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INVESTIGATION OF THERMOPHYSICAL PROPERTIES OF CARBON TETRACHLORIDE WITH ALKOXYETHANOLS AT 298.15 K-313.15 K.

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ABSTRACT

In this article, the behavior of carbon tetrachloride + 2-methoxyethanol, carbon tetrachloride + 2-ethoxyethanol and carbon tetrachloride + 2-butoxyethanol are studied. Density and Viscosity of above three binary mixtures have been measured, studied as a function of temperature and composition. Molar volume, Viscosity deviations and Excess Gibb's free energy of activation of flow have been calculated. Excess properties are fit to the Redlich-Kister model to obtain the coefficients and standard error. The results of three binary liquid mixtures signify a strong specific type of interaction between the unlike molecules.

Keywords: Density, Viscosity, Excess Properties, Molecular Interactions

INTRODUCTION

Non-ideal solutions are recognized by determining the strength of the intermolecular forces among the different molecules in particular solution[1]. The data on liquids and liquid mixtures are associated with some of the properties that are finding wide application in solution theory. These findings are useful to study the Thermophysical properties of liquid mixtures and their dependence on temperature and composition. In recent years, the need for the thermophysical properties are raising and it is very significant in different applications, like the design of distillation columns, pipeline systems, and mass transfer operations[2]. Alkoxyethanols, which are oxygenated compounds, are used as additives to gasoline as a result enriching of octane and reducing pollution. The mixture included in this work contains a wide range of applications in industries, as paint thinners, stain removers, solvents and also used in industries as a refrigerant, cleaning fluid, decreasing agent to an extend of insecticides, pesticides, and medicines.

EXPERIMENTAL

Analytical grade carbon tetrachloride was supplied by S.D. fine chemicals Pvt. Ltd., Mumbai and 2-methoxyethanol 2-ethoxyethanol and 2-butoxyethanol were obtained from SRL Pvt. Ltd., Mumbai (India). All the chemicals were degassed prior to use[3,4]. The purities of all the chemicals were compared with literature values and verified. In all cases, the purity was satisfactory to fulfill our requirement and no additional purification was essential. All the binary mixtures, carbon tetrachloride + 2-methoxyethanol, carbon tetrachloride + 2-ethoxyethanol and carbon tetrachloride + 2-butoxyethanol were placed in air-tight bottles[5]. The mass measurements were done on a digital electronic balance (Mettler AE 240, Switzerland) accurate to 0.1 mg. The binary mixtures were ready just before use[6]. The pure liquids and liquid mixtures densities were measured with bicapillary pycnometer. The density values are quite accurate and satisfactory. The capillary viscometer was used to measure the viscosity of pure liquids and liquids mixtures with a good accuracy. All the experiments were performed by using a thermostat, which is maintained to ± 0.01 K[7].

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RESULTS AND DISCUSSION

The pure compounds ρ and η values are compared with literature values and presented in Table-1. The values observed from Table-1 the experimental values are fairly well with the literature values. The experimentally measured ρ and η for studied three binary mixtures at 298.15 K - 303.15 K are reported in Table-2.

Table-1: Experimental ρ and η Data of Pure Substance, Comparing with Literature Values at 298.15K-313.15 K

T/K	Density ρ (g.cm^{-3})		Viscosity η (mPa.s)	
	Expt.	lit.	Expt.	lit.
Carbon tetrachloride				
298.15	1.5837	1.5840 [8] 1.5839 [14]	0.9441	0.9443 [14]
303.15	1.5743	1.5748 [8] 1.5737 [14]	0.8845	0.8430 [8] 0.8841[14]
308.15	1.5651	1.5650 [8] 1.5639 [14]	0.8290	0.8292 [14]
313.15	1.5558	1.5542 [14]	0.7785	0.7788 [14]
2-Methoxyethanol				
298.15	0.9605	0.9603 [24]	1.5626	1.5620 [24]
303.15	0.9556	0.95576 [9] 0.9527 [10]	1.4716	1.4710 [9] 1.476 [11]
308.15	0.95117	0.95112 [9] 0.9503 [10]	1.2553	1.254 [9] 1.257 [12]
313.15	0.9467	0.94628 [9] 0.9456 [10]	1.1626	1.162 [9]
2-Ethoxyethanol				
298.15	0.9262	0.9256 [24] 0.9256 [25]	1.8545	1.850 [24] 1.850 [25]
303.15	0.9219	0.92117 [9] 0.9186 [10]	1.6458	1.647 [9] 1.643 [11]
308.15	0.9167	0.91642 [9] 0.9160 [10]	1.4879	1.4870 [9] 1.480 [12]
313.15	0.9123	0.91225 [9] 0.9103 [10]	1.2901	1.2890 [9] 1.293 [11]
2-Butoxyethanol				
298.15	0.8969	0.8966 [24] 0.8966 [26]	2.7891	2.7950 [24] 2.7950 [26]
303.15	0.8927	0.89213 [9] 0.8921 [10]	2.4017	2.4020 [9] 2.4030 [10]
308.15	0.8885	0.88705 [9] 0.8870 [10]	2.2878	2.2880 [9] 2.2880 [10]
313.15	0.8843	0.88224 [9] 0.8822 [10]	2.1098	2.1180 [9] 2.1190 [10]

