Excess parameters of binary mixtures of tetrahydro- furfurylalcohol with cyclopentanol and 1-pentanol at (293.15, 303.15 and 313.15K)

Dhafir T.Ajeel Al-heetimi
College Education for pure science
Ibn-Al-Haitham,University of Baghdad.

Abstract

Density and viscosity of the binary liquid mixtures of (THFA + cyclopentanol, THFA + 1-pentanol and cyclopentanol + 1-pentanol) have been measured as a function of composition range at 293.15, 303.15, 313.15K. From density and viscosity data, the values of excess molar volume (V^E), the excess viscosity (η^E) and excess Gibbs free energy of activation flow (ΔG^{*E}) were calculated and correlated by the Redlich-kister type function to derive the coefficients and estimate the standard error. Deviations from ideal behavior are discussed from the point of view of the molecular interactions present between the unlike molecules. As for all the binary mixtures studied the excess molar volume showed a positive deviation from ideal behavior at the three temperatures studied except for two points was negative at 293.15K for the system THFA+ cyclopentanol, while the excess viscosity and excess Gibbs free energy showed a negative from ideal behavior at the three temperatures.

Introductions

A knowledge of excess thermodynamic properties of multicomponent liquid systems is essential in many practical problems concerning heat transport, mass transport, fluid flow, etc. [1, 2, 3].The thermodynamic excess functions are of great importance in helping to comprehend the nature and extent of the patterns of molecular aggregation that exist in a real mixture, resulting from intermolecular interactions. In fact, the interaction between the molecules can be established from a study of characteristic sudden departure from ideal behavior of some physical properties volume, viscosity, dielectric constant, refractive index, and others that reflects the real behavior of solutes in solvents. [4, 5, 6].Alcohols are organic compound which is widely used within the chemical industry. Alcohols are in use as fuel, perfumes, cosmetics, paints, drugs, gums, resins, explosives, fats, waxes, plastics, rubber, lacquers, varnishes,detergents, etc. [7, 8].

In the present work, density and viscosity, were determined over the whole concentration range of the binary mixtures of (THFA+ cyclopentanol) and (THFA+1-pentanol) in the different temperature (293.15, 303.15 and 313.15K). The excess molar volume and the deviation of the viscosity were derived. Related to these systems I have not found published work for V^E and η^E at any temperature.

Experimental

Chemicals: THFA,cyclopentanol and 1-pentanol were purchased from Merck with purity higher than 99% (all) and used without further purifications. The stated purity,density and viscosity of pure components are reported in Table (1). The resultant values are in good agreement with values found in literature[9-12].

Density measurements:

Densities of pure components and binary mixtures were measured with an Anton paar digital densimeter (model DMA60/602) with an accuracy of ± 10^{-5} gcm^{-3}. The temperature of measuring cell was maintained at (293.15K,303.15K and 313.15K) using a (HaKKE-D1-E) with an uncertainty of ±0.01K . Experiments were generally repeated at least three times for each composition , and the results were averaged.

Viscosity measurements:

The kinematic viscosity υ (= η/ρ) of pure solvents and their mixture were measured by using (cannon- Ubbelohde semi Micro) Viscometer ; the uncertainty in the kinematic viscosity was ± 0.001 mpa.s . All measurements were performed in a thermostat maintained at desired temperature with accuracy of ± 0.01K . Its described above were performed at least three times , and the results were averaged to give the final values.

Results and discussion

The obtained experimental data of density and viscosity for binary systems THFA + cyclopentanol , THFA + 1-pentanol and cyclopentanol + 1-pentanol at three temperature (293.15, 303.15 and 313.15K) shown in Tables(2, 3 and 4) on the basisof experimental data, the corresponding excess properties were calculated as follows :

Excess molar volumes (V^E) :

$$\mathbf{V^E = (X_1M_1 + X_2M_2) / \rho_m - X_1M_1 / \rho_1 - X_2M_2 / \rho_2} \qquad \mathbf{(1)}$$

Where X_i, M_i, $\rho_i$are the mole fraction , the molar mass and the density of component i and ρ_m is the density of the mixture ,respectively.

Excess viscosities were obtained by using:

$$\mathbf{\eta^E = \eta_m - (X_1\eta_1 + X_2\eta_2)} \qquad \mathbf{(2)}$$

Where X_1 , X_2 are the mole fraction of components 1 and 2 respectively and η_1 , η_2 the viscosities of pure components 1 and 2 and η_m is the viscosity of the mixture.

