Research Article

The study of thermo physical properties of binary liquid mixtures of 2-(2-methoxy ethoxy) ethanol(methyl carbitol) with n-butyl amine, sec-butyl amine, tert-butyl amine, n-hexyl amine, n-octyl amine and cyclo hexyl amine at 308.15 K

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ABSTRACT

Densities and viscosities of binary liquid mixtures of 2–(2-Methoxy ethoxy) ethanol[Methyl carbitol(MC)]with n-butyl amine(NBA),sec-butyl amine(SBA).ter-butylamine(TBA),n-hexylamine (NHA), n-octylamime (NOA) and cyclohexylamine (CHA) have been measured at 308.15 K. From the experimental data the excess volume (V^E), excess viscosity(η^E)and the excess molar Gibbs free energy of the activation of viscous flow (G^{*E}) have been computed and presented as function of composition. The interaction parameter d^l of the Grunberg and Nissan has been calculated. The observed variations of the properties for the above mixtures conclude that the interactions between unlike molecules predominate over the dissociation effects in the individual components. It is also evident that the presence of strong interactions between unlike molecules is predominant and characterized by the negative V^E and positive(η^E), (G^{*E}) and d^l values. The excess volume, excess Viscosity and excess molar Gibb's free energy of the activation of viscous flow have been fitted to Redlich–Kister equation to derive the coefficients and standard deviations.

Key words: Binary liquid mixtures, Methyl carbitol, Amines, excess volume, Redlich-kister equation, molecular interactions.

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INTRODUCTION

The formation of hydrogen bond in solutions and its effect on the physical properties of the mixtures have received much attention. Hydrogen bonding plays an important role in fundamental sciences and in industrial applications. Although many experimental and theoretical studies have been directed towards understanding of hydrogen bonding, it remains an area of active research. Knowledge of physico – chemical properties of liquid mixtures formed by two or more components associated through hydrogen bonds is important from theoretical and process design aspects.

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Properties such as densities, viscosities and the excess properties and their variation with composition of the binary mixtures are useful to design engineering processes and in chemical and biological industries. The investigation on the possible changes in these properties of mixtures has been found to be an excellent qualitative and quantitative way to elicit the information about molecular structure and intermolecular forces present in the liquid mixtures.

In continuation of on our ongoing programme of studies on binary liquid mixtures [1-5],we present here some new experimental data on the density (ρ) and viscosity (η) for the binary liquid mixture systems of 2- (2-Methoxy ethoxy)ethanol (MC) with different amines [n-butyl amine (NBA), sec-butyl amine(SBA). ter-butylamine (TBA), n-hexylamine (NHA), n-octylamine(NOA) and cyclohexylamine(CHA)] at 308.15K.

These systems are particularly chosen in view of their importance in chemical engineering design and polymer processing industries. Moreover; such data for these systems are not available in the literature.

In the present study, 2- (2-Methoxy ethoxy) ethanol (MC) is chosen because it finds a wide range of applications, namely, as a solvent, a solublizing agent in many industries [6]and has unique solvating properties associated with its quasi-aprotic character [7]. MC, ether alcohol, shows physico-chemical characteristics midway between protic and aprotic dipolar solvents. It is a quite-toxic solvent, a weak narcotic and systemic poison [8] and must be handled with care. 2- (2-Methoxy ethoxy) ethanol (MC) is amphiprotic, a potentially acidic medium with a low autoprotolysis constant (Pk$_{autoprot}$ = 20.5 at 20°C)[9]and low dielectric constant (€= 16.94 at 25°C). It is therefore, hardly a dissociating solvent [10-14] either for ionogenorinophore solutes. Because of its dipolar character (μ = 2.3 D)[15]2- (2-Methoxy ethoxy) ethanol (MC) shows a tendency to Polymerize and form a hydrogen-bonded network.

The molecular interaction studiesof2- (2-Methoxy ethoxy) ethanol (MC) are of interest because of investigating the effect of simultaneous presence of etherial and alcoholic oxygen atoms in the same molecule. The presence of etheric oxygen enhances the ability of the –OH group of the same molecule to form hydrogen bonds with other organic molecules [16-19].

On the other handthe other components chosen are amines. It is popularly believed that alcohols and amines in dilute aqueous solutions behave as soluble hydrocarbons and it has been said that the functional group provides only a minor contribution to the measured thermodynamic properties [20-21]. But chemical intuition tells that -OH group and -NH$_2$ group would behave differently especially in a hydrogen bonded solvent like water and will have different and appreciable contributions to the measuring properties.

