

Erratum: Density and viscosity of the binary mixtures of hexan-1-ol with isomeric xylenes at T = (308.15 and 318.15) K and atmospheric pressure

著者	Habibullah M., Das Kamalendra N., Rahman Ismail M. M., Uddin M. Ashraf, Saifuddin Khaled, Iwakabe Koichi, Hasegawa Hiroshi
journal or publication title	Journal of Chemical and Engineering Data
volume	55
number	11
page range	5370-5374
year	2010-11-11
URL	http://hdl.handle.net/2297/25762

doi: 10.1021/je100823t

1 Density and Viscosity of the Binary Mixtures of Hexan-
2 1-ol with Isomeric Xylenes at $T = (308.15 \text{ and } 318.15) \text{ K}$
3 and Atmospheric Pressure

4
5 *M. Habibullah^{a*}, Kamalendra N. Das^{a*}, Ismail M. M. Rahman^{a, b*}, M. Ashraf Uddin^a, Khaled*
6 *Saifuddin^a, Koichi Iwakabe^c and Hiroshi Hasegawa^b*

7 ^aDepartment of Chemistry, Faculty of Science, University of Chittagong, Chittagong-4331, Bangladesh

8 ^bGraduate School of Natural Science and Technology, Kanazawa University, Kakuma, Kanazawa 920-
9 1192, Japan

10 ^cPrime Polymer Co., Ltd., Ichihara, Chiba 299-0108, Japan

11

12

13

14 *Author(s) for correspondence.

15 E-mail: mhu786@gmail.com (M. Habibullah); kamalctgu@hotmail.com (K.N. Das);

16 I.M.M.Rahman@gmail.com (I.M.M. Rahman).

17 Tel/ Fax: +81-76-234-4792

1 **Abstract**

2 Densities and viscosities of binary liquid mixtures of hexan-1-ol + *o*-xylene, or + *m*-xylene, or + *p*-
3 xylene were measured at a number of mole fractions at $T = (308.15 \text{ and } 318.15) \text{ K}$ and atmospheric
4 pressure. The excess volumes and the viscosity deviations from the mole fraction average were
5 calculated from the experimental density and viscosity data. The experimental data were correlated with
6 Redlich-Kister equation. Variations in the calculated excess and deviation properties for the liquid
7 mixtures were studied in terms of intermolecular interactions.

8

9

10

11

12

13

14

15

16

17

18

19

20

21

22

23

24

1 **Introduction**

2 Density and viscosity of liquid mixtures are required in most engineering calculations and different
3 analytical applications where fluid flow or mixing is an important factor.¹⁻⁴ Knowledge about the
4 density and viscosity of multi-component mixtures are also important for understanding and
5 rationalizing the behavior of mixed liquids.⁵⁻⁹ The studies of excess and deviation properties are of
6 considerable interest in understanding the intermolecular interactions in the multi-component liquid
7 mixtures.¹⁰⁻¹⁵ Therefore, evaluation and prediction of these properties of solvent mixtures as functions
8 of temperature and composition are of theoretical and practical importance.¹⁶

9 We are interested in the accumulation of the binary physical property data of organic liquid mixtures^{10,}
10 ¹²⁻¹⁵ to explore the possible interactions in the mixed liquid systems. Here we report the values of
11 densities and viscosities for some binary systems of hexan-1-ol with isomeric xylenes (*o*-xylene, *m*-
12 xylene and *p*-xylene) at 308.15 K and 318.15 K and atmospheric pressure, working with the pure
13 species and with number of mixtures covering the entire miscibility range. All liquids are widely used as
14 solvents in scientific studies and industrial applications. Aliphatic polar liquid and monohydric alcohol,
15 hexan-1-ol, herein has been considered as the solute and the other three liquids, *o*-xylene, *m*-xylene and
16 *p*-xylene, are considered as solvents. Thus, there is a possibility of favorable interaction with hydroxyl
17 group of hexan-1-ol with the delocalized π -electrons of aromatic rings in the xylenes,¹⁷ and the
18 experimental results will allow us to study the interactions.

19 The excess molar volume and viscosity deviation have been calculated from the experimental density
20 and viscosity measurements. The calculated results were fitted to the Redlich-Kister type polynomial
21 equation,¹⁸ to derive the binary coefficients and estimate the standard deviations between experimental
22 and calculated results. Some previous observations for the binary systems were used to interpret the
23 experimental data and the derived quantities.

24 In the literature, there are reports on the volumetric and viscometric behavior of xylenes with different
25 alkanols¹⁹⁻²⁵ other than hexan-1-ol. Excess molar volumes of hexan-1-ol + xylenes at 298.15 K was

1 reported by Rodriguez-Nuñez *et al.*²⁶. Das *et al.*¹³ and Habibullah *et al.*¹⁵ reported the excess and
2 deviation properties of the hexan-1-ol + *m*-xylene and + *p*-xylene systems, respectively, at $T = (303.15,$
3 313.15 and $323.15)$ K. But, no experimental data are available at the comparable conditions for hexan-
4 1-ol with *o*-xylene, or *m*-xylene, or *p*-xylene at $T = (308.15$ and $318.15)$ K.

6 **Experimental**

7 *Materials*

8 Hexan-1-ol and *o*-, *m*- and *p*-xylenes from Merck-Schuchard, Germany (0.98 mass fraction purity) were
9 used without further treatment. The density and viscosity values of pure solvents were compared with
10 the literature data and are shown in Table 1.