Excess Gibbs energy of activation of viscous flow (ΔG^{*E}):

$$\Delta G^{*E} = RT\ [\ \ln(\eta_m V_m) - (X_1 \ln \eta_1 V_1) - (X_2 \ln \eta_2 V_2)\ ] \qquad (3)$$

Where R is the universal constant of gases. T is the absolute temperature ,V_1 and V_2 are the molar volumes of component 1 and 2 , X_1 and X_2 represents the mole fraction of component 1 and 2. η_1, η_2 and η_m are the viscosity of component 1, 2 and mixture respectively.

V_m is obtained from equation 4 below:

$$V_m = (X_1 M_1 + X_2 M_2)/\rho_m \qquad (4)$$

The excess functions of the binary systems can be represented by a Redlich-Kister [13] type equation:

$$X^E = X_i X_j \sum_{K=0}^{n} A_K (X_i - X_j)^k \qquad (5)$$

Where X^E represents any of the following properties: V^E , η^E,ΔG^{*E} ; X_i and $X_j$are the mole fractions of the components i and j , respectively , and A_k denotes the polynomial coefficients.

The values of these coefficients and the standard deviation are given in Table (5). The standard deviation , σ, for the excess parameters were evaluated by the following equation:

$$\sigma = \left[\sum \frac{(X^E_{calc} - X^E_{exp})^2}{m-n} \right]^{1/2} \qquad (6)$$

Where (m) is the number of data points and (n) is the number of estimated parameters.

In figure 1 (a-c), excess molar volumes (V^E) are plotted against (X_1) mole fractions for the binary mixtures of [(a) (X_1 THFA + X_2cyclopentanol), (b) (X_1 THFA + X_2 1-pentanol) and (c) (X_1 cyclopentaol + X_2 1-pentanol)]. It can be seen that the isothermal curves at (293.15,303.15 and 313.15 K) are positive for all the systems studied over the entire composition range at all the temperatures except for two points was negative at 293.15K for the system(THFA+ cyclopentanol). Several effects may contribute to the values of V^E, such as breaking of liquid order on mixing , contribution to the difference in size and shape of the components,difference in free volumes, and hydrogen bonding interactions[14].

Positive contributions arise from the breakup of interactions between molecules namely, the rupture of hydrogen bonded chains and loosing of dipole interactions [15]. In all plots , V^E increase with increase in temperature (except for mixtures cyclopentanol + 1-pentanol), V^E decrease with increase in

temperature. The excess molar volume for all the systems attains a maximum between 0.19-0.39 of the mole fraction of THFA.

In figure 2 (a- c) , the viscosity deviations are negative over the whole composition range. The viscosity deviations are decreasing as the temperature increase, and this behavior is similar in all systems. The negative values of the deviation in viscosity (η^E) suggest the existence of weak intermolecular interactions for all systems studied[16]. This show that the strength of the specific forces is not the factor influencing the viscosity deviation in the liquid mixture. This lead to suggestions that combinations of an interactive and non interactive force are responsible in negative interactions [17].

The plots of excess Gibbs free energy of activation of viscous flow against mole fractions at 293.15,303.15 and 313.15 for THFA + cyclopentanol, THFA+ 1-pentanol and cyclopentanol + 1-pentanol are presented in figure 3 (a-c). Excess properties provide information about the molecular interactions and macroscopic behavior of fluid mixtures which can be used to test and improve thermodynamic models for calculating and predicting fluid phase equilibria [18]. Excess Gibbs free energy of activation of viscous flow was found to be negative for all plots. In all plots ΔG^{*E} decreased with increase in temperature for THFA+ 1-pentanol and cyclopentanol + 1-pentanol while increases with increasing temperature of the binary mixture THFA + cyclopentanol. The magnitude of ΔG^{*E} indicative of weak interactions between unlike molecules [19]. The excess Gibbs free energy of activation of viscous flow attains a maximum between 0.74-0.92 of mole fraction of THFA.

Conclusion

The densities and viscosities of the pure components were measured at (293.15,303.15 and 313.15K). The densities and viscosities of the binary systems [THFA+ cyclopentanol,THFA + 1-pentanol and cyclopentanol + 1-pentanol] at these temperatures were also determined over the whole composition range. The excess molar volume (V^E), excess viscosity (η^E) and excess Gibbs free energy ΔG^{*E}were determined from experimental results of density and viscosity and fitted to the Redlich-Kister polynomial equation. Excess molar volumes are positive for all the binary mixtures studied here(except for two points was negative at 293.15K for the system THFA+ cyclopentanol). All systems studied showed a negative deviation from ideal behavior in excess viscosity and excess Gibbs free energy over the whole temperature and composition ranges.

