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Densities and Viscosities of Binary (Butyl acetate + n-Alkanes) Mixtures at T= (303.15, 308.15 and 313.15)K

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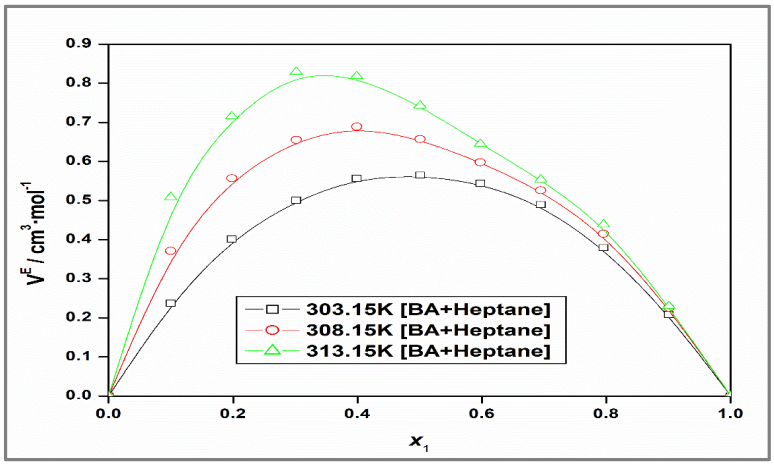
ABSTRACT

Densities (ρ), viscosities (η) of binary mixtures of butyl acetate with heptane, decane, dodecane and tridecane have been measured over the entire range of composition at 303.15, 308.15 and 313.15K and at atmospheric pressure. From the experimental values excess volumes (V^E) and deviation in viscosities ($\Delta\eta$), have been calculated. The excess volume is positive, while the deviation in viscosities is negative. The derived properties have been fitted to Redlich-Kister Polynomial equation. The experimental data of viscosity is used to test the applicability of empirical relations of Frenkel, Eyring Van-Laar, and Krishnan-Laddha for the systems studied.

Graphical Abstract



Excess volume (V^E) Vs mole fraction (x_1)for Butyl acetate with Heptane

Keywords: Butyl acetate, Alkanes, Excess volumes, Viscosities, Binary mixture.

INTRODUCTION

Over the past two decades several researcher's particularly physical chemists and chemical engineers have shown much interest in knowing accurately the thermodynamic and transport properties of

binary liquid mixtures in relation to the theoretical and applied areas of research. These data are needed for design process in chemical, petrochemical and pharmaceutical industries. Many a times predictive methods for the excess quantities could be more useful than direct experimental measurements especially when quick estimates are needed. The variation of molar volumes, viscosities and their excess values of binary mixtures of protic, aprotic and associated liquids have been a subject of extensive investigation. The volumetric, transport and acoustic properties of binary mixtures containing butyl acetate as a component have been studied extensively [**1-14**]. There are also some reports on binary mixtures consisting of alkanes [**15-17**] in alcohols or acetates and binary mixtures of hydroxyl compounds in polar liquids [**18**]. Kavitha *et al.*, [**19**] have also investigated ultrasonic velocity, density, and viscosity for ternary liquid mixtures of Quinoline, o-xylene and methanol with butyl acetate as common component.

Butyl acetate is a flavoring ingredient used in apple flavours. It is an organic compound commonly used as a solvent in the production of lacquers and other products. It is used as synthetic fruit flavoring in foods such as candy, ice cream, cheeses and baked goods. Butyl acetate is also used as solvent in the production of nail polish, and other nail-care products. It is used in the manufacture of artificial leather cleaners, photographic films, plastics, and safety glass. Alkanes are not very reactive and have little biological activity. They belong to a class of homologous non-polar organic solvents. Alkanes also pose a threat to the environment due to biodegradability character. They have often been used in the study of solute dynamics due to their physicochemical properties as a function of chain length [**20**]. The most important source of alkanes is natural gas and crude oil. Therefore, mixing of these non-polar alkanes in a polar solvent like butyl acetate revels some interesting results on the density, viscosity of binary mixtures. Our interest in this research is motivated primarily from understanding the possible impact of the molecular interaction between the butyl acetate and alkanes.

