Densities, Viscosities, Refractive Indices and Sound Speeds of Acetophenone with Methylacetate at Different Temperatures

K. SARAVANAKUMAR^S R. BASKARAN*, AND T. R. KUBENDRAN[#]

^S Department of Chemical Engineering, Sathyabama University,
Chennai-600119, India. E-mail: saroo_1978@yahoo.co.in

*Department of Chemical Engineering, St. Joseph's College of Engineering,
Chennai-119, India.

[#] Department of Chemical Engineering, A.C. College of Technology, Anna University,
Chennai-600025, India.

drtrkubendran@yahoo.com

Received 5 September 2011; Accepted 11 November 2011

Abstract: Densities, viscosities, refractive indices and ultrasonic velocities of the binary mixtures of Acetophenone with Methyl acetate were measured over the entire mole fractions at (303.15, 313.15 and 323.15) K. From these experimental results, excess molar volumes V^E , viscosity deviation $\Delta\eta$, refractive index deviation Δn_D , deviations in isentropic compressibility ΔK_s and excess intermolecular free length ΔL_f are calculated. The viscosity values were fitted to the models of Krishnan- Laddha and McAllister. The thermo physical properties under study were fit to the Jouyban - Acree model. The excess values were correlated using Redlich-Kister polynomial equation to obtain their coefficients and standard deviations. It was found that in all cases, the data obtained fitted with the values correlated by the corresponding models very well. The results are interpreted in terms of molecular interactions occurring in the solution.

Keywords: Viscosity; Density; Refractive Index; Ultrasonic Velocity; Molecular interactions.

Introduction

The thermodynamic, acoustic and transport properties of liquids and liquid mixtures¹ are used to study the molecular interactions between the various components of the mixtures and also to understand engineering applications concerning heat transfer, mass transfer, and fluid flow. In chemical process industries, materials are normally handled in fluid form, and as a consequence, the physical, chemical, and transport properties of fluids, assume importance. Thus, data on some of the properties associated with the liquids and liquid mixtures like density, viscosity, refractive index and ultrasonic velocity find extensive application in solution theory and molecular dynamics.² Such results are necessary for

interpretation of data obtained from thermo chemical, electrochemical, biochemical and kinetic studies.³ Acetophenone is an important industrial chemical widely used as an ingredient of flavor and fragrance in soaps, detergents, cosmetics and perfumes. Methylacetate are used as a solvent in inks for coatings, cosmetics and personal-care products, intermediate for pharmaceuticals & agrochemicals, flexographic and rotogravure printing. In our earlier paper, we had studied the transport properties of binary liquid mixtures.^{4, 5} In continuation of this research, we have reported density (ρ), viscosity (η), refractive index (n_D) and sound speed (u) of pure acetophenone and methylacetate for the binary system constituted by these two chemicals at temperatures of 303.15, 313.15 and 323.15 K. The viscosity values have been fitted to McAllister⁶ and Krishnan and Laddha model.⁷ The Jouyban –Acree model⁸ has also been extended to density, viscosity, refractive index and sound speed (u) of binary mixtures. The deviation values have been fitted to Redlich-Kister type⁹ equation. Literature survey showed that no measurements have been previously reported for the mixture studied in this paper.

Experimental Section

Materials and Methods

All the chemicals used in this study were of analytical grade and obtained from Lobo Chemicals, India. The claimed mass fraction purity for the chemicals was ≥ 0.998 . These chemicals were dried over molecular sieves and partially degassed prior to use.^{10, 11} The purity of these experimental chemicals was checked by comparing the observed densities, viscosities, refractive indices and velocities with those reported in the literature. The measured values are included in Table 1 along with the available literature values.

Table 1. Comparison of Experimental Density, Viscosity, Refractive Index and Sound Speed of Pure Liquids with Literature Values at 303.15 K.

Pure liquids	$\rho / \text{g} \cdot \text{cm}^{-3}$		$\eta / \text{mPa} \cdot \text{s}$		n_D		u / ms^{-1}	
	lit	Exp	lit	Exp	lit	Exp	lit	Exp
Acetophenone	1.0194 ¹⁸ 1.0164 ¹⁹	1.0199	1.455 ¹⁹	1.4553	1.5221 ¹⁹	1.5221	1460 ¹⁸	1462
Methyl acetate	0.9195 ²⁰ .9218 ²¹ 0.9128 ²²	0.9209	0.3704 ²⁰ 0.365 ²¹ 0.372 ²²	0.3721	1.3560 ²⁰ 1.3580 ²¹ 1.3592 ²²	1.3560	1148 ²³	1132

Ref.23 at 298.15 K.