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Table (1): Comparison between measured and Literature Data for the density and viscosity of components at (293.15K,303.15K and 313.15K).

Compound	T/ K	ρ(g.cm^{-3})		η mpa.s	
		experimental	literature	experimental	literature
THFA	293.15	1.05240	1.05240[9]	6.88775	6.2400[9]
	303.15	1.04484		3.71614	…..
	313.15	1.03152		3.39783	…..
cyclopentanol	293.15	0.87852		4.64912	…..
	303.15	0.87174	0.93908[9]	3.29518	…..
	313.15	0.86233		2.27241	…..
1-pentanol	293.15	0.81822	0.81503,0.8150[10,11]	1.88233	….
	303.15	0.81054	0.80759,0.80760[12]	1.23429	….
	313.15	0.80870		1.03061	….

Table (2): Experimental values of density and viscosity and calculated values of excess molar volume , excess viscosity and excess Gibbs free energy for binary mixtures of THFA+cyclopentanol at (293.15,303.15, and 313.15) K.

X_1 THFA + X_2 cyclopentanol 293.15K					
X_1	ρ(g.cm^{-3}) 293.15K	η 293.15K	V^E cm^{3}mol^{-1} 293.15K	η^E mpa.s 293.15K	ΔG^{*E} J mol^{-1} 293.15K
0.0000	0.87852	3.71614	0.00000	0.00000	0.00
0.0994	0.89408	3.74977	0.17149	-0.28163	-124.77
0.1953	0.90822	3.84177	0.42887	-0.49378	-200.59
0.2935	0.92352	3.98961	0.59978	-0.65740	-252.99
0.3954	0.94165	4.23743	0.53908	-0.73277	-261.25
0.4962	0.96060	4.54748	0.38140	-0.74241	-243.72
0.5949	0.97950	4.84853	0.20229	-0.75440	-241.29
0.6921	0.99718	5.16938	0.12727	-0.74183	-233.27
0.7962	1.01726	5.62504	-0.05597	-0.61633	-188.40
0.9005	1.03512	6.07036	-0.01695	-0.50181	-158.97
1.0000	1.05240	6.88775	0.00000	0.00000	0.00

X_1 THFA + X_2 cyclopentanol 303.15K					
X_1	ρ(g.cm^{-3}) 303.15K	η 303.15K	V^E cm^{3}mol^{-1} 303.15K	η^E mpa.s 303.15K	ΔG^{*E}J mol^{-1} 303.15K
0.0000	0.87174	3.29518	0.00000	0.00000	0.00
0.0994	0.88508	3.19266	0.41265	-0.23710	-156.30
0.1953	0.89743	3.12090	0.85972	-0.43869	-285.30
0.2935	0.91198	3.23060	1.09945	-0.46196	-277.20
0.3954	0.93098	3.32807	0.92573	-0.50246	-294.94
0.4962	0.95075	3.42955	0.66338	-0.53746	-313.21
0.5949	0.96955	3.52877	0.47781	-0.57186	-324.80
0.6921	0.98826	3.68226	0.28635	-0.54998	-313.35
0.7962	1.00718	3.81802	0.20227	-0.55517	-314.44
0.9005	1.02666	4.03601	0.07523	-0.47840	-268.13
1.0000	1.04484	4.64912	0.00000	0.00000	0.00

X_1 THFA + X_2 cyclopentanol 313.15K					
X_1	ρ(g.cm^{-3}) 313.15K	η 313.15K	V^E cm^{3}mol^{-1} 313.15K	η^E mpa.s 313.15K	ΔG^{*E}J mol^{-1} 313.15K
0.0000	0.86233	2.27241	0.00000	0.00000	0.00
0.0994	0.86581	2.18808	1.52205	-0.19620	-65.03
0.1953	0.87899	2.17392	1.83207	-0.31829	-272.70
0.2935	0.89606	2.25485	1.73669	-0.34788	-282.66
0.3954	0.91508	2.32247	1.50038	-0.39493	-318.36
0.4962	0.93581	2.40541	1.07348	-0.42544	-343.44
0.5949	0.95477	2.49539	0.81732	-0.44653	-357.69
0.6921	0.97456	2.57869	0.46350	-0.47263	-383.08
0.7962	0.99501	2.69727	0.17823	-0.47119	-382.37
0.9005	1.01312	2.83390	0.14010	-0.45195	-363.82
1.0000	1.03152	3.39783	0.00000	0.00000	0.00

Table (3): Experimental values of density and viscosity and calculated values of excess molar volume, excess viscosity and excess Gibbs free energy for binary mixtures of THFA+1-pentanol at (293.15,303.15, and 313.15) K.