Table-2: The Measured Densities and Viscosities Values at 298.15 K - 313.15 K

x_1	ρ (g.cm^{-3})	η (mPa.s)	ρ (g.cm^{-3})	η (mPa.s)	ρ (g.cm^{-3})	η (mPa.s)	ρ (g.cm^{-3})	η (mPa.s)
Carbon tetrachloride (1) +2-Methoxyethanol (2)								
	298.15K		303.15K		308.15K		313.15K	
0.0000	0.9605	1.6490	0.9561	1.4570	0.9517	1.2920	0.9473	1.1500
0.0831	1.0228	1.5690	1.0181	1.3920	1.0132	1.240	1.0084	1.1080
0.1694	1.0852	1.4900	1.0800	1.3280	1.0747	1.1880	1.0694	1.0670
0.2591	1.1475	1.4120	1.1418	1.2650	1.1361	1.1370	1.1304	1.0250

0.3523	1.2098	1.3350	1.2037	1.2020	1.1671	1.1110	1.1913	0.9841
0.4494	1.2721	1.2600	1.2349	1.1710	1.2589	1.0360	1.2522	0.9429
0.5504	1.3344	1.1860	1.3273	1.0790	1.3202	0.9853	1.3134	0.9015
0.6557	1.3967	1.1140	1.3891	1.0190	1.3512	0.9601	1.3738	0.8608
0.7655	1.4589	1.0430	1.4509	0.9601	1.4427	0.8863	1.4345	0.8201
0.8802	1.5212	0.9736	1.5126	0.9020	1.5039	0.8376	1.4951	0.7796
1.000	1.5837	0.9062	1.5743	0.8450	1.5651	0.7897	1.5558	0.7394
Carbon tetrachloride (1) +2-Ethoxyethanol (2)								
	298.15K		303.15K		308.15K		313.15K	
0.0000	0.9262	1.9200	0.9219	1.6820	0.9175	1.4790	0.9132	1.3060
0.0977	0.9903	1.7840	0.9856	1.5720	0.9808	1.3910	0.9760	1.2360
0.1959	1.0547	1.6570	1.0496	1.4700	1.0444	1.3080	1.0392	1.1680
0.2946	1.1195	1.5390	1.1140	1.3730	1.1084	1.2300	1.1027	1.1050
0.3938	1.1847	1.4280	1.1787	1.2830	1.1726	1.1550	1.1665	1.0440
0.4935	1.2503	1.3250	1.2438	1.1970	1.2372	1.0850	1.2306	0.9864
0.5937	1.3162	1.2290	1.3092	1.1180	1.3021	1.0190	1.2950	0.9318
0.6945	1.3824	1.1400	1.3749	1.0430	1.3673	0.9566	1.3597	0.8798
0.7958	1.4491	1.0560	1.4410	0.9725	1.4329	0.8976	1.4247	0.8306
0.8976	1.5161	0.9785	1.5075	0.9067	1.4988	0.8421	1.4901	0.7838
1.0000	1.5837	0.9062	1.5743	0.8450	1.5651	0.7897	1.5558	0.7394
Carbon tetrachloride (1) +2-Butoxyethanol (2)								
	298.15K		303.15K		308.15K		313.15K	
0.0000	0.8969	3.5740	0.8927	3.0990	0.8885	2.6990	0.8843	2.3610
0.1311	0.9656	2.9860	0.9610	2.6140	0.9564	2.2980	0.9517	2.0280
0.2534	1.0343	2.5250	1.0293	2.2300	1.0242	1.9770	1.0191	1.7590
0.3678	1.1030	2.1580	1.0975	1.9220	1.0919	1.7180	1.0863	1.5410
0.4750	1.1717	1.8620	1.1657	1.6720	1.1596	1.5060	1.1536	1.3600
0.5758	1.2403	1.6220	1.2339	1.4660	1.2273	1.3300	1.2207	1.2100
0.6706	1.3090	1.4240	1.3020	1.2960	1.2950	1.1840	1.2879	1.0840
0.7600	1.3776	1.2600	1.3701	1.1540	1.3626	1.0610	1.3549	0.9770
0.8445	1.4463	1.1220	1.4382	1.0340	1.4301	0.9560	1.4219	0.8858
0.9243	1.5149	1.0050	1.5063	0.9323	1.4976	0.8666	1.4889	0.8073
1.0000	1.5837	0.9062	1.5743	0.8450	1.5651	0.7897	1.5558	0.7394