Binary mixtures are prepared by mixing appropriate volumes of the liquid components in the specially designed glass bottles with air tight Teflon coated caps and mass measurements performed on a Shimadzu Corporation Japan type BL 2205 electronic balance, with a precision of ± 0.01 mg. The required properties are measured on the same day immediately after preparing each composition. The uncertainty of the mole fraction is ± 0.0001 . For all measurements, temperatures were controlled by circulating the water through a thermostat (Technico, Madras. made in India) keeping temperature fluctuations within ± 0.03 K.

Density

Densities were determined by using a 25 cm³ bicapillary pycnometer and calibrated with deionized double distilled water with a density of 996.0 kg · m⁻³ at a temperature of 303.15 K. The pycnometer was thermostatted in a transparent walled water bath (maintained constant to ± 0.01 K) for 15 min to attain thermal equilibrium, and the liquid level in the two arms was obtained with a traveling microscope which could read to 0.01 mm. The precision of the density measurements was estimated to be ± 0.0003 g · cm⁻³.

Kinematic Viscosity

The kinematic viscosities were measured with Ostwald viscometer previously calibrated using water. The time was measured with a precision of 0.01s, and the uncertainty in the viscosity was estimated to be less than 0.0003 mPa·s. The kinematic viscosity was obtained from the working equation

$$v = at - b / t \quad (1)$$

Where the two constants a and b were obtained by measuring the flow time t of benzene. The viscosities of mixtures of acetophenone and methyl acetate have been correlated with the model proposed by McAllister for a two-component mixture considering three body interactions.

$$\ln v = x_1^3 \ln v_1 + 3x_1^2 x_2 \ln v_{12} + 3x_1 x_2^2 \ln v_{21} + x_2^3 \ln v_2 - \ln(x_1 + x_2 M_2 / M_1) + 3x_1^2 x_2 \ln((2 + M_2 / M_1) / 3) + x_2^3 \ln(M_2 / M_1) + 3x_1 x_2^2 \ln((1 + 2M_2 / M_1) / 3) \quad (2)$$

In equation 2, v_1 and v_2 refer to the kinematic viscosity of pure liquids 1 and 2 having mole fractions x_1 and x_2 , respectively. The parameters v_{12} and v_{21} represent the interaction parameters obtained by multiple regression analysis, while M_1 and M_2 are the molar masses of the components.

The kinematic viscosity was correlated by means of the Krishnan and Laddha model for a two-component mixture, which gives

$$\ln v = x_1 \ln v_1 + x_2 \ln v_2 + x_1 \ln M_1 + x_2 \ln M_2 + \ln(x_1 M_1 + x_2 M_2 - 2.30x_1 x_2 (B + C(x_1 - x_2) \dots)) \quad (3)$$

Where B and C are interaction parameters. Jouyban et. al proposed a model for correlating the thermal properties of liquid mixtures at various temperatures.

$$\ln y_{m,T} = f_1 \ln y_1 + f_2 \ln y_2 + f_1 f_2 \sum [A_j (f_1 - f_2)^j / T] \quad (4)$$

Where $y_{m,T}$, $y_{1,T}$, and $y_{2,T}$ are the viscosity of the mixture and solvents 1 and 2 at temperature T , respectively. A_j is the model constant.

Refractive Index

Refractive indices were measured using thermostatically controlled Abbe refractometer (Atago 3T) with accuracy less than 0.001units. Water was circulated in to the prism of the refractometer by a circulation pump connected to an external thermo stated water bath. Calibration was performed by measuring the refractive indices of doubly distilled water and propyl alcohol at defined temperatures. The sample mixture was directly injected in to the prism assembly of the instrument using a syringe. The solutions were pre thermo stated at

the temperature of the experience before the experiments to achieve a quick thermal equilibrium.