X_1 THFA + $X_2$1-pentanol 293.15K					
X_1	ρ(g.cm^{-3}) 293.15K	η 293.15K	V^E cm^{3}mol^{-1} 293.15K	η^E mpa.s 293.15K	ΔG^{*E}J mol^{-1} 293.15K
0.0000	0.81822	1.88233	0.00000	0.00000	0.00
0.1157	0.84102	1.85294	0.23930	-0.60844	-397.01
0.2235	0.85710	1.95316	1.14741	-1.04781	-587.66
0.3308	0.86635	2.03038	2.88879	-1.50768	-791.58
0.4431	0.88701	2.22249	3.36487	-1.87768	-914.30
0.5405	0.89321	2.32485	5.19214	-2.26287	-1064.82
0.6312	0.91022	2.94911	5.55232	-2.09260	-767.74
0.7265	0.95444	3.24700	3.03082	-2.27173	-892.67
0.8273	0.98508	3.67041	2.33510	-2.35289	-929.35
0.9182	1.01790	4.43764	1.29136	-2.09066	-780.03
1.0000	1.05240	6.88775	0.00000	0.00000	0.00

X_1 THFA + $X_2$1-pentanol 303.15K					
X_1	ρ(g.cm^{-3}) 303.15K	η 303.15K	V^E cm^{3}mol^{-1} 303.15K	η^E mpa.s 303.15K	ΔG^{*E}J mol^{-1} 303.15K
0.0000	0.81054	1.23429	0.00000	0.00000	0.00
0.1157	0.82042	1.28978	1.93543	-0.34461	-230.38
0.2235	0.84058	1.39805	2.30365	-0.59945	-377.64
0.3308	0.85098	1.51644	3.90754	-0.84747	-492.33
0.4431	0.87554	1.73357	3.87865	-1.01383	-529.50
0.5405	0.88426	1.87817	5.42806	-1.20184	-615.69
0.6312	0.89521	2.09479	6.51898	-1.29494	-617.09
0.7265	0.93711	2.31429	4.14626	-1.40088	-739.62
0.8273	0.97704	2.53249	2.41089	-1.52689	-891.53
0.9182	1.00506	2.81135	1.83057	-1.55843	-946.86
1.0000	1.04484	4.64912	0.00000	0.00000	0.00

X_1 THFA + $X_2$1-pentanol 313.15K					
X_1	ρ(g.cm^{-3}) 313.15K	η 313.15K	V^E cm^{3}mol^{-1} 313.15K	η^E mpa.s 313.15K	ΔG^{*E}J mol^{-1} 313.15K
0.0000	0.80870	1.03061	0.00000	0.00000	0.00
0.1157	0.81142	1.07789	2.78419	-0.22660	-176.02
0.2235	0.82241	1.14578	4.21552	-0.41390	-316.28
0.3308	0.84301	1.23670	4.35512	-0.57699	-445.62
0.4431	0.86591	1.38719	4.37995	-0.69233	-493.19
0.5405	0.87004	1.51909	6.40110	-0.79100	-509.71
0.6312	0.88568	1.65799	6.79661	-0.86680	-552.85
0.7265	0.91231	1.83429	6.01328	-0.91610	-603.29
0.8273	0.96468	2.10455	2.63156	-0.88446	-641.35
0.9182	0.98506	2.29795	2.69141	-0.90624	-693.30
1.0000	1.03152	3.39783	0.00000	0.00000	0.00

Table (4): Experimental values of density and viscosity and calculated values of excess molar volume , excess viscosity and excess Gibbs free energy for binary mixtures of cyclopentanol +1-pentanol at (293.15, 303.15, and 313.15) K.

X_1 cyclopentanol + $X_2$1-pentanol 293.15K					
X_1	ρ(g.cm^{-3}) 293.15K	η 293.15K	V^E cm^{3}mol^{-1} 293.15K	η^E mpa.s 293.15K	ΔG^{*E}J mol^{-1} 293.15K
0.0000	0.81822	1.88223	0.00000	0.00000	0.00
0.1135	0.81999	1.84203	0.58811	-0.24836	-226.04
0.2451	0.82524	1.96077	0.85959	-0.37095	-284.68
0.3309	0.82876	1.95422	1.03107	-0.53486	-430.57
0.4409	0.83345	1.98028	1.23681	-0.71053	-575.34
0.5572	0.83907	2.07670	1.38299	-0.82739	-648.52
0.6468	0.84433	2.11252	1.39109	-0.95589	-755.12
0.7404	0.85059	2.15415	1.31919	-1.08590	-864.55
0.8259	0.85702	2.22004	1.18215	-1.17682	-936.45
0.9208	0.86615	2.43215	0.81711	-1.13875	-880.83
1.0000	0.87852	3.71614	0.00000	0.00000	0.00