The properties like molar volume, viscosity deviation and excess Gibbs free energy of activation flow were estimated from the experimental value by using the following equations.

$$V_m = (x_1M_1 + x_2M_2) / \rho_m \quad (1)$$

$$\eta^E = \eta - \sum_{i=1}^{n} x_i \eta_i \quad (2)$$

$$\Delta G^{*E} = RT[\ln(V\eta)] - \sum_{i=1}^{n} x_i \ln(V_i\eta_i) \quad (3)$$

Where x_i represents the mole fraction of the pure component i. V, ρ_m,and η are the molar volume, density, and viscosity of liquid mixtures.V_i, and η_i the respective properties of the pure substance. The excess properties values are fitted with Redlich–Kister model [15].

$$A^E = x_1(1-x_1) - \sum_{i=1}^{n} A_i(2x_2-1)^i \quad (4)$$

The values of A_i of Eq. (4) were estimated by using the regression method and the standard deviation values are estimated by the following equation.

$$\sigma = \left[\frac{\sum(x_{exp}-x_{calc})^2}{n-p}\right]^{1/2} \quad (5)$$

Where n is the number of measured points, p is the number of parameters, x_{exp} and x_{cal} are the measured and estimated properties.

The viscosity deviation against composition at 298.15K to 313.15K for binary mixtures of carbon tetrachloride with alkoxyethanols are presented in Fig.-1,2 and 3.The viscosity deviation values all are negative for the system CCl_4 with 2- Methoxyethanol , 2- Ethoxyethanol and 2- Butoxyethanol at temperature 298.15 K -313.15 K for the complete range of composition. The obtained values of viscosity deviation differ in the following order 2-Methoxyethanol < 2-Ethoxyethanol < 2-Butoxyethanol at all studied temperature. The negative values viscosity deviation indicates that the dispersion forces are dominant.[16-18] The viscosity deviation (Δη) values indicate that there is a survival of dispersion and dipolar forces between dissimilar molecules and associated with the variation in shape and size of the dissimilar molecules. The obtained values suggest that the existence of intermolecular force upon mixing of three binary liquid mixtures.

Table-3: The Calculated Excess Properties Values , V_m, Δη, and ΔG^{*E} of Binary Mixtures at 298.15 K - 313.15 K

