

Density, viscosity, and surface tension of water+ethanol mixtures from 293 to 323 K

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(Received 11 May 2011 • accepted 9 September 2011)

Abstract—Density, viscosity, and surface tension of liquids are important physicochemical properties which affect mass and heat transfer in solutions. The density, viscosity, and surface tension of binary mixture of water+ethanol at 293, 298, 303, 308, 313, 318, and 323 K are reported and compared with the available literature data. The findings of these comparisons show how the measured data are reproducible from different laboratories. The molar volume of water+ethanol mixtures are also calculated using measured density values. The Jouyban-Acree model was used for mathematical correlation of the data. The relative deviation (RD) was used as an error criterion and the RD values for correlation of density, viscosity, surface tension and molar volume data at investigated temperatures are $0.1 \pm 0.1\%$, $10.4 \pm 9.5\%$, $4.2 \pm 3.6\%$, and $0.3 \pm 0.3\%$, respectively. The corresponding RDs for the predicted properties after training using the experimental data at 298 K are $0.2 \pm 0.2\%$, $14.1 \pm 15.8\%$, $5.4 \pm 4.6\%$ and $0.4 \pm 0.3\%$, respectively, for density, viscosity, surface tension, and molar volume data. This study shows that the Jouyban-Acree model can correlate/predict physicochemical properties of the mixtures of solvents at different temperatures with acceptable error in calculation.

Key words: Density, Viscosity, Surface Tension, Water+Ethanol, Binary Mixture, Jouyban-Acree Model

INTRODUCTION

Density, viscosity, and surface tension of liquids are important physicochemical properties which affect mass and heat transfer in solutions. The mass and heat transfer in solutions influence many chemical and pharmaceutical processes such as flows in pipelines and capillaries, pharmaceutical formulations, and chemical and pharmaceutical analyses. So, availability of the related data should be helpful in designing and engineering of such processes. However, in most of the cases different blends of solvents are used. It has been observed that physicochemical properties in mixture of solvents show deviation from ideal mixing. Thus, finding a suitable blend of solvents for a desired amount of physicochemical property requires some experimental determinations or accurate models. One of the most accurate mathematical models for the correlation of physicochemical properties in a mixture of solvents is the Jouyban-Acree model [1-8].

The Jouyban-Acree model for correlation of physico-chemical properties (PCPs) of the binary solvent mixtures is [1-8]:

$$\ln PCP_{m,T} = x_1 \cdot \ln PCP_{1,T} + x_2 \cdot \ln PCP_{2,T} + J_0 \left[\frac{x_1 \cdot x_2}{T} \right] + J_1 \left[\frac{x_1 \cdot x_2 \cdot (x_1 - x_2)}{T} \right] + J_2 \left[\frac{x_1 \cdot x_2 \cdot (x_1 - x_2)^2}{T} \right] \quad (1)$$

where $PCP_{m,T}$, $PCP_{1,T}$, $PCP_{2,T}$ are the physicochemical properties of the mixture, solvent 1 and solvent 2, respectively; x_1 and x_2 denote mole fractions of the solvents 1 and 2, respectively; T is the absolute temperature; and J_i terms are the coefficients of the model which could be computed using a no-intercept regression of the experi-

mental data by:

$$\ln PCP_{m,T} = x_1 \cdot \ln PCP_{1,T} + x_2 \cdot \ln PCP_{2,T} = J_0 \left[\frac{x_1 \cdot x_2}{T} \right] + J_1 \left[\frac{x_1 \cdot x_2 \cdot (x_1 - x_2)}{T} \right] + J_2 \left[\frac{x_1 \cdot x_2 \cdot (x_1 - x_2)^2}{T} \right] \quad (2)$$

Density and viscosity of water+ethanol at 293 and 298 K were reported by Gonzalez et al. [9]. Pires et al. [10] reported density and viscosity of the mixture at 298 and 318 K. Viscosity data of binary and ternary mixtures of water, alcohols, acetone, and hexane at 293 K were reported by Song and Peng [11]. The viscosity of non-aqueous binary mixtures at several temperatures was investigated by employing a number of mathematical models [12]. Surface tension and viscosity of aqueous mixtures of two ionic liquids were investigated by Kim et al. [13].

The aim of this work is to report experimentally determined density, viscosity, and surface tension values of water+ethanol mixtures at different temperatures, and to give a predictive model for density, viscosity, and surface tension values of water+ethanol mixtures at different temperatures. The molar volume of the mixtures is also computed using density values. We report both experimental and calculated (fitted and predicted) data for water+ethanol mixtures at different temperatures.

