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Excess Properties of Binary Mixtures of Ethanolamine with Water at Different Higher Temperatures

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ABSTRACT

Densities and viscosities for binary mixtures of ethanolamine with water are reported over the entire composition range at temperature (318.15, 320.15, 322.15, 324.15, 326.15 and 328.15 K). The density data were used to evaluate excess molar volumes (VE). The experimental viscosity data were also used to calculate the viscosity deviations and the excess Gibbs energies (ΔG^*E) of activation. All the binary systems studies showed negative values of excess molar volume and positive values of viscosity deviation indicating strong hydrogen bonding interaction for the entire mole fraction.

Keywords: Viscosity deviation, Excess molar volumes, Binary mixtures, Free energy, Mole fraction

INTRODUCTION

The thermodynamic properties of binary mixtures such as density and viscosity are important from practical and theoretical points of view to understand liquid theory. Their properties are extremely useful for the design of process equipment in chemical industries. Binary liquid mixtures due to their unusual behaviour have attracted considerable attention [1]. In chemical process industries materials are normally handled in fluid form and as a consequence, the physical, chemical and transport properties associated with the liquids and liquid mixtures like density and viscosity find extensive application in solution theory and molecular dynamics [2]. Such results are necessary and interpretation of data obtained from thermochemical, electrochemical, biochemical and kinetic studies [3] Ethanolamine's derivatives are widespread in nature, e.g. lipids. In the present work reports the experimental values of density and viscosity of the ethanolamine with water measured at the temperature 318.15, 320.15, 322.15, 324.15, 326.15 and 328.15 K. The intermolecular interactions have been estimated in the light of the excess parameters.

EXPERIMENTAL

Solvents were purified by the standard methods [4] Ethanolamine (A.R. Grade from S.D. Fine Chemicals) was double distilled under reduced pressure. Then fraction was stored in dark coloured bottle and protected against atmospheric moisture and carbon dioxide. Conductivity water was prepared by double distillation of water. The liquid mixtures of various compositions covering the entire mole fraction were made using single pan balance having sensitivity 0.1 mg. The prepared mixtures were preserved in air tight narrow ground stoppered bottles taking due to precautions to minimize the evaporation losses.

Densities of the pure components and their compositions were measured on a vibrating tube density meter (Anton Paar Model DMA-5000). The results were reproducible to 1×10^{-5} g/cm³. This unit offered high temperature accuracy (± 0.001 K) in a wide temperature. The result calibration was done with air and triple distilled water showing density 0.998212 g/cm³ at 20°C which is closure to literature value [4]. Viscosities were measured at desired temperature using Ostwald's Viscometer, which was calibrated using liquids, tripled distilled water, benzene, toluene (HPLC grade). The flow time has been measured after the attainment of bath temperature by pure components and their mixtures. The flow measurements were made with an electronic stop watch (Raser) reading to 0.01 s. The time flow and densities were measured for every pure component and their mixtures at the interval of 2°C between 318.15-328.15 K.

CALCULATIONS

From the experimental data of density and viscosity, various thermodynamics parameter were evaluated using Standard equations mentioned below:

Excess molar volume

Where, x_1 and x_2 are mole fractions, M_1 and M_2 the molecular weights and V_1 and V_2 are the molecular volumes of ethanolamine (1)+water (2). ρ is the density liquid mixture [5,6].

$$V^E = \frac{(x_1 M_1 + x_2 M_2)}{\rho} - (x_1 V_1 + x_2 V_2) \quad (1)$$

Viscosity deviations

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

Where, η_1 and η_2 , viscosities of ethanolamine (1)+water (2), η viscosity of mixture.

Gibbs energies (ΔG^{*E}) of activation of viscous flow

$$\frac{\Delta G^{*E}}{RT} = \left\{ \ln \left(\frac{\eta V}{\eta_2 V_2} \right) - x_1 \ln \left(\frac{\eta_1 V_1}{\eta_2 V_2} \right) \right\} \quad (3)$$

Where, V , V_1 , V_2 are the molar volumes the binary mixture and pure components [7].