In continuation of our earlier work [**21-25**] in this paper we report the density, viscosity of binary mixtures of butyl acetate with heptane, decane, dodecane and tridecane at 303.15, 308.15, and 313.15K. Using these experimental data excess volumes and deviation in viscosity has been calculated at each investigated temperature. These results were discussed in terms of molecular interactions. Further the mixture viscosities were correlated using Frenkel [**26**], Eyring Van-Laar [**27**], Krishnan-Laddha [**28**] models to test their relative applicability.

MATERIALS AND METHODS

Butyl acetate, heptane, decane, dodecane and tridecane all chemicals were of analytical grade supplied by Sigma-Aldrich. The mass fraction purity of these chemicals was approximately higher than 0.99. These chemicals were stored over 0.4 nm molecular sieves to reduce water content and distilled just before the use. The purity of all these chemicals was further checked by gas chromatography (GC-8610) and the analysis of the purity was found to be >0.995.The binary liquid mixtures were prepared by mixing known masses of pure liquids in airtight stoppered bottles. All mass measurements were made using a Mettler one-pan balance (AE, 240, Switzerland). The resulting mole fraction uncertainty was estimated to be less than $\pm$ 0.0001. Densities of pure and their binary mixtures were determined using a density meter (DDM -2910 Rudolph Research Analytical). Viscosities of the pure liquids and their mixtures were determined by using Ubbelohde viscometer. The details of methods, calibration of density meter and viscometer are described in our earlier report [**25**]. The estimated uncertainties in density and viscosity respectively are $\pm$ 0.0004 g·cm^{-3} and $\pm$ 0.007 mPa·s.

RESULTS AND DISCUSSION

The experimental values of density (ρ), viscosity (η) along with calculated viscosities (η_{cal}) at 303.15, 308.15 and 313.15 K are given in table 1.

Table 1. Mole Fraction (x_1) of Butyl acetate, Density (ρ), Excess volumes (V^E), Viscosities (ηexp) and Calculated Viscosities (ηcal) using selected models for the binary mixtures at different temperature

x_1	ρ	V^E	η_{exp}	Frenkel	Eyring Van-Laar	Krishnan-Laddha
	g·cm^{-3}	cm^3·mol^{-1}	mPa·s	η_{cal}/mPa·s	η_{cal}/mPa·s	η_{cal}/mPa·s
Butyl acetate (1) + heptane (2)						
			T = 303.15K			
0.0000	0.6753		0.376			
0.0997	0.6919	0.237	0.383	0.375	0.382	0.382
0.1981	0.7089	0.401	0.386	0.378	0.388	0.387
0.3017	0.7275	0.501	0.392	0.386	0.396	0.393
0.3989	0.7455	0.556	0.401	0.399	0.405	0.401
0.5007	0.7650	0.565	0.417	0.418	0.417	0.416
0.5975	0.7841	0.544	0.436	0.441	0.434	0.436
0.6948	0.8039	0.489	0.464	0.472	0.458	0.465
0.7956	0.8252	0.379	0.506	0.512	0.499	0.505
0.9007	0.8483	0.209	0.560	0.565	0.574	0.561
1.0000	0.8710		0.627			
			T = 308.15K			
0.0000	0.6710		0.342			
0.0997	0.6869	0.371	0.343	0.344	0.338	0.342
0.1981	0.7037	0.557	0.343	0.347	0.339	0.344
0.3017	0.7222	0.655	0.349	0.353	0.346	0.349
0.3989	0.7402	0.689	0.358	0.361	0.357	0.358
0.5007	0.7598	0.657	0.374	0.372	0.374	0.373
0.5975	0.7790	0.598	0.393	0.389	0.396	0.393
0.6948	0.7988	0.526	0.421	0.415	0.426	0.422
0.7956	0.8200	0.415	0.463	0.457	0.466	0.462
0.9007	0.8431	0.226	0.517	0.534	0.519	0.517
1.0000	0.8658		0.584			
			T = 313.15K			
0.0000	0.6667		0.334			
0.0997	0.6819	0.509	0.325	0.330	0.324	0.326
0.1981	0.6985	0.715	0.325	0.328	0.320	0.323
0.3017	0.7168	0.829	0.325	0.329	0.322	0.325
0.3989	0.7349	0.818	0.331	0.333	0.329	0.331
0.5007	0.7546	0.743	0.343	0.342	0.344	0.344
0.5975	0.7739	0.645	0.364	0.357	0.365	0.363
0.6948	0.7937	0.554	0.390	0.382	0.393	0.390
0.7956	0.8148	0.439	0.430	0.425	0.433	0.429
0.9007	0.8379	0.230	0.484	0.505	0.489	0.485
1.0000	0.8605		0.558			
Butyl acetate (1) +decane (2)						
			T = 303.15K			
0.0000	0.7227		0.790			
0.0997	0.7319	0.299	0.763	0.760	0.760	0.763
0.2036	0.7423	0.568	0.736	0.737	0.734	0.735
0.2985	0.7527	0.752	0.711	0.715	0.712	0.711
0.3964	0.7646	0.844	0.689	0.694	0.693	0.689
0.4981	0.7783	0.853	0.672	0.676	0.675	0.672
0.598	0.7931	0.808	0.660	0.660	0.661	0.660
0.6962	0.8094	0.659	0.651	0.646	0.649	0.651
0.7986	0.8282	0.453	0.645	0.637	0.640	0.645
0.8998	0.8485	0.257	0.637	0.644	0.632	0.637
1.0000	0.8710		0.627			
			T = 308.15K			
0.0000	0.7189		0.717			
0.0997	0.7279	0.331	0.691	0.689	0.689	0.691
0.2036	0.7382	0.600	0.666	0.668	0.665	0.665
0.2985	0.7485	0.785	0.644	0.649	0.646	0.644
0.3964	0.7603	0.874	0.626	0.630	0.629	0.626
0.4981	0.7738	0.897	0.611	0.614	0.614	0.611
0.598	0.7885	0.842	0.602	0.601	0.603	0.602
0.6962	0.8046	0.700	0.597	0.590	0.595	0.597

