 kg. m^{-3}
$\eta/mPa.s = 2.24834 - 0.00575 \times T + (32.49396 - 0.1965 \times T + 3.0477 \times 10^{-4} \times T^2)X_1 + (-58.8596 + 0.34176 \times T - 5.1278 \times 10^4 \times T^2)X_1^2 + (30.95515 - 0.17545 \times T + 2.5689 \times 10^{-4} \times T^2)X_1^3$	0.008 mPa.s
$V^E/10^{-6}m^3\ mol^{-1} = (-63.4765 + 0.47047 \times T - 8.97446 \times 10^{-4} \times T^2)X_1(1 - X_1) + (173.3128 - 1.21537 \times T + 0.00205 \times T^2)X_1(1 - X_1)(1 - 2X_1)$	3 × 10^{-8} m^3 mol^{-1}
$\Delta\eta/mPa.s = (11.04488 - 0.0696 \times T + 1.12876 \times 10^4 \times T^2)X_1(1 - X_1) + (3.74364 - 0.01006 \times T)X_1(1 - X_1)(1 - 2X_1)$	0.002 mPa.s

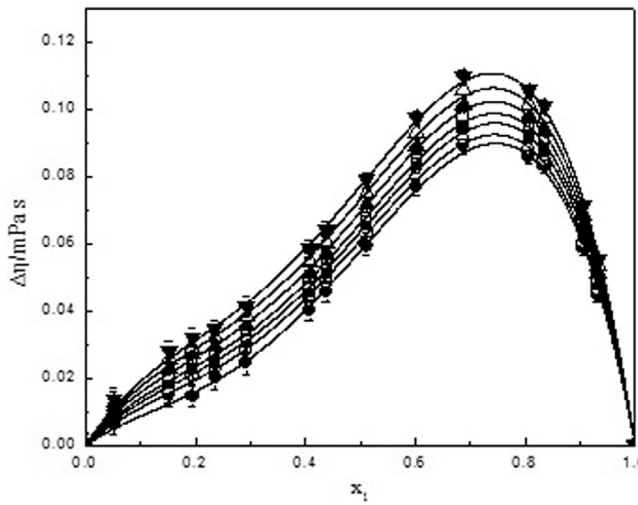

Fig. 8. Viscosity deviation versus concentration for [x_1Butylamine + (1-x_1) Propanone]: 288.15K (●); 293.15K (○); 298.15K (■); 303.15K (□); 308.15K (▲); 313.15K (△); 318.15K (▼). The lines represent the adjustment.

(b) The viscosity deviation is positive in the entire range of composition. It is more positive at higher temperatures. This behavior confirms the previous statement and the proposed stoichiometry.

3. For the [Butylamine (1) ± MIK (2)] binary system:
   (a) The graph of molar excess volume is sigmoid. It presents negative values to mole fractions $x_1 \leq 0.7$ (T = 288.15K) and $x_1 \leq 0.85$ (T = 318.15 K) and the remainder of the interval is positive. It presents greater (more negative or more positive) values when the temperature increases.
   (b) The viscosity deviation is positive in the range $x_1 \leq 0.7$ (T = 288.15 K) and $x_1 \leq 0.85$ (T = 318.15 K) and the remainder of the interval is negative. It presents greater (more negative or more posi-

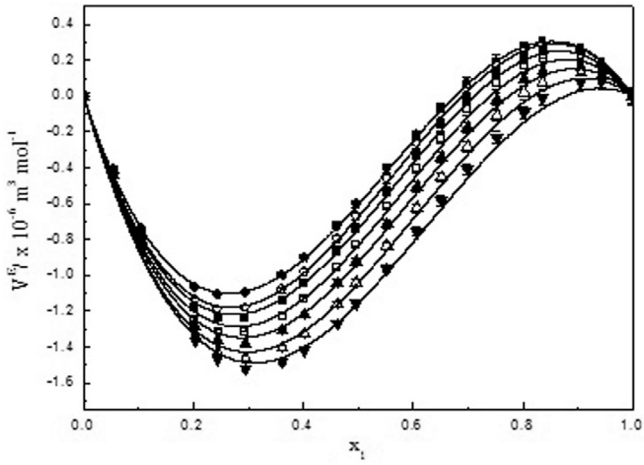

Fig. 9. Excess molar volume versus concentration for [x_1Butylamine + (1-x_1) MIK]: 288.15K (●); 293.15K (○); 298.15K (■);303.15K (□); 308.15K (▲); 313.15K (△); 318.15K (▼). The lines represent the adjustment.

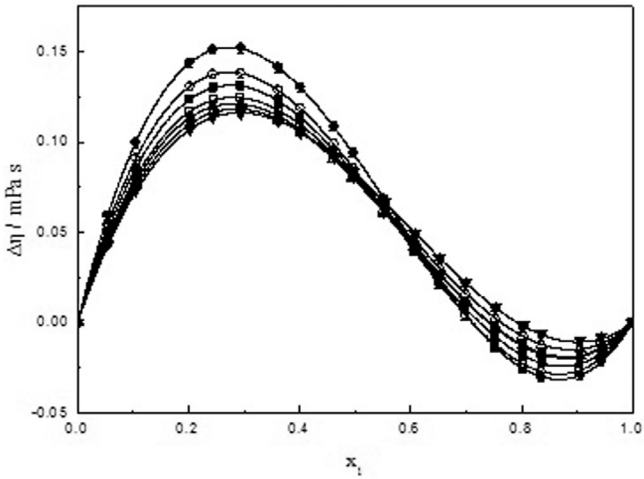

Fig. 10. Viscosity deviation versus concentration for [x_1Butylamine + (1-x_1) MIK]: 288.15K(●); 293.15K(○); 298.15K(■); 303.15K(□); 308.15K(▲); 313.15K(△); 318.15K(▼). The lines represent the adjustment.

tive) values when the temperature decreases. It is known that the butylamine is strongly associated by N–H-N hydrogen bonding [14,15]. Therefore, and from the results it is concluded that at high concentrations of butylamine ($x_1 \geq 0.7$) the most significant process is breaking of hydrogen bonding in the butylamine. For lower concentrations the more significant process is the formation of hetero link with a decreased volume in the mixing process, which is facilitated by increasing the temperature and therefore the mobility of the species.

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