Table 1: Densities, viscosities, excess molar volume, excess viscosities and Gibb's energies of activation of viscous flow for ethanolamine (1)+water (2)

(a) Temperature: 318.15 K						
S. No.	X_1	Density (ρ) (g/cm ³)	Density (η) (mPas)	Excess molar volume (V^E) (cm ³ .mol ⁻¹)	Viscosity deviation ($\Delta\eta$) (mPas)	Excess Gibb's energy of activation ($\Delta G^{*E} \times 10^{-4}$) (J/mol ⁻¹)
1	0.0000	0.990188	0.598680			
2	0.1001	0.999510	1.294132	-0.171377	-0.041444	1.696820
3	0.3000	1.010830	3.812127	-0.521329	1.002759	1.863727
4	0.3502	1.011328	4.559290	-0.562406	1.381474	1.878190
5	0.4001	1.011658	5.310478	-0.599779	1.764214	1.884575
6	0.4502	1.011040	5.920028	-0.603884	2.005316	1.878619
7	0.5003	1.010253	6.504184	-0.598811	2.221024	1.867978
8	0.5500	1.009398	7.051735	-0.587586	2.400127	1.853359
9	0.6001	1.008227	7.427893	-0.559060	2.407838	1.829883
10	0.8002	1.002562	8.123940	-0.342840	1.630092	1.700313
11	1.0000	0.996470	7.967642	-	-	-
(b) Temperature: 320.15 K						
1	0.0000	0.989416	0.576280			
2	0.1001	0.998499	1.220277	-0.171393	-0.023619	1.699408
3	0.3000	1.009467	3.506535	-0.519500	0.927407	1.864788
4	0.3502	1.009922	4.177625	-0.560565	1.264689	1.879309
5	0.4001	1.010212	4.852145	-0.597840	1.605401	1.885974
6	0.4502	1.009568	5.389440	-0.602096	1.808888	1.880002
7	0.5003	1.008757	5.902129	-0.597112	1.987769	1.869425
8	0.5500	1.007880	6.384654	-0.585936	2.136486	1.854805
9	0.6001	1.006697	6.725934	-0.557741	2.143958	1.832499
10	0.8002	1.000998	7.374383	-0.342307	1.457175	1.706720
11	1.0000	0.994872	7.252440	-	-	--
(c) Temperature: 322.15 K						
1	0.0000	0.988644	0.553880			
2	0.1001	0.997477	1.146433	-0.171136	-0.005793	1.706114
3	0.3000	1.008103	3.200972	-0.517546	0.852054	1.866699
4	0.3502	1.008516	3.795989	-0.558614	1.147898	1.881090
5	0.4001	1.008766	4.393852	-0.595775	1.446588	1.887754
6	0.4502	1.008096	4.858898	-0.600167	1.612461	1.881616
7	0.5003	1.007261	5.300124	-0.595256	1.754514	1.870917
8	0.5500	1.006362	5.717627	-0.584112	1.872844	1.856314
9	0.6001	1.005167	6.024036	-0.556235	1.880080	1.834365
10	0.8002	0.999418	6.624907	-0.341525	1.284259	1.709727
11	1.0000	0.993278	6.537340	-	-	-