0.7986	0.8232	0.494	0.594	0.586	0.589	0.593
0.8998	0.8434	0.279	0.590	0.597	0.585	0.590
1.0000	0.8658		0.584			
			T = 313.15K			
0.0000	0.7151		0.691			
0.0997	0.7239	0.362	0.662	0.686	0.662	0.663
0.2036	0.7342	0.605	0.637	0.666	0.636	0.636
0.2985	0.7444	0.790	0.615	0.646	0.616	0.615
0.3964	0.7559	0.922	0.597	0.627	0.599	0.597
0.4981	0.7693	0.935	0.583	0.612	0.585	0.583
0.598	0.7838	0.888	0.573	0.599	0.574	0.573
0.6962	0.7997	0.750	0.568	0.589	0.566	0.566
0.7986	0.8182	0.524	0.563	0.585	0.560	0.563
0.8998	0.8382	0.303	0.561	0.596	0.558	0.561
1.0000	0.8605		0.558			
			Butyl acetate (1) + dodecane (2)			
			T = 303.15K			
0.0000	0.7416		1.240			
0.0710	0.7464	0.208	1.176	1.131	1.176	1.176
0.1861	0.7548	0.552	1.082	0.988	1.081	1.081
0.2987	0.7642	0.803	0.998	0.881	0.997	0.997
0.3920	0.7731	0.930	0.935	0.811	0.934	0.934
0.4984	0.7847	0.982	0.869	0.749	0.867	0.868
0.5983	0.7971	0.973	0.812	0.704	0.809	0.811
0.6988	0.8115	0.874	0.760	0.670	0.756	0.759
0.8025	0.8289	0.658	0.710	0.646	0.708	0.710
0.9005	0.8479	0.407	0.667	0.632	0.674	0.667
1.0000	0.8710		0.627			
			T = 308.15K			
0.0000	0.7379		1.115			
0.0710	0.7426	0.223	1.061	1.184	1.060	1.060
0.1861	0.7509	0.568	0.979	1.096	0.978	0.979
0.2987	0.7601	0.845	0.907	1.013	0.906	0.907
0.3920	0.7690	0.944	0.853	0.948	0.851	0.852
0.4984	0.7804	1.011	0.795	0.876	0.793	0.795
0.5983	0.7927	0.992	0.746	0.811	0.743	0.746
0.6988	0.8069	0.898	0.701	0.750	0.697	0.700
0.8025	0.8240	0.698	0.657	0.689	0.656	0.657
0.9005	0.8429	0.421	0.619	0.635	0.627	0.619
1.0000	0.8658		0.584			
			T = 313.15K			
0.0000	0.7343		1.054			
0.0710	0.7387	0.297	1.010	1.150	1.005	1.009
0.1861	0.7469	0.636	0.941	1.026	0.932	0.941
0.2987	0.7560	0.904	0.878	0.925	0.867	0.877
0.3920	0.7648	0.997	0.828	0.854	0.818	0.828
0.4984	0.7761	1.050	0.774	0.785	0.766	0.774
0.5983	0.7883	1.014	0.726	0.731	0.721	0.726
0.6988	0.8023	0.921	0.681	0.684	0.679	0.680
0.8025	0.8191	0.732	0.636	0.643	0.640	0.636
0.9005	0.8379	0.425	0.596	0.611	0.613	0.596
1.0000	0.8605		0.558			
			Butyl acetate (1) + tridecane (2)			
			T = 303.15K			
0.0000	0.7491		1.540			
0.0955	0.7547	0.311	1.427	1.202	1.414	1.426
0.2039	0.7619	0.596	1.306	1.201	1.284	1.305
0.3043	0.7696	0.786	1.200	1.175	1.177	1.200
0.4057	0.7785	0.905	1.099	1.123	1.079	1.099
0.5011	0.7881	0.953	1.010	1.056	0.994	1.010
0.6027	0.7999	0.950	0.921	0.968	0.912	0.921
0.6989	0.8128	0.866	0.842	0.873	0.842	0.842
0.8029	0.8293	0.693	0.762	0.764	0.773	0.762
0.8972	0.8475	0.380	0.695	0.664	0.721	0.695
1.0000	0.8710		0.627			