X_1 cyclopentanol + $X_2$1-pentanol 303.15K					
X_1	ρ(g.cm^{-3}) 303.15K	η 303.15K	V^E cm^{3}mol^{-1} 303.15K	η^E mpa.s 303.15K	ΔG^{*E}J mol^{-1} 303.15K
0.0000	0.81054	1.23429	0.00000	0.00000	0.00
0.1135	0.81431	1.31918	0.34453	-0.14902	-101.10
0.2451	0.82041	1.52695	0.52744	-0.21247	-48.13
0.3309	0.82398	1.62555	0.70809	-0.29069	-94.92
0.4409	0.82912	1.76702	0.87666	-0.37591	-148.44
0.5572	0.83498	1.92981	1.01415	-0.45281	-206.47
0.6468	0.84108	2.06199	0.93479	-0.50528	-260.01
0.7404	0.84876	2.14499	0.70928	-0.61518	-394.66
0.8259	0.85608	2.25902	0.48548	-0.67735	-478.70
0.9208	0.86404	2.37957	0.27743	-0.75239	-585.15
1.0000	0.87174	3.29518	0.00000	0.00000	0.00

X_1 cyclopentanol + $X_2$1-pentanol 313.15K					
X_1	ρ(g.cm^{-3}) 313.15K	η 313.15K	V^E cm^{3}mol^{-1} 313.15K	η^E mpa.s 313.15K	ΔG^{*E}J mol^{-1} 313.15K
0.0000	0.80870	1.03061	0.00000	0.00000	0.00
0.1135	0.81409	1.03455	0.03198	-0.13701	-13.36
0.2451	0.81927	1.09127	0.22505	-0.24371	-13.45
0.3309	0.82367	1.18321	0.22572	-0.25840	-86.69
0.4409	0.82856	1.33630	0.33409	-0.24182	-133.89
0.5572	0.83443	1.48695	0.37252	-0.23559	-178.24
0.6468	0.84019	1.62577	0.25941	-0.20804	-217.19
0.7404	0.84653	1.78584	0.11572	-0.16420	-309.94
0.8259	0.85030	1.96368	0.23864	-0.09253	-343.53
0.9208	0.85156	2.10761	0.72867	-0.06645	-216.21
1.0000	0.86233	2.27241	0.00000	0.00000	0.00

Table (5): coefficient, A_k, from equation (5) and standard deviation, σ for all binary mixtures studied at different temperature.

T/K		A_0	A_1	A_2	σ
X_1 THFA + X_2 cyclopentanol					
V^E cm^3 mol^{-1}	293.15	1.6170	-2.4952	-0.9526	0.0015
	303.15	2.8860	-3.7940	0.7792	0.0019
	313.15	4.2895	-8.4156	6.5375	0.0020
η^E mpa.s	293.15	-3.0041	-0.7051	-1.7874	0.0033
	303.15	-2.0933	-0.8135	-2.7851	0.0037
	313.15	-1.6244	-0.9646	-2.6537	0.0035
ΔG^{*E} J.mole^{-1}	293.15	-1001.32	-42.00	-792.54	0.0003
	303.15	-1222.04	-342.89	-1742.66	0.0050
	313.15	-1349.10	-883.18	-1758.29	0.0046
X_1 THFA+ X_2 1-pentanol					
V^E cm^3 mol^{-1}	293.15	19.4241	8.4195	-27.7442	0.0029
	303.15	22.7645	2.8314	-25.3931	0.0025
	313.15	26.7259	-0.9284	-25.4650	0.0003
η^E mpa.s	293.15	-10.1566	-2.7832	12.7017	0.0013
	303.15	-5.9258	-2.0130	7.7661	0.0017
	313.15	-3.8904	-1.2408	4.9316	0.0021
ΔG^{*E} J.mole^{-1}	293.15	-3451.12	-2885.07	6249.09	0.0019
	303.15	-3122.27	-730.16	3747.87	0.0007
	313.15	-2649.76	-517.03	3093.18	0.0006
X_1 cyclopentanol + X_2 1-pentanol					
V^E cm^3 mol^{-1}	293.15	6.3792	0.6118	-6.8803	0.0017
	303.15	4.1421	0.1933	-4.3037	0.0021
	313.15	1.4349	0.1906	-1.5871	0.0019
η^E mpa.s	293.15	-4.2956	-2.1144	6.2765	0.0007
	303.15	-2.3629	-1.1645	3.4444	0.0009
	313.15	-1.0703	0.5542	0.5090	0.0007
ΔG^{*E} J.mole^{-1}	293.15	-3406.46	-1606.83	4907.64	0.0004
	303.15	-1218.16	-984.99	2137.60	0.0005
	313.15	-972.53	-925.12	1863.60	0.0038