(d) Temperature: 324.15 K						
S. No.	X_1	Density (ρ) (g/cm ³)	Density (η) (mPas)	Excess molar volume (V^E) (cm ³ .mol ⁻¹)	Viscosity deviation ($\Delta\eta$) (mPas)	Excess Gibb's energy of activation ($\Delta G^{*E} \times 10^{-4}$) (J/mol ⁻¹)
1	0.0000	0.987872	0.531480			
2	0.1001	0.996456	1.072568	-0.170919	0.012032	1.712357
3	0.3000	1.006739	2.895349	-0.515627	0.776701	1.870529
4	0.3502	1.007109	3.414283	-0.556671	1.031107	1.884338
5	0.4001	1.007320	3.935480	-0.593756	1.287776	1.890903
6	0.4502	1.006623	4.328265	-0.598252	1.416033	1.884055
7	0.5003	1.005765	4.698019	-0.593458	1.521259	1.875808
8	0.5500	1.004844	5.050490	-0.582352	1.609202	1.858186
9	0.6001	1.003637	5.322018	-0.554800	1.616202	1.837535
10	0.8002	0.997846	5.875271	-0.340842	1.111343	1.719454
11	1.0000	0.991682	5.82204	-	-	-
(e) Temperature: 326.15 K						
1	0.0000	0.987100	0.509080			
2	0.1001	0.995434	0.998713	-0.170684	0.029857	1.718107
3	0.3000	1.005376	2.589756	-0.513738	0.701348	1.871172
4	0.3502	1.005703	3.032612	-0.554760	0.914316	1.884361
5	0.4001	1.005874	3.477147	-0.591734	1.128963	1.890728
6	0.4502	1.005151	3.797678	-0.596373	1.219606	1.883137
7	0.5003	1.004269	4.095963	-0.591657	1.288003	1.871290
8	0.5500	1.003326	4.383409	-0.580589	1.345561	1.856538
9	0.6001	1.002107	4.620059	-0.553363	1.352323	1.837005
10	0.8002	0.996274	5.125714	-0.340157	0.938426	1.724266
11	1.0000	0.990086	5.10684	-	-	-
(f) Temperature: 328.15 K						
1	0.0000	0.986328	0.486680			
2	0.1001	0.994413	0.955858	-0.170477	0.078682	1.732078
3	0.3000	1.004012	2.288118	-0.511816	0.629950	1.870062
4	0.3502	1.004296	2.650941	-0.552813	0.797525	1.881864
5	0.4001	1.004428	3.018814	-0.589708	0.970150	1.887848
6	0.4502	1.003678	3.267090	-0.594452	1.023178	1.879163
7	0.5003	1.002773	3.493908	-0.589853	1.054748	1.866364
8	0.5500	1.001808	3.716327	-0.578821	1.081919	1.851297
9	0.6001	1.000577	3.918101	-0.551922	1.088445	1.833163
10	0.8002	0.994702	4.376158	-0.339470	0.76551	1.727340
11	1.0000	0.98849	4.39164	-	-	-

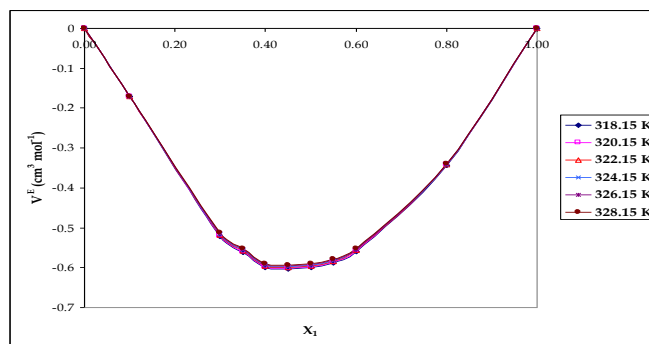
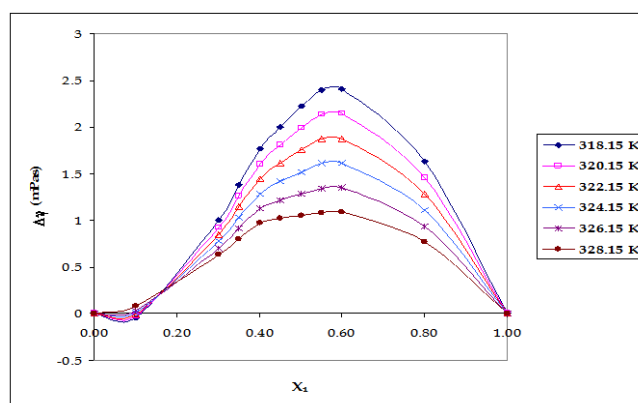
Figure 1: Excess molar volume (V^E) for the system of ethanolamine (1)+water (2) from 318.15 K-328.15 K