x_1	Δη (mPa.s)	V_m (cm^3/mol)	ΔG^{*E} (J/mol)	Δη (mPa.s)	V_m (cm^3/mol)	ΔG^{*E} (J/mol)
Carbon tetrachloride (1) +2-Methoxyethanol (2)						
	298.15 K			303.15 K		
0.0000	0.0000	79.2244	0.0000	0.0000	79.5890	0.0000
0.0831	-0.0182	80.7155	4.3214	-0.0141	81.0882	3.1995
0.1694	-0.0331	82.2553	7.5813	-0.0253	82.6514	6.6061
0.2591	-0.0445	83.8626	10.0345	-0.0334	84.2812	10.1149
0.3523	-0.0523	85.5331	11.1770	-0.0394	85.9665	11.0966
0.4494	-0.0552	87.2707	12.6569	-0.0410	87.7258	13.9606
0.5504	-0.0542	89.0797	12.3606	-0.0412	89.5562	11.6981
0.6557	-0.0480	90.9647	12.0738	-0.0367	91.4624	10.7413
0.7655	-0.0374	92.9370	9.4992	-0.0284	93.4494	8.8976
0.8802	-0.0216	94.9892	5.1958	-0.0163	95.5292	5.2410
1.0000	0.0000	97.1336	0.0000	0.0000	97.7012	0.0000
	308.15 K			313.15 K		
0.0000	0.0000	79.9569	0.0000	0.0000	80.3283	0.0000
0.0831	-0.0102	81.4803	4.0236	-0.0079	81.8682	3.2331
0.1694	-0.0189	83.0590	6.6741	-0.0134	83.4706	8.1307
0.2591	-0.0248	84.7041	10.2126	-0.0186	85.1312	9.5085
0.3523	-0.0290	86.4116	12.0849	-0.0212	86.8613	12.6874
0.4494	-0.0303	88.1857	14.4788	-0.0226	88.6576	13.7493
0.5504	-0.0302	90.0378	13.2001	-0.0225	90.5040	12.0766
0.6557	-0.0272	91.9655	11.7435	-0.0200	92.4810	12.2202
0.7655	-0.0212	93.9806	9.3361	-0.0156	94.5178	9.7630
0.8802	-0.0123	96.0819	5.2216	-0.0090	96.6474	5.7954
1.0000	0.0000	98.2755	0.0000	0.0000	98.8630	0.0000
	Carbon tetrachloride (1) +2-Ethoxyethanol (2)					
	298.15 K			303.15 K		
0.0000	0.0000	97.3030	0.0000	0.0000	97.7568	0.0000
0.0977	-0.0370	97.2868	11.2615	-0.0282	97.7508	11.2406
0.1959	-0.0644	97.2755	18.2942	-0.0481	97.7481	18.4382
0.2946	-0.0824	97.2596	22.5899	-0.0625	97.7398	22.8628
0.3938	-0.0928	97.2402	24.7827	-0.0694	97.7352	26.7339
0.4935	-0.0947	97.2181	25.9579	-0.0719	97.7262	27.9542
0.5937	-0.0891	97.2012	24.8752	-0.0670	97.7209	26.7185
0.6945	-0.0759	97.1890	20.0149	-0.0577	97.7192	21.3137
0.7958	-0.0572	97.1677	14.2449	-0.0434	97.7139	14.4767
0.8976	-0.0315	97.1514	6.2240	-0.0240	97.7056	6.7083
1.0000	0.0000	97.1336	0.0000	0.0000	97.7012	0.0000

	308.15 K			313.15 K		
0.0000	0.0000	98.2256	0.0000	0.0000	98.6881	0.0000
0.0977	-0.0207	98.2291	11.1405	-0.0147	98.7122	11.3971
0.1959	-0.0360	98.2348	19.4130	-0.0270	98.7264	19.7414
0.2946	-0.0460	98.2336	23.8462	-0.0341	98.7414	25.3566
0.3938	-0.0526	98.2437	27.5049	-0.0389	98.7574	28.5630
0.4935	-0.0538	98.2475	28.9903	-0.0400	98.7744	29.7791
0.5937	-0.0507	98.2538	27.1398	-0.0378	98.7925	28.7097
0.6945	-0.0437	98.2624	22.3639	-0.0327	98.8116	23.8307
0.7958	-0.0329	98.2662	14.4911	-0.0245	98.8318	14.9171
0.8976	-0.0182	98.2728	6.7462	-0.0136	98.8465	7.0279
1.0000	0.0000	98.2755	0.0000	0.0000	98.8630	0.0000
	Carbon tetrachloride (1) +2-Butoxyethanol (2)					
	298.15 K			303.15 K		
0.0000	0.0000	131.7605	0.0000	0.0000	132.3804	0.0000
0.1311	-0.2384	127.2225	12.3656	-0.1896	127.8315	12.4735
0.2534	-0.3731	122.9862	21.2074	-0.2979	123.5837	21.1001
0.3678	-0.4348	119.0225	26.3283	-0.3480	119.6190	26.6375
0.4750	-0.4447	115.3061	27.8935	-0.3563	115.8996	29.2431
0.5758	-0.4159	111.8234	28.6787	-0.3352	112.4034	27.7993
0.6706	-0.3609	108.5361	26.2087	-0.2914	109.1196	25.6004
0.7600	-0.2864	105.4440	22.9349	-0.2319	106.0212	21.7862
0.8445	-0.1991	102.5158	16.5972	-0.1616	103.0931	15.6545
0.9243	-0.1031	99.7523	7.9103	-0.0832	100.3218	8.7654
1.0000	0.0000	97.1336	0.0000	0.0000	97.7012	0.0000
	308.15 K			313.15 K		
0.0000	0.0000	133.0062	0.0000	0.0000	133.6379	0.0000
0.1311	-0.1508	128.4464	12.7988	-0.1205	129.0807	12.8131
0.2534	-0.2383	124.1990	21.1208	-0.1911	124.8206	20.6327
0.3678	-0.2788	120.2325	27.1722	-0.2236	120.8523	27.6617
0.4750	-0.2860	116.5092	30.0434	-0.2307	117.1152	28.9647
0.5758	-0.2696	113.0079	28.8349	-0.2173	113.6189	29.4175
0.6706	-0.2346	109.7094	27.1299	-0.1895	110.3143	27.3233
0.7600	-0.1869	106.6048	23.3891	-0.1515	107.2106	22.8508
0.8445	-0.1307	103.6771	16.3836	-0.1058	104.2750	16.9133
0.9243	-0.0676	100.9046	8.8073	-0.0548	101.4942	9.0401
1.0000	0.0000	98.2755	0.0000	0.0000	98.8630	0.0000