Like ammonia, amines are polar compounds and can form intermolecular hydrogen bonds except for tertiary amines. Primary and secondary amines are hydrogen bond donors and all other amines are hydrogen bond acceptors.
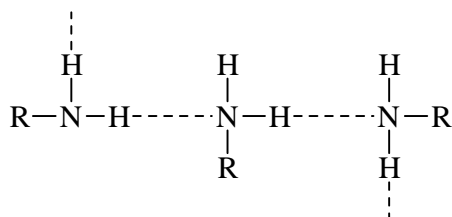
Amines have higher boiling points than nonpolar compounds of the same molecular weight, but lower boiling points than alcohols and carboxylic acids. This is because the polarity of N-H bond in amines is less than that of O-H bond in alcohols and carboxylic acids. Amines of all the 3 classes are capable of forming hydrogen bonds with water. As a result smaller aminesare quite soluble in water with border line solubility being reached at about six carbons atoms. Amines are soluble in less polar solvents like ether, alcohol, benzene etc. Amines exhibit self-association [22-24] through hydrogen bonding in pure state. Amines in general are better electron donors and the existence of specific interactions between some amines and electron acceptors is well documented. Huyskens [25]and Kehiaian *et al*.[26] explained the weak self-association of primary and secondary amines on the basis of Hydrogen bond formation.

According to Letcher and Bayles [27] and Letcher [28] amines interact more strongly with a Component containing electron withdrawing groups than with other molecules and these Interactions fall off as the alkyl chain length in the amines increase.

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The above said amines chosen fall into three categories –

1. Normal amines :   n-butyl amine (NBA), n-hexylamine (NHA) and n-octylamine (NOA).
2. Branched amines: sec-butyl amine (SBA) and tert-butylamine (TBA).
3. Cyclic amines   :   cyclohexylamine (CHA)

which are known as industrially important liquids of special interest in the recent years. In chemical industry there exists a continuing need for reliable thermodynamic data of binary systems. A survey of the literature shows that very few attempts [29-31] have been made to study excess properties for mixtures containing alkoxy alcohols (carbitols). Amines and alkoxy alcohols[32-33] in their pure state exhibit self-association through hydrogen bonding. Amines are proton acceptors, which allow them to have specific interactions. Further, amines form water insoluble compounds of medicinal importance. The molecular interaction study of alkoxy alcohols (carbitols) is of interest because of investigating the effect of simultaneous presence   of ether and alcoholic functional groups in the same molecule. The presence of ethereal oxygen enhances the ability of the –OH group of the same molecule to form hydrogen bonds with other organic molecules [34-36].These   characteristics of amines and alkoxy alcohols (carbitols) make them interesting for our study and the results are presented here.

EXPERIMENTAL SECTION

2-(2-Methoxyethoxy) ethanol (Methyl carbitol) (MC), n-butyl amine (NBA), sec-butyl amine (SBA), ter-butylamine (TBA), n-hexylamine (NHA).n-octylamine (NOA), andcyclohexylamine(CHA) were purchased from Merck, Mumbai, India and used as purchased. Mixtures were prepared by mixing weighed amounts of the pure liquids adopting the method of closed system. The weightings' were done by using Mettler balance with the precision of ± 0.1mg. The uncertainty in the mole fraction was estimated to be less than ± 1×10^{-4}.Mixtures were allowed to stand for some time before every measurement so as to avoid air bubbles.

The densities of pure liquids and their binary mixtures were measured by using a single-capillary pycnometer (made of Borosil glass) having a bulb capacity of ≈ 10 mL. The capillary, with graduated marks, had a uniform bore and could be closed by a well-fitting glass cap. The marks on the capillary were calibrated by using triple distilled water. The uncertainty in density measurements was within ± 2×10^{-5}kg m^{-3}.

Viscosity measurements were carried out with a precision of ± 0.2% using calibrated Schott-Gerate AVS 400 viscometer (U.S.A), whose flow time for doubly distilled water was found to be 375 seconds at 25^0C. The temperature of the test liquids during the measurements was maintained within an uncertainty of± 0.01 K in an electronically controlled thermostatic water bath.

The measurements were made with proper care in an AC room to avoid evaporation loss. The purities of the liquids were checked by comparing the values of densities and viscosities with literature data (Table 1) and are found in good agreement in general.

Table 1: Comparison of experimental density and viscosity of pure liquids with literature values at 308.15 K

Liquid	$\rho \times 10^{-3}$ Kg m^{-3}		$\eta \times 10^{3}$ Kg m^{-1} s^{-1}	
	Exptl.	Lit.	Exptl.	Lit.
2-(2-Methoxyethoxy)ethanol	1.0073	1.0154 [a]	0.2546	0.2547[b]
n-Butyl amine	0.7241	0.7239[b]	0.4248	0.4249 [b]
Sec.butyl amine	0.7084	0.7083 [b]	0.3994	0.3996 [b]
Tertiary butyl amine	0.6809	0.6812 [b]	0.4122	0.4126[b]
n-Hexyl amine	0.7522	0.7522 [b]	0.6001	0.6000 [b]
n-Octyl amine	0.7704	0.7702 [b]	0.9263	0.9267 [b]
Cyclo hexyl amine	0.8525	0.8527 [b]	1.3245	1.3249 [b]

a fromreference 50
b fromreference 51

RESULTS AND DISCUSSION

The experimental results of the measurement of densities (ρ) and Viscosities(η) of binary liquid mixtures are presented in Table 2. The molar volume (V), excess volume(V^E),excess viscosity(η^E),excess Gibbs free energy of