EXPERIMENTAL METHODS AND CALCULATIONS

1. Materials

Ethanol A.R grade (99.9 in mass fraction) was purchased from Merck, Germany. The water used in this study was ultrapure reagent grade type 1 water, prepared using a Millipore water purifier system (Milli-Q Synthesis, France) with conductivity of $5.49 \times 10^{-6} \text{ S} \cdot \text{m}^{-1}$ and TOC < 10 ppb.

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2. Apparatus and Procedures

Suitable proportions of the solvents were mixed with each other volumetrically to produce different blends of water and ethanol mixtures by intervals of 0.10 in volume fraction. The prepared solvent mixtures were placed on a shaking water bath (Mettler, Germany) with a set temperature accuracy of 0.1 °C (fluctuation ± 0.1 °C) at 293, 298, 303, 308, 313, 318, and 323 K. After 24 hours and assurance of equilibrium, the samples were analyzed. A Mettler Toledo Densito portable 30PX density meter, (USA) was used for density measurements of the equilibrated solvent mixtures. The viscosity of the solvent mixtures was measured using an Ostwald U-tube glass

viscometer (Union Scientific Appliances, India) suspended in a constant temperature water bath. Surface tension of the prepared blends of solvents was determined by drop number method. The accuracy for reported data was 0.1 (kg·m⁻³), 0.1 $\times 10^{-6}$ (Pa·s), and 0.1 $\times 10^{-4}$ (N·m⁻¹) for density, viscosity, and surface tension, respectively. The lowest and highest standard deviations of the measurements for density were 0.0001 and 0.0081 with overall relative standard deviation of 0.08%. These values were 0.0032, 0.0719, and 1.32% for viscosity, and 0.1534, 0.9549, and 1.12% for surface tension measurements, respectively. All measurements were done at least in triplicates.

Table 1. Mole fraction of ethanol (x_2), experimental and calculated (by Eqs. (5)-(8)) data of density (ρ), viscosity (η), surface tension (σ), and molar volume (V) at different temperatures of water+ethanol binary mixtures

x_2	$\rho \times 10^{-3}$ (kg·m ⁻³)		$\eta \times 10^3$ (Pa·s)		$\sigma \times 10^3$ (N·m ⁻¹)		$V \times 10^6$ (m ³ mol ⁻¹)	
	Exp	Cal	Exp	Cal	Exp	Cal	Exp	Cal
T=293 (K)								
0.000	0.9987	0.9987	1.0030	1.0030	72.88	72.88	18.02	18.02
0.033	0.9840	0.9871	1.2887	1.2910	53.43	56.22	19.24	19.19
0.072	0.9737	0.9741	1.8106	1.6223	43.71	44.34	20.55	20.57
0.117	0.9630	0.9594	2.3133	1.9670	37.16	36.12	22.09	22.23
0.171	0.9473	0.9429	2.6163	2.2671	33.88	30.77	24.06	24.26
0.236	0.9298	0.9243	3.0791	2.4433	31.36	27.74	26.48	26.76
0.316	0.9086	0.9036	3.0705	2.4270	28.95	26.61	29.58	29.91
0.419	0.8844	0.8811	2.7908	2.2174	27.45	26.78	33.64	33.95
0.552	0.8589	0.8570	2.3723	1.9215	26.00	26.66	39.01	39.28
0.735	0.8329	0.8307	1.9501	1.6906	24.49	23.44	46.39	46.67
1.000	0.7910	0.7910	1.1890	1.1890	22.85	22.85	58.24	58.24
T=298 (K)								
0.000	0.9971	0.9971	0.8914	0.8914	72.15	72.15	18.05	18.05
0.033	0.9823	0.9855	1.1703	1.1441	51.44	55.82	19.27	19.21
0.072	0.9709	0.9723	1.5963	1.4346	42.70	44.12	20.61	20.59
0.117	0.9577	0.9575	2.0140	1.7371	36.87	35.99	22.22	22.25
0.171	0.9419	0.9408	2.2875	2.0019	33.43	30.67	24.19	24.28
0.236	0.9232	0.9220	2.3869	2.1609	30.11	27.62	26.66	26.78
0.316	0.9021	0.9011	2.4236	2.1540	28.76	26.42	29.80	29.94
0.419	0.8788	0.8782	2.2249	1.9796	27.35	26.47	33.85	34.00
0.552	0.8529	0.8536	2.0271	1.7293	25.78	26.19	39.28	39.37
0.735	0.8266	0.8266	1.6594	1.5368	24.12	22.89	46.74	46.84
1.000	0.7858	0.7858	1.0995	1.0995	22.07	22.07	58.63	58.63
T=303 (K)								
0.000	0.9940	0.9940	0.7982	0.7982	71.41	71.41	18.11	18.11
0.033	0.9865	0.9824	1.0200	1.0229	50.96	55.45	19.19	19.27
0.072	0.9681	0.9693	1.4539	1.2817	42.16	43.97	20.67	20.65
0.117	0.9554	0.9545	1.7660	1.5525	36.86	35.97	22.27	22.30
0.171	0.9385	0.9377	2.0492	1.7925	32.97	30.71	24.28	24.32
0.236	0.9203	0.9189	2.2487	1.9422	29.44	27.67	26.75	26.83
0.316	0.8989	0.8980	2.0666	1.9483	28.08	26.45	29.90	29.99
0.419	0.8752	0.8749	1.8958	1.8074	26.44	26.46	33.99	34.06
0.552	0.8499	0.8500	1.7968	1.5990	25.67	26.14	39.42	39.47
0.735	0.8217	0.8226	1.5189	1.4441	24.11	22.83	47.02	47.01
1.000	0.7813	0.7813	1.0606	1.0606	21.93	21.93	58.97	58.97