			T = 308.15K			
0.0000	0.7455		1.319			
0.0955	0.7509	0.352	1.226	1.219	1.231	1.227
0.2039	0.7581	0.608	1.136	1.117	1.136	1.135
0.3043	0.7657	0.798	1.055	1.032	1.052	1.055
0.4057	0.7743	0.965	0.975	0.953	0.972	0.976
0.5011	0.7838	1.004	0.903	0.885	0.900	0.904
0.6027	0.7955	0.986	0.829	0.819	0.828	0.829
0.6989	0.8083	0.885	0.762	0.761	0.763	0.761
0.8029	0.8246	0.706	0.693	0.706	0.697	0.692
0.8972	0.8424	0.419	0.634	0.664	0.641	0.636
1.0000	0.8658		0.584			
			T = 313.15K			
0.0000	0.7419		1.178			
0.0955	0.7472	0.360	1.108	1.317	1.098	1.109
0.2039	0.7541	0.677	1.031	1.123	1.015	1.030
0.3043	0.7616	0.862	0.960	0.986	0.945	0.959
0.4057	0.7702	0.994	0.894	0.879	0.881	0.892
0.5011	0.7796	1.024	0.833	0.801	0.825	0.834
0.6027	0.7912	0.990	0.777	0.737	0.770	0.776
0.6989	0.8038	0.893	0.724	0.692	0.722	0.724
0.8029	0.8199	0.707	0.668	0.658	0.674	0.668
0.8972	0.8373	0.445	0.618	0.638	0.639	0.616
1.0000	0.8605		0.558			

The density values have been used to calculate excess volume V^E using following relation.

$$V^E\ (cm^3.mol^{-1}) = (x_1M_1 + x_2M_2)/\rho_{12} - (x_1M_1/\rho_1 + x_2M_2/\rho_2) \quad \ldots(1)$$

Where, ρ_{12} is the density of mixture and x_1, M_1, ρ_1 and x_2, M_2,ρ_2 are the mole fraction, molecular weight and density of pure components 1 and 2 respectively. The deviations in viscosity Δη have been calculated using the following relation.

$$\Delta\eta = \eta_{12} - (x_1\eta_1 + x_2\eta_2) \quad \ldots(2)$$

Where η_{12} is the viscosity of mixture and η_1, η_2 are the viscosity of pure components 1 and 2 respectively. For each binary mixture the composition dependence of V^E and Δη versus mole fraction x_1 can be expressed by using the Redlich-Kister [**29**] polynomial equation.

$$Y = x_1x_2 \sum_{i=0}^{m} Ai(x_1 - x_2)^i \quad \ldots(3)$$

Where Y is the concerned property (V^E or Δη) and 'm' is the number of estimated parameters . The polynomial coefficients Ai were obtained by fitting the equation to the experimental results with the least squares regression method. The standard deviation σ are defined as

$$\sigma(Y) = [\ \sum(Yexpt - Ycal)^2/(n - m)\ ]^{1/2} \quad \ldots(4)$$

Where, n and m represent the number of experimental data points and that of estimated parameters respectively used in Eq 4. The value of coefficient Ai of Eq.3 and the corresponding standard deviation σ obtained by Eq.4 are given in table 2.