Table-4: Coefficients (A_k) and Standard Deviation (σ) of Three Binary Liquid Mixtures at 298.15 K - 313.15 K

Parameter/ Function	T/K	A_0	A_1	A_2	A_3	A_4	σ
Carbon tetrachloride (1) +2-Methoxyethanol (2)							
$\Delta\eta$ (mPa.s)	298.15	-0.2212	0.0259	0.0050	-0.0077	-0.0091	0.0006
	303.15	-0.1665	0.0136	-0.0029	0.0082	-0.0016	0.0016
	308.15	-0.1223	0.0113	-0.0137	0.0009	0.0146	0.0011
	313.15	-0.0915	0.0070	0.0057	0.0045	-0.0139	0.0016
ΔG^{*E} (J/mol)	298.15	50.3430	5.8339	13.0842	-17.3607	-16.4821	1.1255
	303.15	50.7534	-7.6944	-4.7442	19.4650	-1.8380	3.5453
	308.15	55.9978	-1.0687	-29.5076	1.4757	33.9056	2.7043
	313.15	51.8299	-4.2845	22.8112	14.3584	-39.7333	4.5207
Carbon tetrachloride (1) +2-Ethoxyethanol (2)							
$\Delta\eta$ (mPa.s)	298.15	-0.3778	0.0479	-0.0017	0.0000	-0.0053	0.0015
	303.15	-0.2857	0.0313	0.0069	0.0079	-0.0225	0.0021
	308.15	-0.2149	0.0201	0.0052	0.0043	-0.0112	0.0012

	313.15	-0.1590	0.0172	-0.0105	-0.0076	0.0205	0.0020
ΔG^{*E} (J/mol)	298.15	-2.9334	0.0883	7.9261	-0.0788	-13.7889	3.1828
	303.15	-0.8303	-1.2342	19.7691	10.5082	-42.7671	4.1266
	308.15	-1.0693	-3.8750	14.6969	8.4331	-22.1016	2.4668
	313.15	2.4638	5.1088	-17.8229	-18.0825	43.4183	4.6881
Carbon tetrachloride (1) +2-Butoxyethanol (2)							
$\Delta\eta$ (mPa.s)	298.15	-1.7627	0.3957	-0.0431	0.0086	-0.0397	0.0009
	303.15	-1.4148	0.2961	-0.0504	0.0131	0.0028	0.0010
	308.15	-1.1364	0.2310	-0.0352	-0.0026	0.0023	0.0014
	313.15	-0.9152	0.1770	-0.0291	-0.0024	0.0079	0.0015
ΔG^{*E} (J/mol)	298.15	112.725	13.8493	45.1352	-7.6513	-74.0007	2.1043
	303.15	115.621	2.5890	-6.1931	10.3278	10.6045	1.8164
	308.15	119.034	13.8729	1.2788	-7.7984	-2.2758	2.7206
	313.15	118.734	15.5018	-2.2492	-8.0542	8.5555	2.8687