Sound Speed

Speed of sound was measured by using a variable path, single crystal interferometer. (Mittal Enterprises, New Delhi) at a frequency of 2MHz. The interferometer was calibrated using toluene. The interferometer cell was filled with the test liquid, and the temperature of the solution was maintained constant within ± 0.01 K by circulation of water from a thermostatically regulated water bath through the water jacketed cell. The uncertainty was estimated to be 2 ms^{-1} . The isentropic compressibility was calculated by the equation

$$\kappa_s = 1/\rho u^2 \quad (5)$$

where ρ is the density of the mixture and u is the ultrasonic velocity of the mixture. The intermolecular free length (L_f) was calculated by the equation

$$L_f = K^* \kappa_s^{1/2} \quad (6)$$

where $K = ((91.368 + 0.3565T) 10^{-8})$ is temperature dependent Jacobson's constant.

Results and Discussion

Measured values of densities, viscosities, refractive indices and ultra sonic velocities of acetophenone with methyl acetate at temperatures of (303.15, 313.15, and 323.15) K are listed in Table 2.

Table 2. Densities ρ , Viscosities η , Refractive Indices n_D and Sound Speed u for the Acetophenone (1) + Methyl Acetate (2).

x_1	$\rho / \text{g}\cdot\text{cm}^{-3}$	$\eta / \text{mPa}\cdot\text{s}$	n_D	u / ms^{-1}
303.15K				
0.0000	0.9209	0.3721	1.3560	1132
0.0637	0.9299	0.4705	1.3716	1161.8
0.1313	0.9390	0.5690	1.3867	1191.6
0.2032	0.9480	0.6675	1.4018	1221.5
0.2799	0.9570	0.7659	1.4169	1251.3
0.3617	0.9660	0.8644	1.4321	1281.1
0.4494	0.9750	0.9629	1.4472	1310.9
0.5434	0.9840	1.0614	1.4623	1340.7
0.6446	0.9930	1.1598	1.4773	1372.5
0.7537	1.0020	1.2583	1.4925	1403.4
0.8718	1.0109	1.3568	1.5075	1432.1
1.0000	1.0199	1.4553	1.5221	1462
313.15K				
0.0000	0.9072	0.3358	1.3511	1087
0.0637	0.9166	0.4173	1.3659	1118.9
0.1313	0.9260	0.4989	1.3807	1150.8
0.2032	0.9354	0.5804	1.3956	1182.7
0.2799	0.9448	0.6620	1.4104	1214.6
0.3617	0.9542	0.7435	1.4252	1246.5
0.4494	0.9636	0.8251	1.4401	1278.4

0.5434	0.9730	0.9066	1.4548	1310.3
0.6446	0.9824	0.9882	1.4697	1342.2
0.7537	0.9918	1.0697	1.4845	1374.1
0.8718	1.0012	1.1513	1.4994	1406.0
1.0000	1.0106	1.2329	1.5142	1436
323.15k				
0.0000	0.8948	0.2998	1.3468	1045
0.0637	0.9043	0.3689	1.3612	1078.6
0.1313	0.9137	0.4381	1.3756	1112.27
0.2032	0.9231	0.5073	1.3901	1145.9
0.2799	0.9326	0.5765	1.4044	1179.5
0.3617	0.9420	0.6457	1.4188	1213.18
0.4494	0.9515	0.7149	1.4332	1246.8
0.5434	0.9606	0.7841	1.4476	1280.4
0.6446	0.9704	0.8533	1.4621	1314.1
0.7537	0.9798	0.9225	1.4764	1347.7
0.8718	0.9893	0.9917	1.4917	1381.4
1.0000	0.9987	1.0609	1.5061	1412

The density values have been used to calculate excess molar volumes V^E using the following equation

$$V^E = (x_1 M_1 + x_2 M_2) / \rho_m - (x_1 M_1 / \rho_1 + x_2 M_2 / \rho_2) \quad (7)$$

where x_1 and x_2 refer to the mole fraction of components 1 and 2. ρ_1 , ρ_2 , and ρ_m refer to the density of components 1 and 2 and the density of the mixture, respectively. The viscosity deviations $\Delta\eta$ were calculated from the viscosity values using

$$\Delta\eta = \eta - (x_1 \eta_1 + x_2 \eta_2) \quad (8)$$

where η , η_1 , and η_2 are the viscosity of the mixture and the viscosity of pure components 1 and 2, respectively. The uncertainty in the calculation of $\Delta\eta$ from viscosity measurements was estimated to be ± 0.0001 . The changes of refractive index (Δn_D), from linear additive value of the mole fraction is obtained by

$$\Delta n_D = n_D - (x_1 n_{D1} + x_2 n_{D2}) \quad (9)$$

The isentropic compressibility deviation ($\Delta\kappa_s$) over the entire composition range was obtained by

$$\Delta\kappa_s = \kappa_s - (x_1 \kappa_{s1} + x_2 \kappa_{s2}) \quad (10)$$

where x_1 and x_2 refer to the mole fraction of components 1 and 2. κ_{s1} , κ_{s2} , and κ_s refer to the isentropic compressibility of components 1 and 2 and the isentropic compressibility of the mixture, respectively.