Table 1. Continued

x_2	$\rho \times 10^{-3} \text{ (kg} \cdot \text{m}^{-3})$		$\eta \times 10^3 \text{ (Pa} \cdot \text{s)}$		$\sigma \times 10^3 \text{ (N} \cdot \text{m}^{-1})$		$V \times 10^6 \text{ (m}^3 \text{ mol}^{-1})$	
	Exp	Cal	Exp	Cal	Exp	Cal	Exp	Cal
T=308 (K)								
0.000	0.9924	0.9924	0.7202	0.7202	70.66	70.66	18.14	18.14
0.033	0.9785	0.9807	0.9015	0.9198	49.95	55.07	19.35	19.30
0.072	0.9665	0.9675	1.2355	1.1491	41.22	43.82	20.70	20.67
0.117	0.9546	0.9526	1.4731	1.3886	36.31	35.94	22.29	22.33
0.171	0.9359	0.9357	1.7568	1.6011	31.84	30.74	24.35	24.35
0.236	0.9168	0.9167	1.7896	1.7346	29.32	27.72	26.85	26.85
0.316	0.8930	0.8955	1.6249	1.7425	27.66	26.49	30.10	30.02
0.419	0.8707	0.8720	1.5197	1.6214	26.17	26.46	34.16	34.11
0.552	0.8454	0.8466	1.4360	1.4408	25.00	26.09	39.63	39.56
0.735	0.8169	0.8183	1.2371	1.3077	23.65	22.79	47.30	47.20
1.000	0.7761	0.7761	0.9698	0.9698	21.82	21.82	59.36	59.36
T=313 (K)								
0.000	0.9905	0.9905	0.6531	0.6531	69.62	69.62	18.17	18.17
0.033	0.9763	0.9788	0.7975	0.8305	49.56	54.45	19.39	19.33
0.072	0.9633	0.9655	1.0857	1.0335	41.17	43.45	20.77	20.70
0.117	0.9503	0.9505	1.3168	1.2446	34.73	35.73	22.39	22.35
0.171	0.9328	0.9336	1.5674	1.4310	29.77	30.61	24.43	24.37
0.236	0.9139	0.9145	1.5924	1.5472	27.72	27.62	26.94	26.88
0.316	0.8896	0.8931	1.4442	1.5528	26.09	26.38	30.21	30.05
0.419	0.8671	0.8694	1.3584	1.4450	25.02	26.31	34.31	34.16
0.552	0.8415	0.8436	1.2748	1.2846	23.91	25.90	39.81	39.63
0.735	0.8139	0.8148	1.1262	1.1655	23.16	22.60	47.47	47.35
1.000	0.7718	0.7718	0.8661	0.8661	21.58	21.58	59.69	59.69
T=318 (K)								
0.000	0.9867	0.9867	0.5964	0.5964	69.19	69.19	18.24	18.24
0.033	0.9727	0.9749	0.7057	0.7555	49.40	54.25	19.46	19.40
0.072	0.9589	0.9616	0.7495	0.9367	39.54	43.39	20.87	20.77
0.117	0.9448	0.9465	0.8414	1.1245	33.24	35.72	22.52	22.43
0.171	0.9278	0.9295	0.9757	1.2898	29.38	30.62	24.56	24.45
0.236	0.9087	0.9102	1.0482	1.3925	27.40	27.61	27.09	26.97
0.316	0.8893	0.8886	1.1037	1.3970	25.55	26.31	30.22	30.15
0.419	0.8636	0.8647	1.0285	1.3009	24.61	26.14	34.45	34.29
0.552	0.8388	0.8384	0.9814	1.1580	23.72	25.61	39.94	39.82
0.735	0.8101	0.8089	0.8941	1.0514	22.36	22.25	47.69	47.64
1.000	0.7651	0.7651	0.7841	0.7841	21.05	21.05	60.21	60.21
T=323 (K)								
0.000	0.9837	0.9837	0.5467	0.5467	68.45	68.45	18.30	18.30
0.033	0.9719	0.9719	0.6174	0.6899	48.37	53.85	19.48	19.45
0.072	0.9572	0.9586	0.7008	0.8524	38.77	43.18	20.90	20.83
0.117	0.9429	0.9435	0.8126	1.0202	32.67	35.63	22.57	22.48
0.171	0.9255	0.9264	0.9349	1.1674	29.24	30.58	24.62	24.51
0.236	0.9047	0.9071	0.9516	1.2585	27.31	27.58	27.21	27.02
0.316	0.8825	0.8854	0.9587	1.2621	25.46	26.26	30.46	30.22
0.419	0.8603	0.8613	1.0145	1.1760	23.92	26.04	34.58	34.36
0.552	0.8345	0.8348	0.9474	1.0481	23.22	25.45	40.15	39.93
0.735	0.8062	0.8048	0.8256	0.9523	22.15	22.08	47.92	47.83
1.000	0.7605	0.7605	0.7126	0.7126	20.80	20.80	60.58	60.58