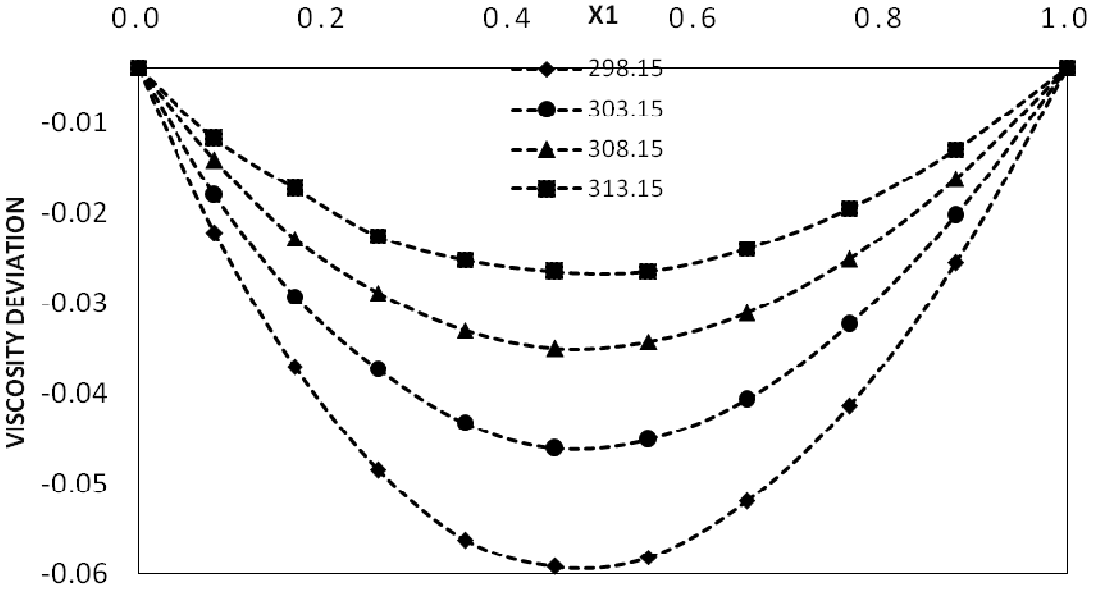

Fig.-1: Viscosity Deviation ($\Delta\eta$) of CCL_4 (1) + 2- Methoxy Ethanol (2) vs mole Fraction of x_1

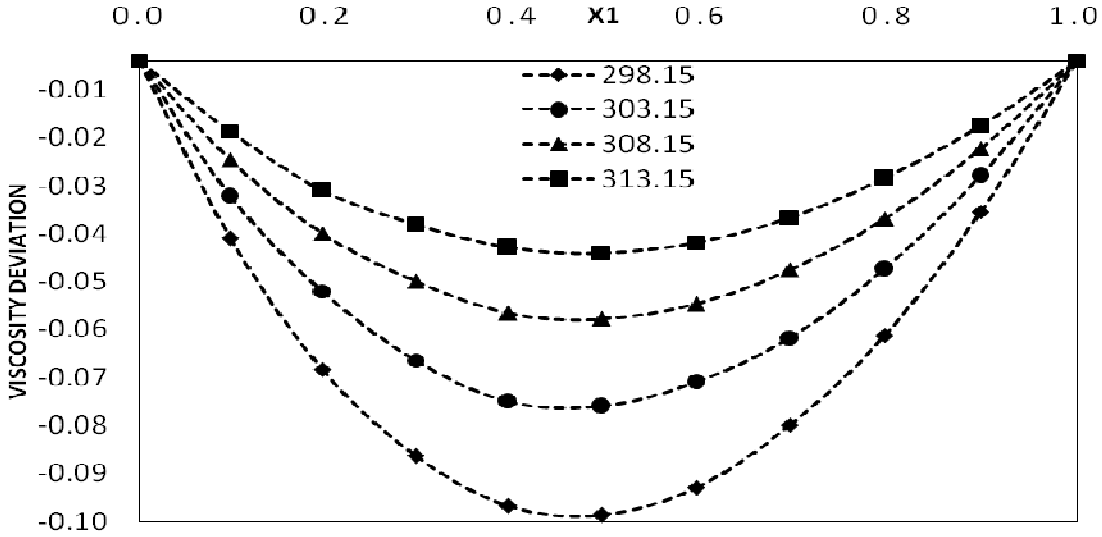

Fig.-2: Viscosity Deviation ($\Delta\eta$) of CCL_4 (1) + 2-Ethoxy Ethanol (2) vs mole Fraction of x_1