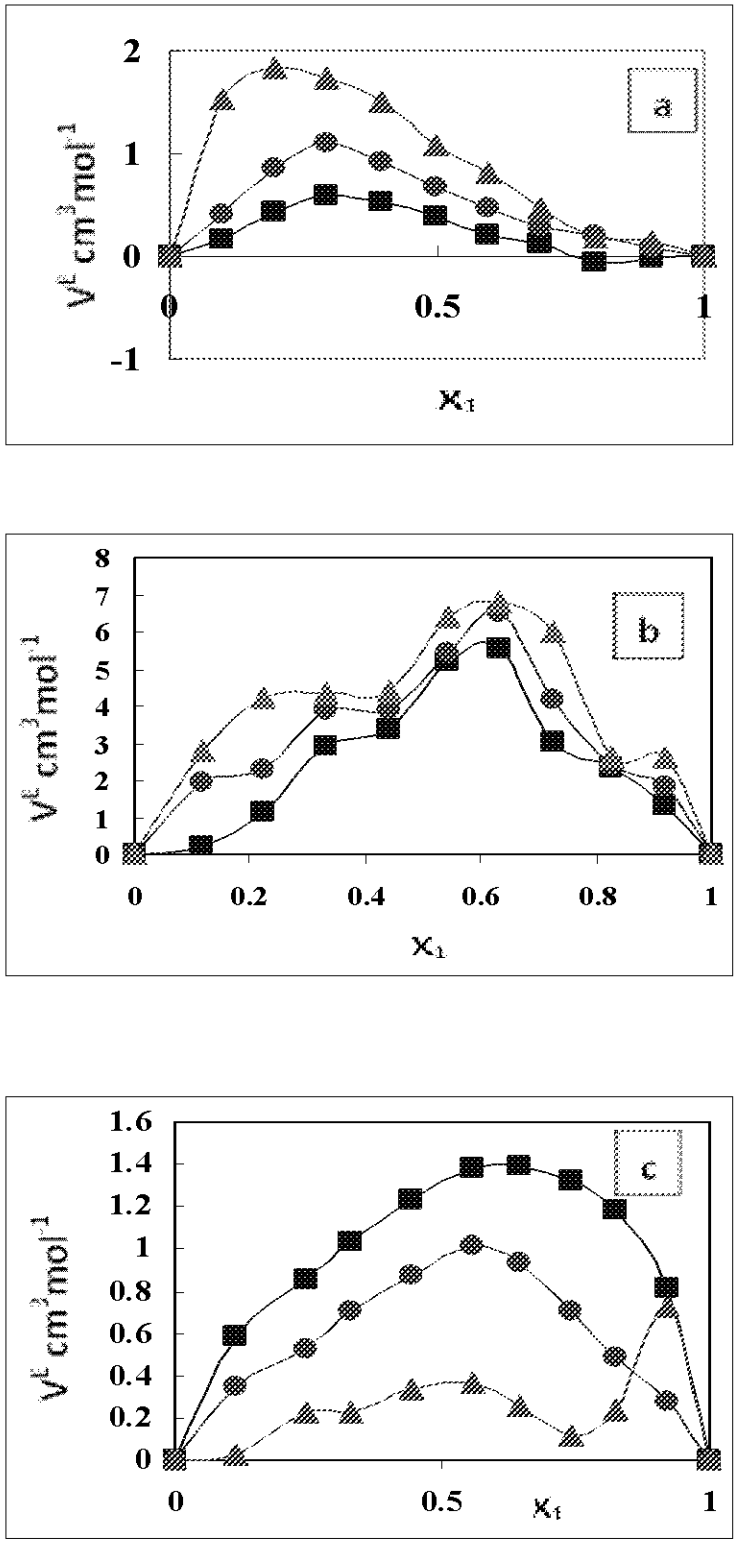

Fig. (1): Excess molar volumeV^E versus X_1 for (a) X_1THFA +X_2cyclopentanol ,(b)X_1THFA+$X_2$1-pentanol and (c)X_1 cyclopentanol +X_2 1-pentanol at ■293.15K, ●303.15Kand ▲313.15K.