The change of intermolecular free length (ΔL_f) on mixing were calculated by the equation

$$\Delta L_f = L_f - (x_1 L_{f1} + x_2 L_{f2}) \quad (11)$$

where L_{f1} and L_{f2} refer to the intermolecular free length of component 1 and 2. The excess molar volumes were fitted to a Redlich–Kister equation of the type

$$Y = x_1 x_2 \sum A_i (x_1 - x_2)^i \quad (12)$$

where Y is either V^E , and n is the degree of polynomial. Coefficients A_i were obtained by fitting equation 12 to experimental results using a least-squares regression method. In each case, the optimum number of coefficients is ascertained from an examination of the variation in standard deviation (S). S was calculated using the relation

$$S(Y) = [\sum (A_{\text{exp}} - A_{\text{cal}})^2 / (N - n)]^{1/2} \quad (13)$$

where N is the number of data points and n is the number of coefficients. The calculated values of coefficients along with the standard deviation (S) are given in Table 3.

Table 3. Parameters and Standard Deviations (S) of Redlich–Kister Equation for Acetophenone (1) + Methyl Acetate (2) $T = (303.15, 313.15, \text{ and } 323.15) \text{ K}$.

Functions	A0	A1	A2	A3	A4	S
303.15K						
$V^E / \text{cm}^3 \text{mol}^{-1}$	-0.1014	0.1462	0.0973	-0.0804	0.0065	0.0013
$\Delta\eta / \text{mPa}\cdot\text{s}$	0.5949	-0.9028	-0.6719	0.5571	0.0574	0.0312
Δn_D	0.1026	-0.1519	-0.1186	0.0982	0.0124	0.0016
$\Delta\kappa_s \times 10^{-11} \text{ m}^2 \text{N}^{-1}$	-66.919	73.125	71.881	-49.08	-3.1896	0.9797
$\Delta L_f \times 10^{-11} \text{ m}$	2.4952	-0.326	-1.7153	0.4629	-0.8869	0.0224
313.15K						
$V^E / \text{cm}^3 \text{mol}^{-1}$	-0.1848	0.237	0.2042	-0.1523	-0.0146	0.0022
$\Delta\eta / \text{mPa}\cdot\text{s}$	0.4934	-0.7475	-0.5572	0.4613	0.0475	0.0121
Δn_D	0.0867	-0.1361	-0.0975	0.0841	0.0078	0.0014
$\Delta\kappa_s \times 10^{-11} \text{ m}^2 \text{N}^{-1}$	-82.753	91.085	87.808	-61.568	-2.8089	1.7866
$\Delta L_f \times 10^{-11} \text{ m}$	-2.3385	2.9023	2.5207	-1.9154	-0.1139	0.0525
323.15K						
$V^E / \text{cm}^3 \text{mol}^{-1}$	-0.2245	0.3235	0.2626	-0.2290	-0.0297	0.0040
$\Delta\eta / \text{mPa}\cdot\text{s}$	0.4158	-0.6338	-0.4697	0.3908	0.0402	0.0183
Δn_D	0.0765	-0.1335	-0.0835	0.0853	0.0041	0.0013
$\Delta\kappa_s \times 10^{-11} \text{ m}^2 \text{N}^{-1}$	-100.8	110.71	106.77	-75.552	-3.2353	2.8211
$\Delta L_f \times 10^{-11} \text{ m}$	-2.7373	3.446	2.9469	-2.2969	-0.1288	0.0794

Interaction parameters and standard deviations of the McAllister model and Krishnan and Laddha model for the viscosity of acetophenone and methyl acetate mixture at (303.15, 313.15, and 323.15) K are presented in Table 4 and 5. Constants and standard deviations of the Jouban-Acree model of the acetophenone and methyl acetate at (303.15, 313.15, and 323.15) K are presented in Table 6.

Table 4. Parameters and Standard Deviation of the of the McAllister model for Acetophenone (1) + Methyl Acetate (2).