11 *Apparatus and Procedure*

12 The liquid mixtures were prepared by mass on an analytical balance (B 204-S, Mettler Toledo,
13 Switzerland) with uncertainty of ± 0.0001 g which was operated in a dry box. The average uncertainty
14 in the mole fraction of the mixtures was estimated to less than $\pm 1.0 \times 10^{-4}$. Caution was taken to
15 prevent evaporation of the samples after preparation.

16 The density of the pure components and their mixtures was measured with a 10 mL bi-capillary
17 pycnometer. Before each series of measurements the instrument was calibrated at atmospheric pressure
18 with double-distilled water. The uncertainty in density measurements was $0.0004 \text{ g}\cdot\text{cm}^{-3}$.

19 Viscosity was measured using an A-type Ostwald viscometer, calibrated with double-distilled water.
20 An electronic digital stopwatch with a readability of ± 0.01 s was used for flow-time measurement. The
21 overall uncertainty of the viscosity measurements was $\pm 0.005 \text{ mPa}\cdot\text{s}$.

22 All measurements were carried out in a transparent glass-walled thermostatic water bath. The Thermo
23 Haake DC10 controller (Thermo Fisher Scientific, MA, USA) was used to control the bath temperature,
24 and a minimum-maximum thermometer (Brannan Thermometers, Cumberland, UK) was used for
25 temperature monitoring. The uncertainty in the temperature during the measurements was ± 0.05 K.

1 Triplicate measurements were performed for all mixture compositions and pure solvents, and the
2 average of these values was considered in all calculations. Microsoft Office Excel 2007 (The Microsoft
3 Corporation, USA) software was used for tabulation and data processing. LAB Fit²⁷ and LSM²⁸ curve-
4 fitting program were used for least-square regression analyses. Sma4 for Windows²⁹ was used for
5 graphical representation of data.

6

7 **Results and Discussion**

8 The binary compositions and the experimental densities (ρ) at all the investigated temperatures are
9 summarized in Table 2. The excess molar volumes of mixing (V_m^E) were calculated using the following
10 relation:

$$11 \quad V_m^E = [(x_1 M_1 + x_2 M_2) / \rho - \{(x_1 M_1) / \rho_1 + (x_2 M_2) / \rho_2\}] \quad (1)$$

12 where x_1 , M_1 and ρ_1 represent mole fraction, molar mass and density of component 1 (hexan-1-ol),
13 respectively, and x_2 , M_2 and ρ_2 are the corresponding quantities of component 2 (*o*-xylene, or *m*-xylene,
14 or *p*-xylene).

15 Table 2 summarizes the binary composition of the solvent mixtures and the experimental viscosities
16 (η). The viscosity deviations ($\Delta\eta$) at $T = (308.15 \text{ and } 318.15) \text{ K}$ were calculated from the following
17 relation:

$$18 \quad \Delta\eta = \eta - \exp(x_1 \ln \eta_1 + x_2 \ln \eta_2) \quad (2)$$

19 where x_1 and x_2 are the mole fractions of the first and second components having viscosities η_1 and η_2 ,
20 respectively.

21 The composition dependence of V_m^E or $\Delta\eta$ can be represented by a Redlich–Kister type smoothing
22 equation:¹⁸

$$23 \quad Y = x_1 x_2 \sum_{i=0}^n A_i (1 - 2x_1)^i \quad (3)$$

24 where, Y refers to V_m^E or $\Delta\eta$, and x_1 and x_2 are the mole fractions of hexan-1-ol and *o*-xylene or *m*-

1 xylene, or *p*-xylene. The variables A_i are the equation coefficients, which can be obtained by fitting the
2 equation to the experimental values with a least-squares regression method. The values of the
3 coefficients with standard deviation at each studied temperature are summarized in Table 3. Following
4 relation was used to calculate the standard deviation values:

$$5 \quad \sigma(Y) = \left[\sum (Y_{\text{expt}} - Y_{\text{calc}})^2 / (n - p) \right]^{1/2} \quad (4)$$

6 where n is the number of experimental points, p is the number of coefficients of eq. (3), Y_{expt} and Y_{calc}
7 are the experimental and calculated values of the properties.

8 Figure 1 shows the trend of V_m^E as a function of the binary composition at $T = (308.15 \text{ and } 318.15) \text{ K}$.
9 As it appears, V_m^E is always positive under all experimental conditions. A broad maximum at about $x_1 \approx$
10 0.3000, which becomes more positive as temperature increases, with a sharp increase followed by
11 gradual decrease is observed from the curves. Factors contributing to the expansion or contraction of
12 volume define the sign of V_m^E . Existence of a weak interaction between the components is apparent
13 from the positive values of V_m^E . Hexan-1-ol has an associated structure due to hydrogen bonding, and is
14 mixed with the non-associating solvents, *o*-xylene, or *m*-xylene, or *p*-xylene. At hexan-1-ol low
15 concentration region, high content of the apolar components in the mixed solution systems may cause
16 disintegration in the associated structure of hexan-1-ol causing the sharp changes in the V_m^E . On the
17 contrary, at hexan-1-ol rich region, associated structures of the alcohol remain unchanged which may
18 facilitate the accommodation of the xylenes into the network of alcohol causing a gradual decrease in
19 the V_m^E . The comparative order of V_m^E is as follows: hexan-1-ol + *m*-xylene > hexan-1-ol + *o*-xylene >
20 hexan-1-ol + *p*-xylene. The patterns indicate the variation in the interactions between the delocalized π -
21 electrons of the xylene ring and the –OH group of hexan-1-ol beside the disruption of H-bonding. The
22 variation in the interaction may be due to the effect of the varying position of the two methyl groups on
23 the aromatic ring. For the binary systems of different alkanols with xylenes, similar explanation for the
24 volumetric properties was suggested by Yadav *et al.*,¹⁹ Letcher *et al.*,²⁰ Rodriguez-Nuñez *et al.*,^{21, 26}
25 Sreenivasulu and Naidu,³⁰ Singh *et al.*,³¹ Saleh *et al.*,³² etc.