3. Computational Methods

The Jouyban-Acree model was used as a mathematical model for correlation of the studied PCPs in mixture of solvents. For each property under investigation, it has been trained with experimental data using a no-intercept regression analysis of the Eq. (2).

Molar volume of studied mixtures could be calculated using following equation:

$$V_{m,T} = \frac{x_1 MW_1 + x_2 MW_2}{\rho_{m,T}} \quad (3)$$

where $V_{m,T}$ is molar volume of mixture of solvents at temperature T; MW_1 and MW_2 are molecular weights of solvent 1 and 2, respectively; and $\rho_{m,T}$ is density of solvent mixtures at temperature T.

The relative deviation (RD) was used as error criterion which is defined as:

$$RD = \frac{100}{N} \sum \frac{|PCP_{Exp} - PCP_{Cal}|}{PCP_{Exp}} \quad (4)$$

where N is the number of data points in each set, PCP_{Exp} and PCP_{Cal} are the experimental and calculated physicochemical properties.

RESULTS AND DISCUSSION

Experimental and calculated values of density, viscosity, surface tension and molar volume are tabulated in Table 1. The behavior of the density in a mixture of water+ethanol is rather linear. There is a remarkable peak at fraction 0.5 of ethanol in viscosity data. The changes trend of surface tension in water+ethanol mixture is almost a power function. Available experimental data of density, viscosity, and surface tension of water and ethanol at different temperatures were compared with reported data in Table 2. Figs. 1 and 2 show the similarity between previously published data for density and viscosity of water+ethanol mixtures at 293, 298, 303, and 313 K with experimental data reported in this work. Fig. 3 shows the similarity between previously reported surface tension data for water+