The values of excess volumes V^E for the studied binary mixtures (Table 1) at (303.15, 308.15, and 313.15) K are graphically represented as a function of mole fraction of butyl acetate in figure 1.

It is observed that V^E values are positive for all the studied systems over the whole composition range. The positive values of V^E indicate weak interaction between the components of the mixture. Several factors affecting the magnitude of V^E include chemical, physical and structural effects [**30**].

Table 2. Coefficients of Eq. (3) for various functions and corresponding standard deviations (σ) of the binary mixtures at 303.15,308.15, and 313.15K.

Binary mixture	T/K	Excess property	A_o	A_1	A_2	σ
Butyl acetate + Heptane	303.15	V^E	2.2740	-0.1419	0.3879	0.004
		$\Delta\eta$	-0.3438	-0.1572	0.0100	0.001
	308.15	V^E	2.6300	-0.8514	1.0904	0.008
		$\Delta\eta$	-0.3620	-0.1335	-0.0153	0.001
	313.15	V^E	2.97719	-1.6696	1.7657	0.016
		$\Delta\eta$	-0.4070	-0.1365	-0.0710	0.001
Butyl acetate + Decane	303.15	V^E	3.4436	-0.5081	-0.6536	0.013
		$\Delta\eta$	-0.1465	0.0322	0.0915	0.001
	308.15	V^E	3.5859	-0.4866	-0.4220	0.009
		$\Delta\eta$	-0.1548	0.0374	0.0740	0.001
	313.15	V^E	3.7454	-0.3700	-0.4000	0.016
		$\Delta\eta$	-0.1656	0.0333	0.0388	0.001
Buyl acetate + Dodecane	303.15	V^E	3.9735	0.4746	-0.0877	0.016
		$\Delta\eta$	-0.2666	0.1526	-0.1919	0.003
	308.15	V^E	4.0680	0.4891	0.1142	0.018
		$\Delta\eta$	-0.2226	0.1359	-0.1727	0.003
	313.15	V^E	4.2009	0.2101	0.6221	0.013
		$\Delta\eta$	-0.1343	0.1000	-0.1536	0.003
Butyl acetate + Tridecane	303.15	V^E	3.8506	0.4991	0.2646	0.015
		$\Delta\eta$	-0.2886	0.0097	-0.0040	0.001
	308.15	V^E	4.0043	0.4889	0.3097	0.016
		$\Delta\eta$	-0.1854	-0.0159	-0.0945	0.001
	313.15	V^E	4.0903	0.2501	0.6113	0.011
		$\Delta\eta$	-0.1302	0.0479	0.0762	0.001

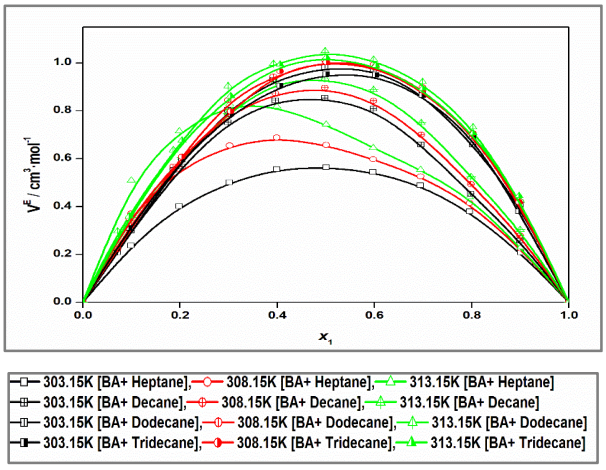


Figure 1. Excess volumes Vs mole fraction (x_1) of butyl acetate.]