1 Negative trend in the $\Delta\eta$ values throughout the whole range of mole fraction are observed for the
2 binary mixtures of hexan-1-ol with the xylenes at $T = (308.15 \text{ and } 318.15) \text{ K}$ (Figure 2) with a minimum
3 at around 0.6000 mole fraction of alcohol. The negative $\Delta\eta$ values represent repulsion-type interactions
4 between the polar and apolar components of the binary mixtures. When mixed with the xylenes, at low
5 concentration region, the associated structure of hexan-1-ol undergoes disruption to form less flow-
6 resistant monomeric, oligomeric or small scaled multimeric species resulting in the negative viscosity
7 deviations. The interstitial accommodation of the xylenes into the structured network of hexan-1-ol may
8 occur at high concentration region. Such effect may create compact and well-shaped flowing species
9 with favorable geometric fitting having reduced frictional resistance with a subsequent decrease in $\Delta\eta$.
10 The boiling point, dielectric constant and dipole moment of the xylenes are in the following order: *o*-
11 xylene > *m*-xylene > *p*-xylene (Table 4). While the depth of the negative viscosity deviations follows the
12 reverse order. A dipole-dipole type interaction, which is purely physical in nature, is possible between
13 hexan-1-ol and isomeric xylenes. *o*-xylene, the most polar among the xylenes, interacts with hexan-1-ol
14 more strongly than the less polar *m*-xylene or the non polar *p*-xylene. Therefore, it may be predicted
15 from the comparative profile that the greater the interaction the lesser is the depth of the minima of the
16 negative viscosity deviations. Saleh *et al.*²⁵ proposed the same argument to explain the viscometric
17 behavior of the systems containing different alkanols other than hexan-1-ol and *m*-xylene.

18

19 **Conclusion**

20 Densities and viscosities of the binary systems of hexan-1-ol with *o*-xylene, *m*-xylene, and *p*-xylene
21 were measured at several temperatures and for the whole composition range. The excess molar volumes
22 (V_m^E) and viscosity deviations ($\Delta\eta$) were computed and fitted to the Redlich-Kister type equation. A
23 systematic change with increasing temperature is observed for V_m^E and $\Delta\eta$. V_m^E are positive for all the
24 mixtures over the entire composition range and become more positive with increasing temperature. The
25 $\Delta\eta$ are negative and become less negative with increasing temperature.

1 **Acknowledgment**

2 One of the authors, Ismail M. M. Rahman, acknowledges the support from the Japanese Government
3 (Monbukagakusho: MEXT) Scholarship program that facilitated this research.

4

5

6

7

8

9

10

11

12

13

14

15

16

17

18

19

20

21

22

23

24

25

26

27

28

1 **Literature Cited:**

- 2 (1) Rowlinson, J. S.; Swinton, F. L., *Liquids and Liquid Mixtures*. Butterworth Scientific: London,
3 1982.
- 4 (2) Reichardt, C., *Solvents and Solvent Effects in Organic Chemistry*. 3rd ed.; Wiley-VCH:
5 Weinheim, 2003.
- 6 (3) Dominey, L. A., Current state of the art on lithium battery electrolytes. In *Lithium batteries :
7 new materials, developments, and perspectives*, Pistoia, G., Ed. Elsevier: Amsterdam, 1994; pp
8 137-165.
- 9 (4) Sadek, P. C., *The HPLC Solvent Guide*. 2nd ed.; Wiley-Interscience: New York, 2002.
- 10 (5) Al-Jimaz, A. S.; Al-Kandary, J. A.; Abdul-Latif, A. H. M., Densities and viscosities for binary
11 mixtures of phenetole with 1-pentanol, 1-hexanol, 1-heptanol, 1-octanol, 1-nonanol, and 1-
12 decanol at different temperatures. *Fluid Phase Equilib.* **2004**, *218*, 247-260.
- 13 (6) Kabir-ud-Din; Ajmal Koya, P., Effects of solvent media and temperature on the self-aggregation
14 of cationic dimeric surfactant 14-6-14, 2Br⁻ studied by conductometric and fluorescence
15 techniques. *Langmuir* **2010**, *26*, 7905-7914.
- 16 (7) Kabir-ud-Din; Koya, P. A., Micellar properties and related thermodynamic parameters of the 14-
17 6-14, 2Br⁻ gemini surfactant in water + organic solvent mixed media. *J. Chem. Eng. Data* **2010**,
18 *55*, 1921-1929.
- 19 (8) Sarkar, B.; Lam, S.; Alexandridis, P., Micellization of Alkyl-Propoxy-Ethoxylate Surfactants in
20 Water–Polar Organic Solvent Mixtures. *Langmuir* **2010**, *26*, 10532-10540.
- 21 (9) Kabir-ud-Din; Rub, M. A.; Naqvi, A. Z., Mixed micelle formation between amphiphilic drug
22 amitriptyline hydrochloride and surfactants (conventional and gemini) at 293.15–308.15 K. *J.
23 Phys. Chem. B* **2010**, *114*, 6354-6364.
- 24 (10) Adhikhari, A. B.; Rahman, I. M. M.; Uddin, M. A.; Hasegawa, H.; Majid, M. A., Volumetric
25 behavior of the binary mixtures of methyl ethyl ketone with *n*-hexane, cyclohexane, and benzene