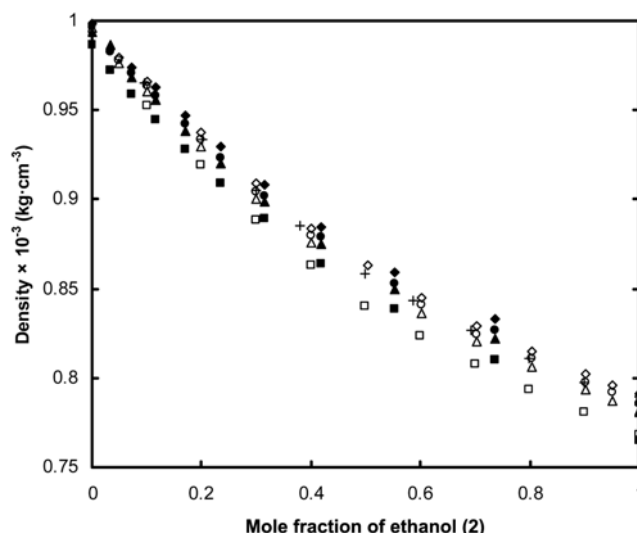


Fig. 1. Comparisons between previously reported experimental data of density of the mixtures of water+ethanol at 293-303 K and the present study. Previously reported density data of water+ethanol mixture by González et al. [9]: (◇) at 293 K, (○) at 298 K, (△) at 303 K; Pires et al. [10]: (+) at 298 K, (□) at 318 K; experimental data from this work: (◆) at 293 K, (●) at 298 K, (▲) at 303 K, (■) at 318 K.

ethanol mixture at 293 to 323 K. There are good agreements between available data and newly reported data [9,10,14-24]. The measured data cover a wider temperature range and also could be used to evaluate the reproducibility of the data measured in different laboratories.

The resulting equations for density, viscosity, surface tension, and molar volume calculation using Jouyban-Acree model are:

$$\ln \rho_{m,T} = x_W \cdot \ln \rho_{W,T} + x_E \cdot \ln \rho_{E,T} - 30.808 \left[\frac{x_W \cdot x_E}{T} \right] - 18.274 \left[\frac{x_W \cdot x_E \cdot (x_W - x_E)}{T} \right] + 13.890 \left[\frac{x_W \cdot x_E \cdot (x_W - x_E)^2}{T} \right] \quad (5)$$

Table 2. Comparisons between experimental data from this work and literature data for density, viscosity, and surface tension of water and ethanol at different temperatures with their references

Solvent	T	$\rho \times 10^3$ (kg·m ⁻³)			$\eta \times 10^3$ (Pa·s)		$\sigma \times 10^3$ (N·m ⁻¹)	
		Expt	Reference	Expt	Reference		Expt	Reference
Water	293	0.9987	0.9982 [15], 0.99820 [9]	1.0030	1.0020 [15], 1.003 [9], 1.013 [20]		72.88	72.75 [14, 15], 72.75 [16]
Water	298	0.9971	0.9970 [15], 0.99705 [9], 0.9970 [18]	0.8914	0.890 [9]		72.15	72.01 [14, 16]
Water	303	0.9940	0.9957 [15], 0.99565 [9], 0.9957 [18]	0.7982	0.7972 [15], 0.797 [9], 0.811 [20]		71.41	71.20 [15], 71.21 [14, 16]
Water	308	0.9924	0.9940 [15], 0.9941 [18]	0.7202	-		70.66	70.42 [14, 16]
Water	313	0.9905	0.9922 [15], 0.9922 [18]	0.6531	0.6532 [15], 0.667 [20]		69.62	69.60 [15], 69.52 [14, 16]
Water	318	0.9867	-	0.5964	-		69.19	68.84 [14, 16]
Water	323	0.9837	0.9880 [15]	0.5467	0.5470 [15], 0.561 [20]		68.45	67.94 [15], 67.92 [14, 16]
Ethanol	293	0.7910	0.78975 [9], 0.7897 [19]	1.1890	1.187 [9], 1.2016 [21]		22.85	22.31 [14], 22.3 [17]
Ethanol	298	0.7858	0.78546 [9], 0.7853 [19], 0.78510 [10]	1.0995	1.082 [9], 1.0957 [21], 1.0858 [14], 1.102 [10]		22.07	21.82 [14], 21.8 [17]
Ethanol	303	0.7813	0.78115 [9], 0.7809 [19]	1.0606	0.987 [9], 0.9944 [21], 0.9732 [22]		21.93	21.41 [14], 21.4 [17]
Ethanol	308	0.7761	0.7765 [19]	0.9698	0.9015 [21], 0.8596 [22]		21.82	21.04 [14], 21.1 [17]
Ethanol	313	0.7718	0.7722 [19]	0.8661	0.8306 [21], 0.8284 [22]		21.58	20.62 [14], 20.8 [17]
Ethanol	318	0.7651	0.76842 [10]	0.7841	0.7642 [21], 0.7493 [22], 0.749 [10]		21.05	20.22 [14], 20.5 [17]
Ethanol	323	0.7605	-	0.7126	-		20.80	19.82 [14], 20.0 [17]