The physical effects involve comparatively weak interactions consisting of mainly dispersion forces or weak dipole-dipole interactions developed due to structure breakage of either both or any one of the mixture components resulting in to volume expansion leading to positive contribution and thus repulsive interaction of mixing solvents than the interaction of pure solvents. The magnitude of V^E values (Figure 1) at equimolar composition follows the order

Dodecane > Tridecane >Decane> Heptane

The variation of Δη with x_1 of butyl acetate for the studied binary systems at (303.15, 308.15 and 313.15) K along with the smoothed values by using eq.3 are graphically presented in figure 2. It is

observed that the values of Δη exhibit negative deviation for all the studied systems over the entire composition range at all the investigated temperatures. These negative Δη values may be attributed to the dispersion or weak dipole-dipole forces between the component molecules. Butyl acetate having a

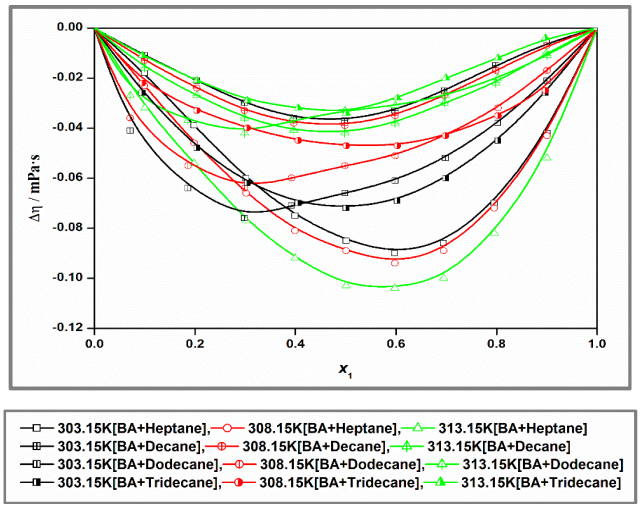


Figure 2. Deviation in viscosity Vs mole fraction (x_1) of butyl acetate.

large dipole moment (u=1.87) on mixing with the non-polar alkanes would induce a small dipole moment in the alkane molecules leading to weak dipole-induced dipole interaction between the component molecules. Fort and Moore [**31**] observed that Δη values may exhibit negative deviation due to difference in molecular size, and molar volumes of the component molecules. In the present study, molar volume of the components butyl acetate (133.36) $cm^3 \cdot mol^{-1}$, heptane (148.39) $cm^3 \cdot mol^{-1}$, decane (196.87) $cm^3 \cdot mol^{-1}$, dodecane (229.69) $cm^3 \cdot mol^{-1}$ and tridecane (246.12) $cm^3 \cdot mol^{-1}$ at 303.15 K differ considerably.

In all the systems investigated it is worthwhile to note that there is a significant effect of temperature on both V^E and Δη. The V^E values are found to increase systematically with increase in temperature while in Δη the values for systems heptane and decane become more negative with increase in temperature and for systems dodecane and tridecane the Δη values becomes less negative with increase in temperature. Further it is interesting to note that V^E and Δη have maxima/minima in the mole fraction range x_1=0.5 - 0.6 (Figure 1 and 2) except for dodecane the minima for Δη is at x_1=x_2= 0.3. These maxima/minima points are clear indication of highest point of interactions between the component molecules in the binary mixtures.

APPLICATION

Several empirical and semi-empirical relations have been used to represent the dependence of viscosity concentration of components in binary liquid mixtures. A number of researchers have proposed a number of equations for the calculation of the viscosity of mixtures. In our present study we selected some of these semi-empirical models to carry out a comparative study for correlating the experimental viscosity data at investigated temperatures. Frenkel [**26**] proposed the one parameter equation of the form.

$$\ln\eta = x_1^2 \ln\eta_1 + x_2^2 \ln\eta_2 + 2x_1x_2 \ln\eta_{12} \quad \ldots (5)$$

In above relation η is the viscosity of the mixture, x_1, x_2 are mole fraction and η_1, η_2 are the viscosities of pure components 1 and 2 respectively, and η_{12} is the interaction parameter. Eyring-Van-Laar [**27**] gave the following two parameter equation

$$\ln \eta V = x_1 \ln(\eta_1 V_1) + x_2 \ln(\eta_2 V_2) + [A_{21} x_1 x_2 / x_1 + A_{12} x_2] \quad \ldots(6)$$

Where, V is the molar volume, η_1 and η_2 are the viscosities of pure components 1 and 2 respectively and A_{21} and A_{12} are interaction parameter for the relation. Krishnan-Laddha [**28**] developed the following three parameter model for correlating kinematic viscosity of binary liquid mixtures.