- 1 at T = (303.15, 313.15, and 323.15) K. *J. Chem. Eng. Data* **2009**, *54*, 1138-1141.
- 2 (11) Chowdhury, M. A.; Majid, M. A.; Saleh, M. A., Volumetric and viscometric behaviour of binary
3 systems: (1-hexanol + hydrocarbons). *J. Chem. Thermodyn.* **2001**, *33*, 347-360
- 4 (12) Saleh, M. A.; Habibullah, M.; Ahmed, M. S.; Uddin, M. A.; Uddin, S. M. H.; Uddin, M. A.;
5 Khan, F. M., Excess molar volumes and viscosities of some alkanols with cumene. *Phys. Chem.*
6 *Liq.* **2006**, *44*, 31-43.
- 7 (13) Das, K. N.; Habibullah, M.; Rahman, I. M. M.; Hasegawa, H.; Uddin, M. A.; Saifuddin, K.,
8 Thermodynamic properties of the binary mixture of hexan-1-ol with m-xylene at T = (303.15,
9 313.15, and 323.15) K. *J. Chem. Eng. Data* **2009**, *54*, 3300-3302.
- 10 (14) Das, K. N.; Habibullah, M.; Uddin, K. S.; Barua, P., The thermodynamic excess properties of
11 binary mixtures: I. hexanol-1 + o-xylene. *J. Solution Chem.* **2006**, *35*, 1017-1028.
- 12 (15) Habibullah, M.; Das, K. N.; Rahman, I. M. M.; Hasegawa, H.; Uddin, M. A.; Saifuddin, K.,
13 Volumetric and viscometric behavior of the binary system: (Hexan-1-ol + p-Xylene). *J. Chem.*
14 *Eng. Data* **2010**, DOI: 10.1021/je100390b.
- 15 (16) Baraldi, P.; Giorgini, M. G.; Manzini, D.; Marchetti, A.; Tassi, L., Density, refractive index, and
16 related properties for 2-butanone plus n-hexane binary mixtures at various temperatures. *J.*
17 *Solution Chem.* **2002**, *31*, 873-893.
- 18 (17) Barker, J. A.; Smith, F., Statistical thermodynamics of associated solutions. *J. Chem. Phys.* **1954**,
19 *22*, 375-380.
- 20 (18) Redlich, O.; Kister, A. T., Algebraic representation of thermodynamic properties and the
21 classification of solutions. *Ind. Eng. Chem.* **1948**, *40*, 345-348.
- 22 (19) Yadav, B. L.; Maken, S.; Kalra, K. C.; Singh, K. C., Excess volumes of (an alkanol + an
23 aromatic hydrocarbon) at the temperature 308.15 K. *J. Chem. Thermodyn.* **1993**, *25*, 1345-1350.
- 24 (20) Letcher, T. M.; Koteswari Prasad, A.; Mercer-Chalmers, J.; Radloff, S. E., Excess molar
25 volumes of (a xylene + an alkanol) at 298.15 K. *J. Chem. Thermodyn.* **1990**, *22*, 1175-1179.

- 1 (21) Rodriguez-Nuñez, E.; Paz-Andrade, M. I.; Ortega, J., Thermodynamic properties of (a xylene +
2 an n-alkanol) IV. Excess molar volumes at 298.15 K for 1-propanol, 1-butanol, and 1-pentanol. *J.*
3 *Chem. Thermodyn.* **1986**, *18*, 303-308.
- 4 (22) Bhardwaj, U.; Maken, S.; Singh, K. C., Excess volumes of 1-butanol, 2-butanol, 2-
5 methylpropan-1-ol, and 2-methylpropan-2-ol with xylenes at 308.15 K. *J. Chem. Eng. Data*
6 **1996**, *41*, 1043-1045.
- 7 (23) Ouyang, G.; Huang, Z.; Ou, J.; Wu, W.; Kang, B., Excess molar volumes and surface tensions of
8 xylene with 2-propanol or 2-methyl-2-propanol at 298.15 K. *J. Chem. Eng. Data* **2002**, *48*, 195-
9 197.
- 10 (24) Al-Kandary, J. A.; Al-Jimaz, A. S.; Abdul-Latif, A.-H. M., Viscosities, densities, and speeds of
11 sound of binary mixtures of benzene, toluene, *o*-xylene, *m*-xylene, *p*-xylene, and mesitylene with
12 anisole at (288.15, 293.15, 298.15, and 303.15) K. *J. Chem. Eng. Data* **2006**, *51*, 2074-2082.
- 13 (25) Saleh, M. A.; Habibullah, M.; Ahmed, M. S.; Uddin, M. A.; Uddin, S. M. H.; Uddin, M. A.;
14 Khan, F. M., Viscosity of the systems *m*-xylene,+ 1-propanol,+ 2-propanol,+ 1-butanol, + *t*-
15 butanol. *Phys. Chem. Liq.* **2005**, *43*, 485-494.
- 16 (26) Rodriguez-Nuñez, E.; Paz-Andrade, M. I.; Bravo, R.; Ortega, J., Thermodynamic properties of
17 (a xylene + an *n*-alkanol) III. Excess molar volumes at 298.15 K for 1-hexanol, 1-heptanol, and
18 1-octanol. *J. Chem. Thermodyn.* **1985**, *17*, 817-821.
- 19 (27) *LAB Fit Curve Fitting Software (Nonlinear Regression and Treatment of Data Program)*; v.
20 7.2.47; online, available from - www.labfit.net (shareware); Wilton and Cleide Pereira da Silva -
21 DF/CCT/UFPB: Brazil, 1999–2010.
- 22 (28) *LSM (Least Squares Method Curve Fitting Program)*; v. 2.2; online, available from -
23 <http://www.prz.edu.pl/~janand/> (freeware); J. A. Mamczur: Poland, 1998–2010.
- 24 (29) *Sma4 for Windows*; v. 1.48 E; online, available from -
25 <http://hp.vector.co.jp/authors/VA002995/soft/sma4win.htm> (shareware); Toshio Suzuki: Japan,