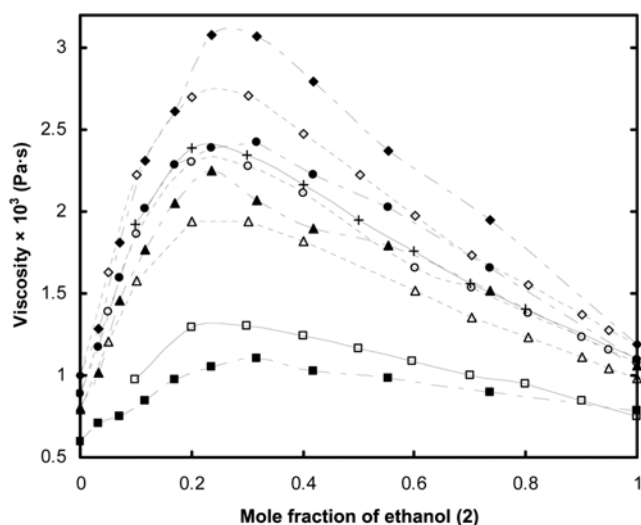


Fig. 2. Comparisons between previously reported experimental data of viscosity of the mixtures of water+ethanol at 293–303 K and the present study. Previously reported viscosity data of water+ethanol mixture by González et al. [9]: (◇) at 293 K, (○) at 298 K, (△) at 303 K; Pires et al. [10]: (+) at 298 K, (□) at 318 K; experimental data from this work: (◆) at 293 K, (●) at 298 K, (▲) at 303 K, (■) at 318 K.

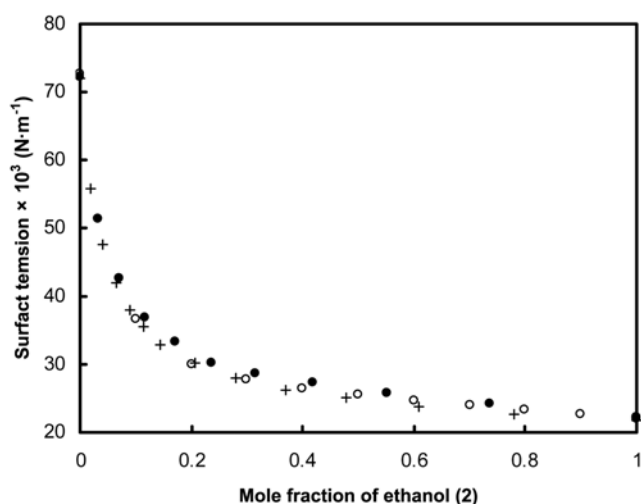


Fig. 3. Comparison between previously reported experimental data of surface tension of the mixtures of water+ethanol at 298 K: (+) by Vaizquez et al. [14]; (○), by Belda et al. [24]; and (●) the present study.

$$\ln \eta_{m,T} = x_W \cdot \ln \eta_{W,T} + x_E \cdot \ln \eta_{E,T} + 724.652 \left[\frac{x_W \cdot x_E}{T} \right] + 729.357 \left[\frac{x_W \cdot x_E \cdot (x_W - x_E)}{T} \right] + 976.050 \left[\frac{x_W \cdot x_E \cdot (x_W - x_E)^2}{T} \right] \quad (6)$$

$$\ln \sigma_{m,T} = x_W \cdot \ln \sigma_{W,T} + x_E \cdot \ln \sigma_{E,T} - 488.012 \left[\frac{x_W \cdot x_E}{T} \right] - 640.785 \left[\frac{x_W \cdot x_E \cdot (x_W - x_E)}{T} \right] - 1073.310 \left[\frac{x_W \cdot x_E \cdot (x_W - x_E)^2}{T} \right] \quad (7)$$

$$\ln V_{m,T} = x_W \cdot \ln V_{W,T} + x_E \cdot \ln V_{E,T} + 161.796 \left[\frac{x_W \cdot x_E}{T} \right]$$

$$+ 59.132 \left[\frac{x_W \cdot x_E \cdot (x_W - x_E)}{T} \right] \quad (8)$$

where ρ , η , σ and V are indicators of density, viscosity, surface tension and molar volume; W, E, and m subscripts stand for water, ethanol, and their mixtures, respectively. The R^2 values for Eqs. (5)–(8) are 0.986, 0.945, 0.985, and 0.998, respectively.