T/K	v_{12}	v_{21}	S
303.15	1.13710	1.33516	0.0011
313.15	0.99661	1.12956	0.0011
323.15	0.94928	1.11237	0.0016

Table 5. Parameters and Standard Deviation of the Krishnan – Laddha model for Acetophenone (1) + Methyl Acetate(2).

T/K	A_0	A_1	A_2	A_3	S
303.15	-0.6624	-0.3801	0.7057	0.1412	0.5798
313.15	0.1056	-0.0193	-0.0293	-0.0806	0.6571
323.15	0.1921	-0.1694	-0.2807	0.0539	0.6424

Table 6. Parameters and Standard Deviations of Jouyban- Acree Model for Acetophenone (1) + Methyl Acetate(2).

Properties	T/K	A0	A1	A2	A3	S
$\rho / \text{g} \cdot \text{cm}^{-3}$	303.15	14.058	-0.8045	-17.502	-12.814	0.0005
	313.15	15.331	-0.826	-19.24	-14.117	0.0005
	323.15	16.139	-0.8515	-20.566	-14.867	0.0005
$\eta / \text{mPa} \cdot \text{s}$	303.15	484.34	-67.716	-966.86	-1226.3	0.0344
	313.15	473.61	-64.926	-902.82	-1150.3	0.0273
	323.15	523.7	-82.505	-981.11	-1275.9	0.0248
n_D	303.15	16.65	-0.5492	-23.567	-16.572	0.0010
	313.15	16.622	-0.9734	-20.935	-14.932	0.0008
	323.15	15.988	-1.9747	-21.757	-11.141	0.0007
$u \text{ m/s}$	303.15	38.861	-2.8624	-50.28	-40.101	1.9602
	313.15	40.287	-2.983	-52.214	-42.901	1.9490
	323.15	43.582	-2.9895	-57.6	-48.329	2.0609

The variation of excess volumes with the mole fraction (x_1) of acetophenone and methyl acetate at (303.15, 313.15 and 323.15) K are represented in figure.1.

Figure 1. Excess Molar Volume, V^E , for the system Acetophenone (1) + Methyl Acetate (2) at temperatures: $\blacklozenge$, $T = 303.15$ K; $\blacksquare$, $T = 313.15$ K; $\blacktriangle$, $T = 323.15$ K.

This shows that the excess molar volumes are always negative for all the studied temperatures. Treszczanowicz et al.¹² and Roux and Desnoyers¹³ suggested that V^E is the resultant contribution from several opposing effects. These may be divided arbitrarily into three types, namely chemical, physical and structural. A physical contribution, that is specific interactions between the real species present in the mixture, contribute a negative term to V^E . The chemical or specific intermolecular interactions result in a volume decrease, and these include charge transfer type forces and other complex forming interactions. This effect contributes negative values to V^E . The structural contributions are mostly negative and arise from several effects, especially from interstitial accommodation and changes of free volume. In other words, structural contributions arising from geometrical fitting of one component into the other due to the differences in the free volume and molar volume between components lead to a negative contribution to V^E . The variation of viscosity deviations, with the mole fraction of component 1 is presented in figures 2. Viscosity values are positive for the acetophenone and methyl acetate mixture at all the studied temperatures. Figure 2 shows that the viscosity deviations are positive¹⁴, indicates that the interaction between binary mixtures is strong.

Figure 2. Viscosity Deviation, $\Delta\eta$, for the system Acetophenone (1) + Methyl Acetate (2) at temperatures: $\blacklozenge$, $T = 303.15$ K; $\blacksquare$, $T = 313.15$ K; $\blacktriangle$, $T = 323.15$ K.

The results of refractive indices versus x_1 at (303.15, 313.15 and 323.15) K for the systems of acetophenone are shown in figure 3. Here the system acetophenone + methyl acetate exhibit a positive deviation at all the studied temperatures. The values of $\Delta\kappa_s$ are negative at all the temperatures and the values of $\Delta\kappa_s$ become less negative as temperature increased (figure 4). This may be attributed to the weakening of structure making interactions at elevated temperatures due to enhanced thermal motion¹⁵. The excess free length is negative over the whole mole fraction range for all binary mixtures at different

temperatures, figure 5. This indicates structural readjustment in the liquid mixtures towards less compressible phase of fluid and closer packing of molecules^{16, 17}.