- 1 1994–1998.
- 2 (30) Sreenivasulu, B.; Naidu, P. R., Excess volumes of binary mixtures of *o*-xylene and *m*-xylene with
3 iso-alcohols (C₃-C₅) at 303.15 K. *Indian J. Technol.* **1993**, *31*, 815-817.
- 4 (31) Singh, K. C.; Kalra, K. C.; Maken, S.; Yadav, B. L., Excess volumes of 1-propanol and 2-
5 propanol with aromatic hydrocarbons at 298.15 K. *J. Chem. Eng. Data* **1994**, *39*, 241-244.
- 6 (32) Saleh, M. A.; Habibullah, M.; Ahmed, M. S.; Uddin, M. A.; Uddin, S. M. H.; Uddin, M. A.;
7 Khan, F. M., Excess molar volumes of the systems *m*-xylene + 1-propanol, + 2-propanol, + 1-
8 butanol, + 2-methyl-2-propanol. *Phys. Chem. Liq.* **2005**, *43*, 139-148.
- 9 (33) Diaz Peña, M.; Tardajos, G., Isothermal compressibilities of *n*-1-alcohols from methanol to 1-
10 dodecanol at 298.15, 308.15, 318.15, and 333.15 K. *J. Chem. Thermodyn.* **1979**, *11*, 441-445.
- 11 (34) Rodriguez, M.; Galan, M.; Munoz, M. J.; Martin, R., Viscosity of triglycerides + alcohols from
12 278 to 313 K. *J. Chem. Eng. Data* **1994**, *39*, 102-105.
- 13 (35) Hovorka, F.; Lankelma, H. P.; Stanford, S. C., Thermodynamic properties of the hexyl alcohols.
14 II. Hexanols-1, -2, -3 and 2-methylpentanol-1 and -4. *J. Am. Chem. Soc.* **1938**, *60*, 820-827.
- 15 (36) Liew, K. Y.; Seng, C. E.; Ng, B. H., Viscosities of long chain *n*-alcohols from 15 to 80°C. *J.*
16 *Solution Chem.* **1993**, *22*, 1033-1040.
- 17 (37) Yang, J. H.; Dai, L. Y.; Wang, X. Z.; Chen, Y. Q., Densities and viscosities of binary mixtures
18 of methyl 4-chlorobutyrate with aromatic hydrocarbons at T = (298.15 to 318.15) K. *J. Chem.*
19 *Eng. Data* **2009**, *54*, 2332-2337.
- 20 (38) Nain, A. K.; Chandra, P.; Pandey, J. D.; Gopal, S., Densities, refractive indices, and excess
21 properties of binary mixtures of 1,4-dioxane with benzene, toluene, *o*-xylene, *m*-xylene, *p*-
22 xylene, and mesitylene at temperatures from (288.15 to 318.15) K. *J. Chem. Eng. Data* **2008**, *53*,
23 2654-2665.
- 24 (39) Song, C. Y.; Shen, H. Z.; Zhao, J. H.; Wang, L. C.; Wang, F. A., Densities and viscosities of
25 binary mixtures of vitamin K₃ with benzene, toluene, ethylbenzene, *o*-Xylene, *m*-Xylene, and *p*-

- 1 Xylene from (303.15 to 333.15) K. *J. Chem. Eng. Data* **2008**, *53*, 1110-1115.
- 2 (40) George, J.; Sastry, N. V., Densities, excess molar volumes, viscosities, speeds of sound, excess
3 isentropic compressibilities, and relative permittivities for $C_mH_{2m+1}(OCH_2CH_2)_nOH$ ($m = 1$ or 2
4 or 4 and $n = 1$) + benzene, + toluene, + (*o*-, *m*-, and *p*-) xylenes, + ethylbenzene, and +
5 cyclohexane. *J. Chem. Eng. Data* **2003**, *48*, 977-989.
- 6 (41) Goud, B. B.; Venkatesu, P.; Rao, M. V. P., Excess volumes and viscosities of isomeric xylenes
7 with *o*-nitrotoluene or *m*-nitrotoluene at 308.15 K. *J. Chem. Eng. Data* **1999**, *44*, 731-734.
- 8 (42) Exarchos, N. C.; Tasioula-Margari, M.; Demetropoulos, I. N., Viscosities and densities of dilute
9 solutions of glycerol trioleate + octane, + *p*-xylene, + toluene, and + chloroform. *J. Chem. Eng.*
10 *Data* **1995**, *40*, 567-571.
- 11 (43) Lide, D. R., *CRC Handbook of Chemistry and Physics (Internet Version)*. 90th ed.; CRC
12 Press/Taylor and Francis: Boca Raton, FL, 2010.