Figure 2: Viscosity deviation for ethanolamine (1)+water (2) from 318.15 K-328.15 K

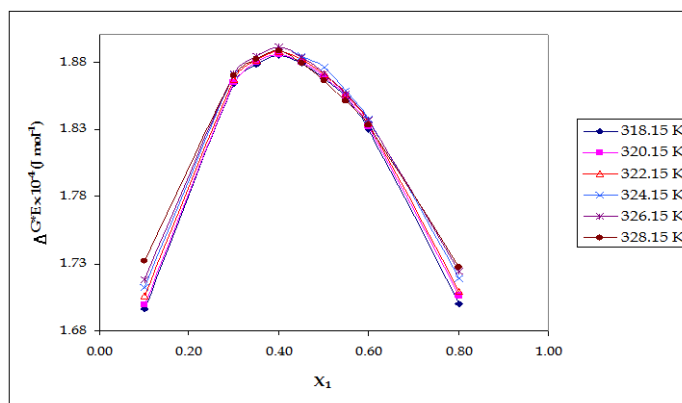


Figure 3: Excess Gibbs energy of activation ΔG^*E for ethanolamine (1)+water (2) from 318.15 K-328.15 K

RESULTS AND DISCUSSION

The experimental values of density (ρ) and viscosity (η) and calculated values of V^E , $\Delta\eta$ and ΔG^*E of pure liquids and for the binary liquid systems at 318.15, 320.15, 322.15, 324.15, 326.15, and 328.15 K are given in Table 1.

The excess properties are found to be more sensitive towards intermolecular interaction between the component molecules of liquid mixtures. The sign and extent of deviation of excess properties depends on the strength of interaction between unlike molecules [8,9].

The graphical variation of excess molar volume (V^E) for binary mixtures of ethanolamine with water at 318.15, 320.15, 322.15, 324.15, 326.15 and 328.15 K is shown in Figure 1. The values of excess molar volume are found to be negative for all the systems. The existence of specific interactions between the mixing components of the various binary systems tends to make excess molar volume negative [10]. The plots of V^E against x_1 are of parabolic shape characterized by well-defined minimum occurring at $x_1 \approx 0.45$ indicating the presence of complex formation [11]. It is observed that, the changes the excess molar volume values are nearly same in the temperature region 318.15 K to 328.15 K.

Figure 2 shows the graphical variation of viscosity deviation ($\Delta\eta$) for the binary mixtures of ethanolamine with water with increasing mole fraction of ethanolamine at 318.15, 320.15, 322.15, 324.15, 326.15, and 328.15 K. The values of viscosity deviation negative at low mole fraction 0.10 of ethanolamine and increase steadily and attain maximum values. The positive deviation indicates the predominance of specific hydrogen bonding interaction between unlike molecules (to form adduct between them) over the dissociation effect in the system [12].

Excess energy of activation for viscous flow are shown in Figure 3. The observed ΔG^*E values are positive for the entire mole fraction of ethanolamine. Large positive values indicate the specific interaction leading to complex formation through intermolecular hydrogen bonding interaction between unlike molecules compared to like molecules [13].

CONCLUSION

Experimental data of the density and viscosity of ethanolamine and water mixtures have been measured over the entire composition range at 318.15, 320.15, 322.15, 324.15, 326.15 and 328.15 K. It has been observed that negative deviations were observed for excess molar volume (V^E) and positive deviation were observed for viscosity deviation ($\Delta\eta$) and positive values of excess energy of activation for viscous flow (ΔG^*E). The result of excess properties reveal that the strong molecular interaction between the mixing components.

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