Figure 3. Refractive Index Deviation, Δn_D , for the system Acetophenone (1) + Methyl Acetate (2) at temperatures: $\blacklozenge$, $T = 303.15$ K; $\blacksquare$, $T = 313.15$ K; $\blacktriangle$, $T = 323.15$ K.

Figure 4. Isentropic Compressibility Deviation, ΔK_s , for the system Acetophenone (1) + Methyl Acetate (2) at temperatures: $\blacklozenge$, $T = 303.15$ K; $\blacksquare$, $T = 313.15$ K; $\blacktriangle$, $T = 323.15$ K.

Figure 5. Intermolecular Free Length Deviation, ΔL_f , for the system Acetophenone (1) + Methyl Acetate (2) at temperatures: $\blacklozenge$, $T = 303.15$ K; $\blacksquare$, $T = 313.15$ K; $\blacktriangle$, $T = 323.15$ K.

Conclusions

Densities, viscosities, refractive indices and ultrasonic velocities for a four binary mixtures have been measured. Excess molar volumes, viscosity deviations, refractive index deviations, compressibility deviation and change in intermolecular free length for mixtures of acetophenone and methyl acetate were obtained from the experimental results and fitted by the Redlich Kister equations. It has been concluded that the Jouyban Acree model is very well suited for correlating the thermo physical properties of the binary mixture studied.

Acknowledgement

The authors thank the University authorities for providing the necessary facilities to carry out the work.

References

1. Ewing M B, Levian B J and Marsh K N, *J Chem Thermodyn.*, 1970, **2**, 689.
2. Mchaweh A, Alsaygh A and Mosh-Feghian M A, *Fluid Phase Equilib.*, 2004, **224**, 157.
3. Kenart C M and Kenart W, *Phys Chem Liq.*, 2000, **38**, 155.
4. Baskaran R and Kubendran T R, *J Chem Eng Data.*, 2008, **53**, 978.
5. Baskaran R and Kubendran T R, *J Chem Eng Data.*, 2008, **53**, 1956.
6. McAllister R A, *AIChE J.*, 1960, **6**, 427.
7. Krishnan M R V and Laddha G S, *Ind Chem Eng Trans* 1963, **57**
8. Jouyban A, Khoubnasabjafari M, Vaezgharamaleki Z, Fekari Z and Acree W E Jr., *Chem Pharm Bull.*, 2005, **53**, 519.
9. Redlich O and Kister A T, *Ind Eng Chem.*, 1948, **40**, 345.
10. Perrin D D and Armerego W L F, *Purification of Laboratory chemistry*, 3ed; Pergamon press: Oxford, 1988.
11. Riddick J A, Bunger W B and Sakano T K, *Organic solvents: physical properties and methods of purification*. 4th Ed.; Wiley- Interscience: New York, 1986.
12. Treszczanowicz A J, Kiyohara O and Benson G C, *J Chem Thermodyn.*, 1981, **13**, 253.
13. Roux A and Desnoyers J, *Indian Acad Proc. Chem.Soc.*, 1978, **98**, 435.
14. Fort R J and Moore W R, *Trans Faraday Soc.*, 1966, **62**, 1112.
15. Maham Y, Hepler L G, Mather A E, Hakin A W and Marriot R M, *J Chem Soc Faraday Trans.*, 1997, **93**, 1747.
16. Oswal S L and Patel N B, *J Chem Eng Data.*, 2000, **45**, 225.
17. Rama Rao G V, Viswanatha Sarma A and Rambabu C, *Indian J Pure Appl Phys.*, 2004, **42**, 820.
18. Syamala V, Venkateshwarlu P and Sivakumar K, *J Chem Eng Data.*, 2006, **51**, 928.
19. Iloukhani H and Rostami Z, *J Chem Eng Data.*, 2007, **52**, 921.
20. Maria M. Palaiologou, *J Chem Eng Data.*, 1996, **41**, 1036.
21. Aralaguppi M I, Jadar C V and Aminabhavi T M, *J Chem Eng Data.*, 1999, **44**, 441.
22. Aminabhavi T M and Kamalika Banerjee., *J Chem Eng Data.*, 1998, **43**, 514.
23. José M. Resa, José M. Goenaga, Ana I. Sánchez-Ruiz and Miguel Iglesias, *J Chem Eng Data.*, 2006, **51**, 3, 1294.