13

14

15

16

17

18

19

20

21

1 **Tables.**2 **Table 1.** Comparison of Experimental Density (ρ) and Viscosity (η) of Pure Liquids with Literature3 Values at $T = (308.15 \text{ and } 318.15) \text{ K}$

Liquid	T/K	$\rho/\text{g}\cdot\text{cm}^{-3}$			$\eta/\text{mPa}\cdot\text{s}$				
		Exp.	Lit.	Ref.	Exp.	Lit.	Ref.		
Hexan-1-ol	308.15	0.8085	0.80854	33	3.318	3.30	34		
			0.80836	35					
	318.15	0.8012	0.80123	33	2.518	2.5416	36		
			0.80105	35					
<i>o</i> -xylene	308.15	0.8667	0.86662	37	0.666	0.665	37		
			0.86705	38					
	318.15	0.8584	0.85812	37	0.591	0.589	37		
			0.85853	38					
<i>m</i> -xylene	308.15	0.8513	0.85119	37	0.521	0.524	37		
			0.85145	38				0.5201	39
			0.85157	40					
			0.85140	41					
	318.15	0.8427	0.84249	37	0.470	0.471	37		
			0.84288	38					
0.8424			39						
<i>p</i> -xylene	308.15	0.8482	0.84796	37	0.541	0.541	37		
			0.84812	38				0.540	40
			0.8479	42					
			0.8479	42					
	318.15	0.8395	0.83920	37	0.486	0.484	37		
			0.83942	38				0.4882	39

4

5

6

1 **Table 2.** Densities (ρ), Viscosities (η), Excess Molar Volumes, (V_m^E) and Viscosity Deviations ($\Delta\eta$) for the
 2 Binary Mixtures of Hexan-1-ol (1) with *o*-, *m*-, and *p*-Xylenes (2) at $T = (308.15 \text{ and } 318.15) \text{ K}$

x_1	ρ /g.cm ⁻³	V_m^E /cm ³ .mol ⁻¹	η /mPa.s	$\Delta\eta$ /mPa.s	x_1	ρ /g.cm ⁻³	V_m^E /cm ³ .mol ⁻¹	η /mPa.s	$\Delta\eta$ /mPa.s
Hexan-1-ol (1) + <i>o</i> -xylene (2)									
$T = 308.15 \text{ K}$									
0.0999	0.8601	0.0886	0.709	-0.073	0.6000	0.8307	0.0970	1.475	-0.270
0.1999	0.8539	0.1260	0.789	-0.129	0.7000	0.8251	0.0730	1.799	-0.250
0.2999	0.8479	0.1403	0.899	-0.178	0.8000	0.8195	0.0540	2.217	-0.189
0.4001	0.8421	0.1292	1.043	-0.222	0.8999	0.8140	0.0254	2.738	-0.087
0.4997	0.8364	0.1136	1.230	-0.255					
$T = 318.15 \text{ K}$									
0.0999	0.8517	0.1203	0.621	-0.062	0.6000	0.8227	0.1471	1.199	-0.211
0.1999	0.8456	0.1593	0.683	-0.107	0.7000	0.8172	0.1228	1.431	-0.199
0.2999	0.8397	0.1747	0.768	-0.145	0.8000	0.8118	0.0878	1.730	-0.154
0.4001	0.8339	0.1790	0.879	-0.177	0.8999	0.8064	0.0583	2.104	-0.074
0.4997	0.8283	0.1636	1.020	-0.200					
Hexan-1-ol (1) + <i>m</i> -xylene (2)									
$T = 308.15 \text{ K}$									
0.1002	0.8464	0.0826	0.562	-0.065	0.5999	0.8247	0.1201	1.298	-0.284
0.2002	0.8417	0.1397	0.638	-0.117	0.6999	0.8206	0.0959	1.629	-0.275
0.3007	0.8372	0.1660	0.742	-0.168	0.7999	0.8166	0.0577	2.072	-0.219
0.4001	0.8330	0.1564	0.875	-0.218	0.8999	0.8126	0.0207	2.643	-0.114
0.5000	0.8288	0.1451	1.057	-0.259					
$T = 318.15 \text{ K}$									
0.1002	0.8376	0.1349	0.502	-0.054	0.5999	0.8166	0.1683	1.066	-0.221
0.2002	0.8330	0.1987	0.561	-0.097	0.6999	0.8127	0.1326	1.306	-0.215
0.3007	0.8287	0.2158	0.643	-0.135	0.7999	0.8088	0.0981	1.623	-0.176
0.4001	0.8246	0.2110	0.747	-0.173	0.8999	0.8050	0.0489	2.031	-0.098
0.5000	0.8206	0.1890	0.885	-0.202					
Hexan-1-ol (1) + <i>p</i> -xylene (2)									
$T = 308.15 \text{ K}$									
0.1001	0.8436	0.0878	0.578	-0.071	0.5999	0.8237	0.0905	1.279	-0.327
0.2001	0.8394	0.1187	0.647	-0.131	0.6999	0.8199	0.0667	1.602	-0.324
0.2999	0.8354	0.1222	0.742	-0.190	0.8000	0.8161	0.0431	2.042	-0.266
0.4001	0.8314	0.1246	0.870	-0.248	0.9000	0.8123	0.0211	2.618	-0.149
0.5009	0.8275	0.1092	1.046	-0.296					
$T = 318.15 \text{ K}$									
0.1001	0.8349	0.1117	0.513	-0.060	0.5999	0.8156	0.1320	1.051	-0.252
0.2001	0.8308	0.1501	0.567	-0.108	0.6999	0.8119	0.1138	1.287	-0.250
0.2999	0.8269	0.1604	0.643	-0.153	0.8000	0.8083	0.0801	1.604	-0.207
0.4001	0.8231	0.1540	0.743	-0.196	0.9000	0.8047	0.0477	2.017	-0.118
0.5009	0.8193	0.1450	0.877	-0.231					