All of these PCPs were correlated perfectly using the Jouyban-Acree model with the overall RD values of $0.1 \pm 0.1\%$, $10.4 \pm 9.5\%$, $4.2 \pm 3.6\%$, and $0.3 \pm 0.3\%$ for density, viscosity, surface tension, and molar volume data, respectively. The model could be trained using measured data at 298 K; the PCP data at other temperatures and solvent compositions could be predicted employing PCP data of mono-solvents at each temperature of interest, i.e., $PCP_{1,T}$ and $PCP_{2,T}$. The resulting RD values for predicted density, viscosity, surface tension, and molar volume data ($N=66$) are $0.2 \pm 0.2\%$, $14.1 \pm 15.8\%$, $5.4 \pm 4.6\%$ and $0.4 \pm 0.3\%$, respectively. The Jouyban-Acree model also produced the most accurate results among other similar models for representing the solubility of drugs in mixed solvents [25], solubility of solutes in binary mixtures of supercritical fluids [26], acid dissociation constants of analytes in binary mixtures [27], electrophoretic mobility of charged species in capillary electrophoresis [28] and retention factor of analytes in high performance liquid chromatography [29].

The previously trained version of the Jouyban-Acree model for surface tension correlation of binary mixture of water+ethanol at different temperatures [4,14], predicts perfectly ($4.9 \pm 3.4\%$) the related property in this report. This might support the similarity here by the presented data and validity of the Jouyban-Acree model for surface tension correlation. In another numerical analysis, the reported density and viscosity data of water+ethanol mixtures at 298 and 318 K [10] are used to train the Jouyban-Acree model, and the measured data ($N=77$) in this work are predicted in which the RDs are $10.4 \pm 10.8\%$ and $0.4 \pm 0.4\%$, respectively.

As a conclusion, the PCP data of water+ethanol mixtures are reported at 293 to 323 K and the model constants of the data are computed. Using these constants, it is possible to predict the PCP data in all solvent compositions of water+ethanol at various temperatures using interpolation technique.

NOMENCLATURE

- J_i : calculated coefficients of the Jouyban-Acree model
- MW_1 : molecular weight of solvent 1 (water)
- MW_2 : molecular weight of solvent 2 (ethanol)
- N : the number of cases in each training set of regression analyze
- $PCP_{1,T}$: any physicochemical property of component 1 at temperature T
- $PCP_{2,T}$: any physicochemical property of component 2 at temperature T
- $PCP_{m,T}$: any physicochemical property of the mixture of solvents at temperature T
- PCP_{Cal} : calculated physicochemical property value
- PCP_{Exp} : experimental physicochemical property value
- RD : relative deviation
- T : temperature [K]

$V_{E,T}$: molar volume of the ethanol at temperature T [$\text{m}^3 \cdot \text{mol}^{-1}$]
 $V_{W,T}$: molar volume of the water at temperature T [$\text{m}^3 \cdot \text{mol}^{-1}$]
 $V_{m,T}$: molar volume of the mixture at temperature T [$\text{m}^3 \cdot \text{mol}^{-1}$]
 x_1 : mole fraction of component 1
 x_2 : mole fraction of component 2
 x_E : mole fraction of ethanol
 x_W : mole fraction of water
 $\eta_{E,T}$: viscosity of ethanol at temperature T [$\text{Pa} \cdot \text{s}$]
 $\eta_{W,T}$: viscosity of water at temperature T [$\text{Pa} \cdot \text{s}$]
 $\eta_{m,T}$: viscosity of mixture of solvents at temperature T [$\text{Pa} \cdot \text{s}$]
 $\rho_{E,T}$: density of ethanol at temperature T [$\text{kg} \cdot \text{m}^{-3}$]
 $\rho_{W,T}$: density of water at temperature T [$\text{kg} \cdot \text{m}^{-3}$]
 $\rho_{m,T}$: density of mixture of solvents at temperature T [$\text{kg} \cdot \text{m}^{-3}$]
 $\sigma_{E,T}$: surface tension of ethanol at temperature T [$\text{N} \cdot \text{m}^{-1}$]
 $\sigma_{W,T}$: surface tension of water at temperature T [$\text{N} \cdot \text{m}^{-1}$]
 $\sigma_{m,T}$: surface tension of mixture of solvents at temperature T [$\text{N} \cdot \text{m}^{-1}$]

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