$$\ln \nu = x_1 \ln \nu_1 + x_2 \ln \nu_2 + x_1 \ln M_1 + x_2 \ln M_2 - \ln [x_1 M_1 + x_2 M_2] - 2.303\, x_1 x_2 [B_{12} + C_{12} (x_1 - x_2) + D_{12}(x_1 - x_2)^2] \quad \ldots(7)$$

Where ν is the kinematic viscosity of the mixture and B_{12}, C_{12} and D_{12} are the interaction parameters. The predicted values of viscosities of binary mixtures using eq (5-7) were compared with experimentally measured values (Table 1). Further the validity of above relation has been checked by evaluating the standard percentage deviation (σ %) using the relation

$$\sigma\,(\%) = (1/n-k\sum\{100(n_{exp}-n_{cal})/n_{exp}\}^2]^{1/2} \quad \ldots(8)$$

The interaction parameter of Eq. (5-7) along with (σ %) values by Eq.8 are presented in table 3.

Table 3. Adjustable parameters and percentage standard deviations (σ%) of several correlations for the viscosities of binary mixtures.

Binary Mixture	T/K	Frenkel		Eyring-Vanlaar			Krishnan Laddha			
		η_{12}	σ%	A_{21}	A_{12}	σ%	B_{12}	C_{12}	D_{12}	σ%
Butyl acetate+ Heptane	303.15	-1.0242	0.152	-2.5862	3.5942	0.134	0.2611	0.0812	-0.0613	0.022
	308.15	-1.1633	0.168	-2.5196	3.0047	0.095	0.3052	0.0521	-0.0383	0.023
	313.15	-1.2940	0.217	-2.6951	2.6783	0.086	0.3826	0.0493	-0.0034	0.036
Butyl acetate+ Decane	303.15	-0.8468	0.080	-2.8409	10.7406	0.053	0.0389	-0.0172	0.0389	0.008
	308.15	-0.5391	0.090	-2.7372	9.2268	0.051	0.0561	-0.0207	-0.0550	0.009
	313.15	-0.5974	0.053	-2.5424	12.4543	0.035	0.0769	-0.0159	-0.0114	0.015
Butyl acetate+ Dodecane	303.15	-0.4539	0.543	-4.2828	21.1998	0.048	-0.0447	-0.0152	-0.0031	0.001
	308.15	-0.1050	0.222	-4.3792	21.1996	0.055	-0.0462	-0.0153	-0.0037	0.001
	313.15	-0.3227	0.379	-3.7591	21.1999	0.141	-0.0879	-0.0146	-0.0048	0.001
Butyl acetate+ Tridecane	303.15	-0.0398	0.808	-2.7922	21.1997	0.208	-0.1395	-0.0200	-0.0056	0.006
	308.15	-0.0772	0.650	-3.0422	21.1997	0.250	-0.1431	-0.0069	0.0432	0.017
	313.15	-0.1416	0.708	-2.7545	21.1998	0.180	-0.1407	-0.0541	-0.0567	0.013

A careful persual of table 3 revels that maximum deviation (σ %) are obtained using Frenkel and Eyring-Vanlaar relation; while the Krishnan-Laddha relation gave very low (σ %) values. On the basis of analysis of (σ %) values (Table 3) and the comparison of viscosities (Table 1) it is clear that the Krishnan-Laddha relation with three interaction parameter predicted the mixture viscosities more satisfactorily as compared to other investigated relations.

CONCLUSION

The Densities and viscosities for binary mixtures of butyl acetate with heptane, decane, dodecane and tridecane at (303.15, 308.15 and 313.15) K have been measured and the values of V^E and $\Delta\eta$ were calculated. The V^E values were found positive for all the mixtures while, the $\Delta\eta$ values are negative. The molecular interactions between the components of butyl acetate and n-alkanes appear to be weak dipole-dipole forces. It is also observed that there is a significant effect of temperature on both the studied properties of V^E and $\Delta\eta$. Further Frenkel, Eyring-vanlaar and Krishnan-laddhasemi-empirical relations have been employed to estimate the viscosities of studied binary mixtures and compared with experimental viscosities. Analysis of the standard percentage deviation (σ%) values showed that Krishnan-Laddha relation with three interaction parameters has predicted the viscosities most satisfactorily for all studied binary systems at all the investigated temperatures.

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