1 **Table 3.** Coefficients, A_i , of Redlich-Kister Equation (Equation 3), Expressing V_m^E and $\Delta\eta$, and Standard
 2 Deviation, σ , for the Binary Mixtures of Hexan-1-ol (1) with *o*-, *m*-, and *p*-Xylenes (2) at $T = (308.15$ and
 3 $318.15)$ K

<i>Function</i>	$T = 308.15$ K					$T = 318.15$ K				
	A_0	A_1	A_2	A_3	σ	A_0	A_1	A_2	A_3	σ
Hexan-1-ol (1) + <i>o</i> -xylene (2)										
$V_m^E / \text{cm}^3 \cdot \text{mol}^{-1}$	0.4592	0.3566	0.2836	0.1098	0.0019	0.6508	0.2905	0.4280	0.2191	0.0048
$\Delta\eta / \text{mPa} \cdot \text{s}$	-1.0343	0.5415	0.1585	-0.6712	0.0033	-0.8117	0.4014	0.0259	-0.4786	0.0030
Hexan-1-ol (1) + <i>m</i> -xylene (2)										
$V_m^E / \text{cm}^3 \cdot \text{mol}^{-1}$	0.5882	0.4023	0.0511	0.0526	0.0044	0.7666	0.4491	0.4181	0.2253	0.0019
$\Delta\eta / \text{mPa} \cdot \text{s}$	-1.0473	0.7338	0.0318	-0.5971	0.0026	-0.8164	0.5311	-0.0764	-0.3474	0.0017
Hexan-1-ol (1) + <i>p</i> -xylene (2)										
$V_m^E / \text{cm}^3 \cdot \text{mol}^{-1}$	0.4311	0.3085	0.2240	0.2356	0.0030	0.5782	0.2248	0.4405	0.3573	0.0021
$\Delta\eta / \text{mPa} \cdot \text{s}$	-1.1974	0.8693	-0.0920	-0.4864	0.0028	-0.9299	0.6284	-0.1296	-0.3310	0.0020

4
5
6
7
8
9
10
11
12
13
14
15
16
17

1 **Table 4.** Boiling Point (t_b), Relative Permittivity (ϵ) and Dipole Moment (μ) of Isomeric Xylenes ⁴³

	$t_b/^\circ\text{C}$	ϵ	μ/D
<i>o</i> -xylene	144.5	2.562	0.64
<i>m</i> -xylene	139.1	2.359	≈ 0
<i>p</i> -xylene	138.4	2.274	0