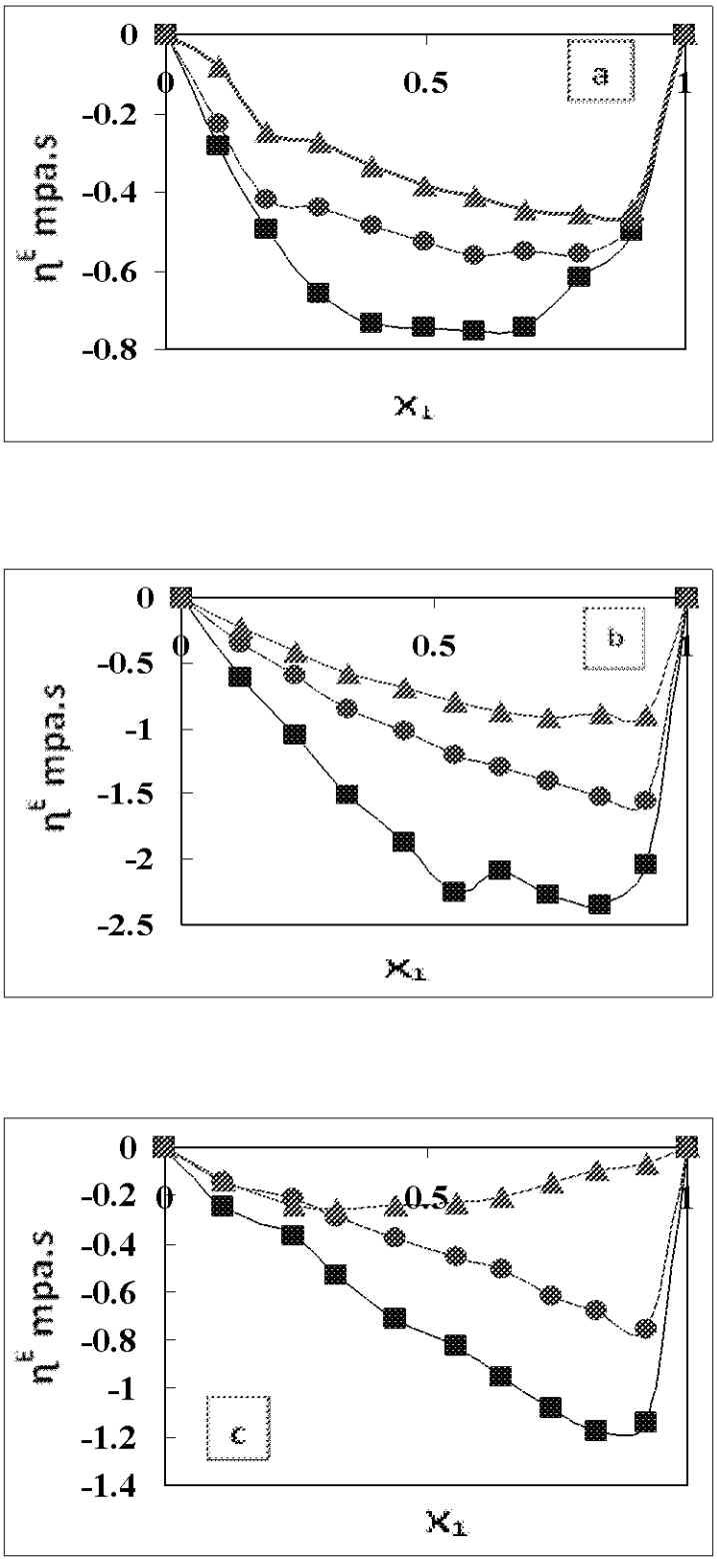

Fig. (2): Excess viscosity η^E versus X_1 for (a) X_1THFA +X_2cyclopentanol ,(b)X_1THFA+X_2 1-pentanol and (c)X_1 cyclopentanol +X_2 1-pentanol at ■293.15K, ●303.15K and ▲313.15K.