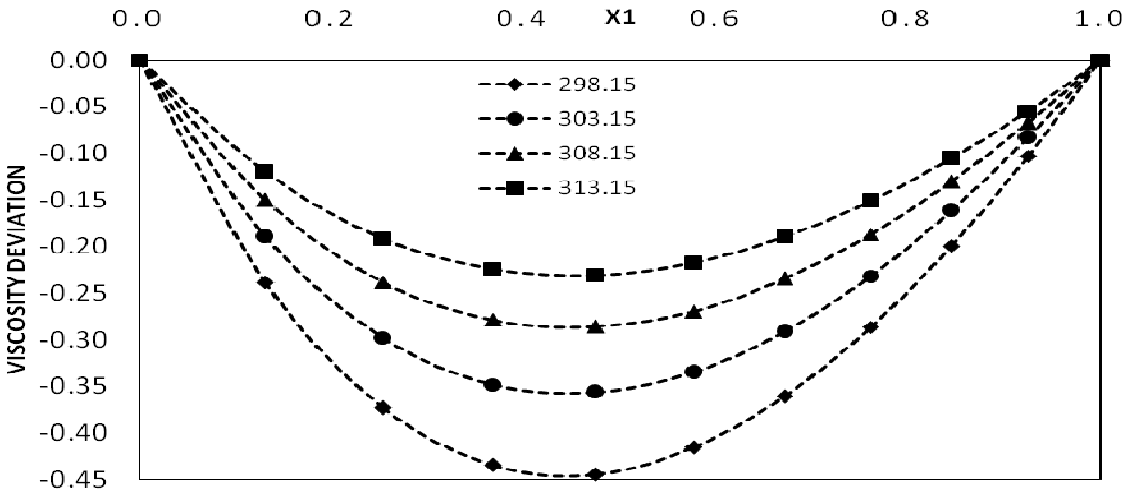

Fig.-3: Viscosity Deviation (Δη) of CCL_4 (1) + 2-Butoxy Ethanol (2) vs mole Fraction of x_1