2

3

4

5

6

7

8

9

10

11

12

13

14

15

16

17

18

19

20

21

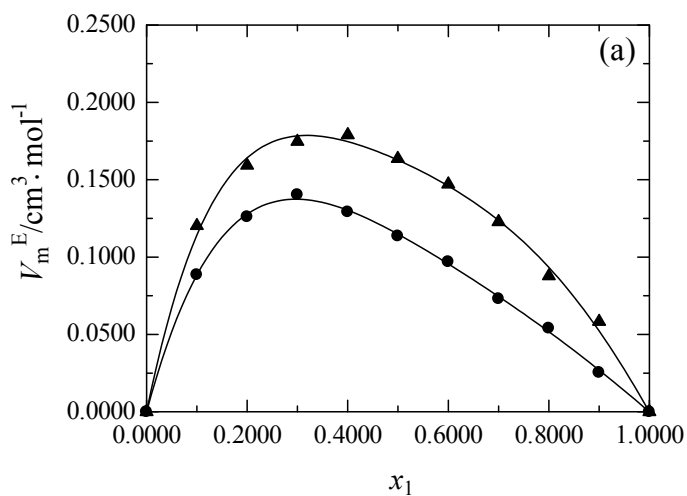
22

23

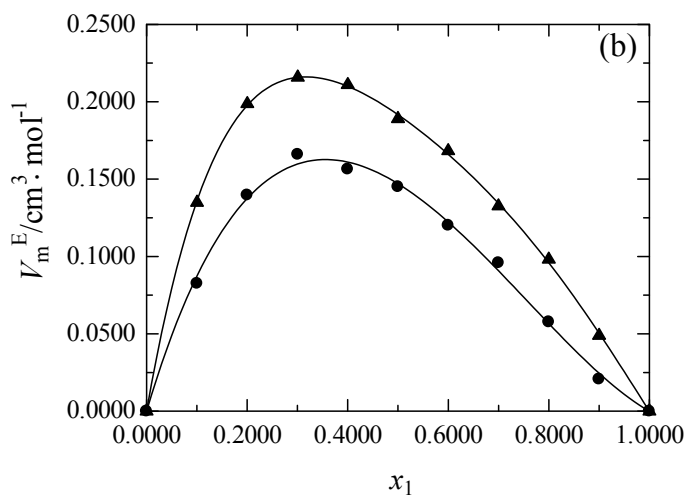
24

25

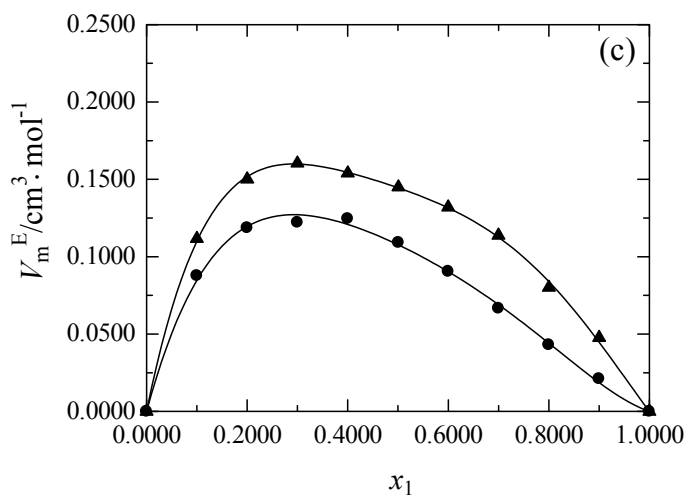
1 **Figures.**



2

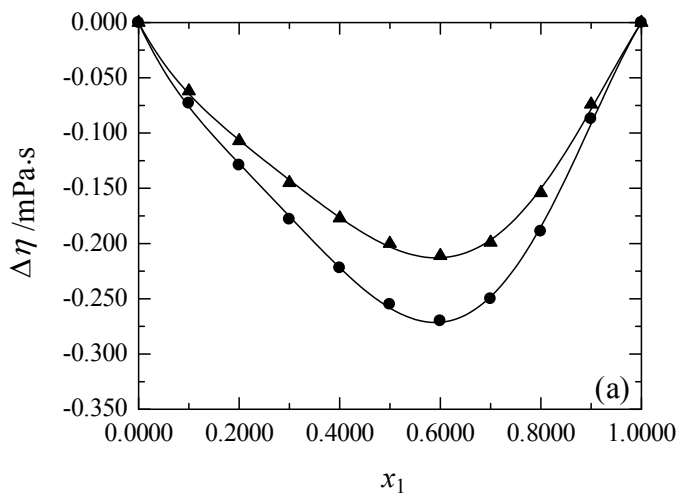


3

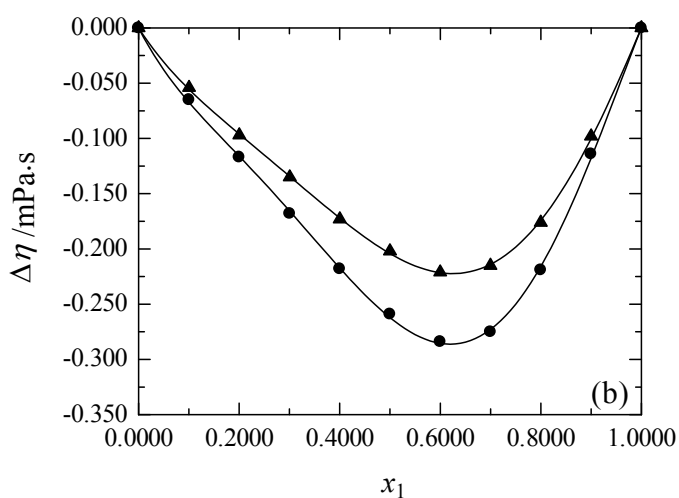


4

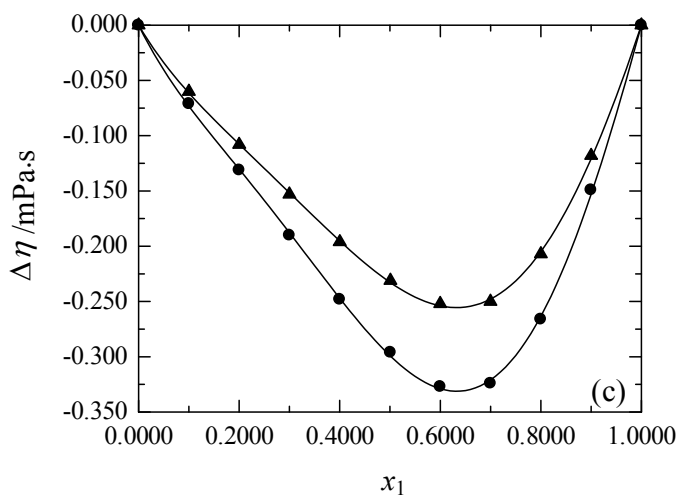
5 Figure 1. Excess molar volumes for the binary mixtures at 308.15 K (●) and 318.15 K (▲): (a) hexan-
6 1-ol (1) + *o*-xylene (2); (b) hexan-1-ol (1) + *m*-xylene (2); (c) hexan-1-ol (1) + *p*-xylene (2)



1



2



3

4 Figure 2. Viscosity deviations for the binary mixtures at 308.15 K (●) and 318.15 K (▲): (a) hexan-1-ol
5 (1) + *o*-xylene (2); (b) hexan-1-ol (1) + *m*-xylene (2); (c) hexan-1-ol (1) + *p*-xylene (2)