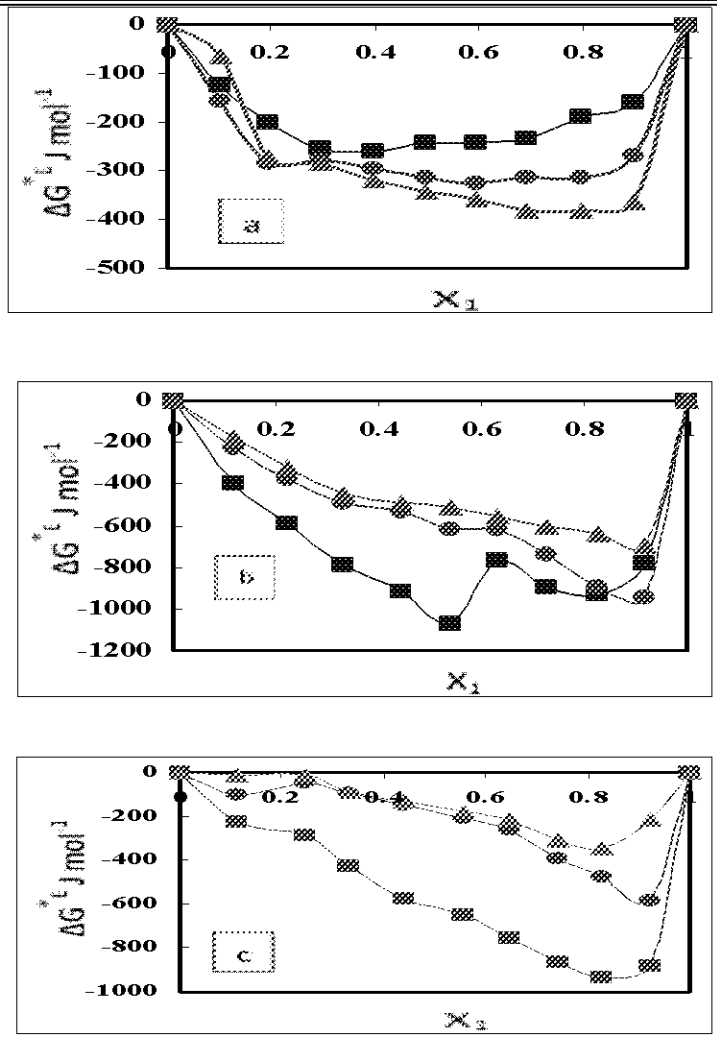

Fig. (3): Excess Gibbs free energy of activation of viscous flow ΔG^{*E} versus X_1 for (a) X_1THFA +X_2cyclopentanol,(b)X_1THFA+$X_2$1-pentanol and (c)X_1 cyclopentanol +X_2 1- Pentanol at ■293.15K, ●303.15Kand ▲313.15K

الخصائص الفائضة للمزيج الثنائي تترا هيدروفورفورايل الكحول مع السايكلوبنتانول و 1- بنتانول عند الدرجات الحرارية 293.15 و303.15 و313.15 كلفن

ظافر تموين عجيل الهتيمي
قسم الكيمياء ، كلية التربية للعلوم الصرفة ابن الهيثم ،جامعة بغداد

الكلمات المفتاحية: النظام الثنائي، تترا هيدروفورفورايل الكحول، السايكلوبنتانول،1- بنتانول،الحجم المولاري الفائض، الكثافة ، اللزوجة

تم قياس الكثافة واللزوجة لمحاليل المخاليط الثنائية المكونة من (تترا هيدروفورفورايل الكحول مع السايكلوبنتانول) و(تترا هيدروفورفورايل الكحول مع 1- بنتانول) و(السايكلوبنتانول مع 1– بنتانول) عند الدرجات الحرارية 293.15 و303.15و313.15 كلفن . من بيانات الكثافة واللزوجة تم حساب كل من الحجم المولاري الفائض واللزوجة الفائضة وكذلك طاقة التنشيط الحرة الفائضة وتم تطبيق النتائج العملية نظريا بأستخدام معادلة Redlich-kister لايجاد معاملات هذه المعادلة والانحراف القياسي لها. الانحرافات عن المثالية نوقشت بواسطة التداخلات الجزيئية بين المكونات غير المتشابهة. بالنسبة للمخاليط الثنائية قيد الدراسة اظهرت بان الحجم الفائض ينحرف انحراف موجب عن السلوك المثالي ولجميع الانظمة ماعدا نقطتين انحرفت انحراف سالب عند درجة الحرارة 293.15 كلفن بالنسبة للنظام الثنائي (تترا هيدروفورفورايل الكحول مع السايكلوبنتانول) اما اللزوجة الفائضة وطاقة التنشيط الفائضة الحرة لجبس فتظهر انحراف سالب عن السلوك المثالي عند جميع درجات الحرارة المدروسة.