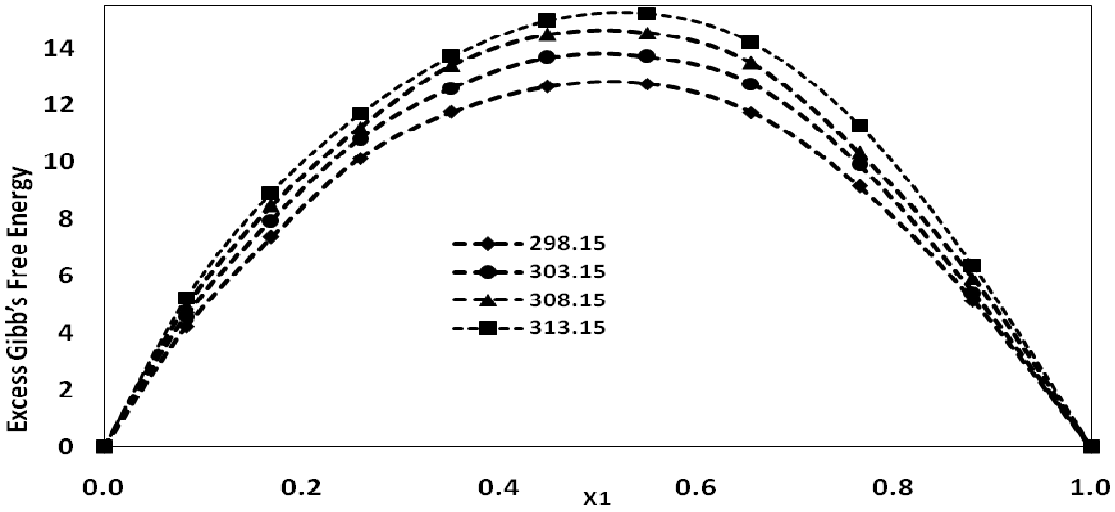

Fig.-4: ΔG^{*E} of CCL4 (1) + 2- Methoxy Ethanol (2) vs mole Fraction of x_1

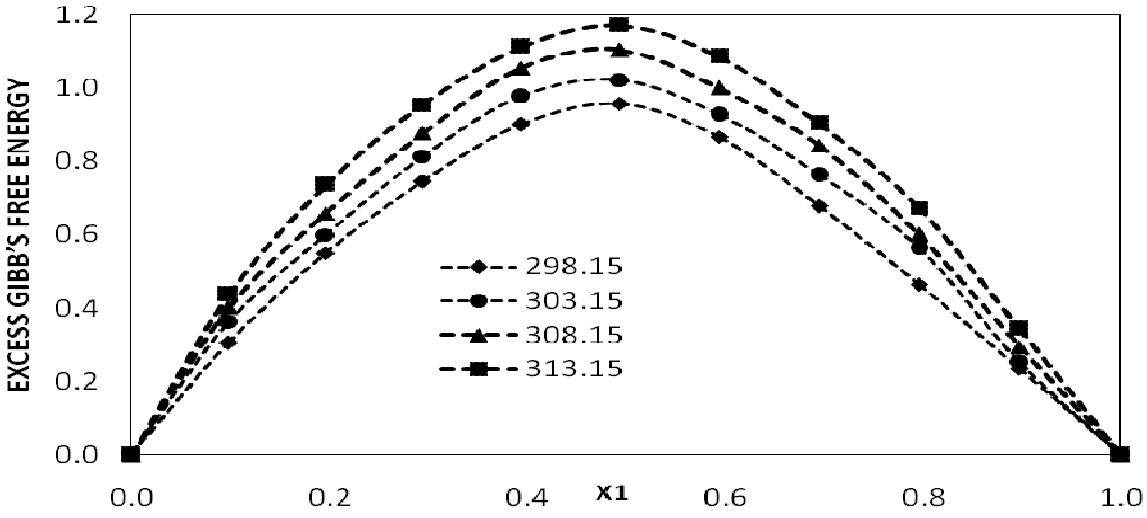

Fig.-5: ΔG^{*E} of CCL_4 (1) + 2- Ethoxy Ethanol (2) vs mole Fraction of x_1

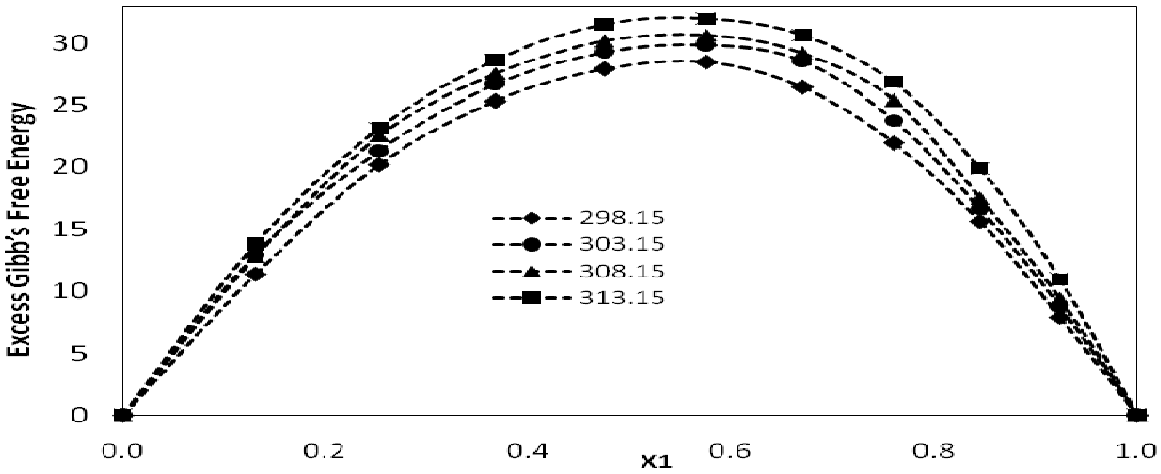

Fig.-6: ΔG^{*E} of CCL_4 (1) +2-Butoxy Ethanol (2) vs mole Fraction of x_1

The Excess Gibbs free energy of activation of viscous flow(ΔG^{*E}) against composition at different temperatures 298.15K to 313.15K for binary mixtures of CCl_4 with alkoxyethanols are presented in Fig.-4, 5, and 6. ΔG^{*E} is found to be positive for all mixtures however it initially increases up to 0.6 mole fractions then it gradually decreases. ΔG^{*E} slightly increases by a change in temperature. The values of ΔG^{*E} represents the potency of interaction among dissimilar molecules.[19,20] The ΔG^{*E} values indicate that there are an exact and strong interaction in the CCl_4 with alkoxyethanols.[21-23]The positive values of ΔG^{*E} for all studied mixtures its show that there is molecular interaction between dissimilar molecules.

CONCLUSION

Thermophysical properties like Densities and viscosities of three binary liquid mixtures are reported. The values of the pure substance mostly concur with the existing literature. Molar volumes, viscosity deviations and excess Gibb's free energy of activation of a flow of carbon tetrachloride + 2-methoxyethanol, carbon tetrachloride + 2-ethoxyethanol and carbon tetrachloride + 2-butoxyethanol were obtained at T = (298.15, 303.15, 308.15 and 313.15) K from the experimental results and it has reported. The excess properties are fitted with Redlich-Kister equations. The results are analyzed in terms of molecular interactions between the components. The investigation studies of three binary liquid mixtures show that there is an intermolecular interaction between the components.

NOMENCLATURE

ρ - Density (g/cm^3)
η - Dynamic Viscosity (mPa.s)
V_m - molar volume (cm^3/mol)
Δη - Viscosity Deviation (mPa.s)
ΔG^{*E}- Excess gibbs free energy of activation flow (J/mol)

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