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activation of viscous flow (G^{*E}), and Grunberg–Nissan interaction parameter (d^1)were calculated from the measured data using the following equations 1to5 respectively.

$$V = (X_1 M_1 + X_2 M_2) / \rho \tag{1}$$

$$V^E = V - (X_1 V_1 + X_2 V_2) \tag{2}$$

$$\eta^E = \eta - (X_1 \eta_1 + X_2 \eta_2) \tag{3}$$

$$G^{*E} = RT[\ln\eta\ V - (X_1 \ln\eta_1 V_1 + X_2 \ln\eta_2 V_2)] \tag{4}$$

$$d^1 = \ln\eta /[X_1 \ln\eta_1 + X_2 \ln\eta_2 + X_1 X_2] \tag{5}$$

where ρ, η and V are the density, viscosity and molar volume of the mixture, M_1 and M_2 are the molar masses,η_1 and η_2 are the viscosities V_1 and V_2 are the molar volumes of the 2-(2-Methoxyethoxy) ethanol(MC)and amines respectively,d^1 is a constant[37-38]and $X_1$and X_2 are the mole fraction of 2-(2-Methoxy ethoxy)ethanol (MC)and corresponding amines respectively. The above calculated values are included in Table -2.

The dependence of η^E, V^E and G^{*E} on the mole fraction of2-(2-Methoxy ethoxy) ethanol (MC)(X_{MC})for all the six systems were fitted to the following Redlich-Kister equation by the least-squares method and the values are given in Table 3.

$$Y^E = x(1-x) \sum_{i=1}^{4} A_i (2x-1)^I \tag{6}$$

where Y^E is η^E, V^E and G^{*E} parameters.

The parameters A_i, obtained by a non-linear least squares polynomial fitting procedure, are also given in Table-3,together with the standard deviation(σ) values.

The variation of the parameters η, V^E, η^E and G^{*E} with mole fraction of 2-(2-Methoxy ethoxy) ethanol (X_{MC}) for the systems under study are shown graphically in Figs 1 to 4 respectively.

From Table 1and Fig-1 it is observed that the viscosity of binary liquid mixtures under study varied non-linearly with the mole fraction of 2-(2-Methoxyethoxy) ethanol (X_{MC}). This suggests the presence of intermolecular interactions between unlike molecules of these mixtures. A similar observation was made by NarayanaSwamyet.al [1] from the viscosity studies of binary liquid mixtures.

It is clear from the Fig.-2that the negative V^E values are obtained over the entire composition range for all these systems except MC+NOA and MC+CHA which indicates the presence of strong molecular interactions between the unlike components of the mixtures. It is also observed from Fig. 2 and Table - 2 that the V^E values fall in the sequence.

MC + NOA>MC + CHA>MC + TBA>MC + NBA >MC +NHA>MC + SBA.

From Fig. 2, it is further observed that the negative/ Positive V^EVsX_{MC} plots were found to be large and symmetrical showing a maximum between 0.5 to 0.8 mole fractions of MC (X_{MC})

According to Subhaet al., [2]several effects may contribute to the sign and values of V^E and the following three effects may be considered as being important.

1. Break up of hydrogen bonds and dipolar interactions in MC and intermolecular Interactions in amines.
2. The possible intermolecular interactions like hydrogen bonding or electron donor-acceptor interactions between unlike molecules.

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3.Interstitial accommodation of one component molecules into the other unlike component molecules due to their differences in size and shape.

The overall signs of these excess functions depend on the combined effects of these three effects. From the Fig. 2 it is noticed that in the case of MC +NOA and MC + CHA positive V^E values are observed. An interpretation to this behavior can be given using the experience made with the quantitative evaluation of alcohol + amine mixtures by the ERAS model proposed by the earlier workers [39 -43].The first effect leads to positive excess volume and the latter two effects leads to negative excess volume. The actual volume change woulddependupon therelativestrengths ofthesethreeeffects.In the present study the observed negative values of V^Eshow that the main contributionto $V^E$is due to hydrogen bond formation between hydroxyl &ethereal groups of MC and amino groups of amines and the difference in size of the unlike molecules.Moreover,the negative values of V^E may also be partly due to the specific acid-base interactions between M C and amine molecules by considering M C as Lewis acid and amines as Lewis bases.

Very recently NamTram [44] emphasized the importance of acid-base interactions between tert butyl amine,N-N dimethyl formamide / N, N -dimethyl acetamide in order to evaluate the interaction energy of alcohol-amine systems. From the examination of the results in Table - 1 and Fig. 2, it its o b s e r v e d that the magnitude values of V^E fall in the sequence:

MC +NOA >MC + CHA >MC+TBA >MC + NBA >MC + NHA >MC + SBA.
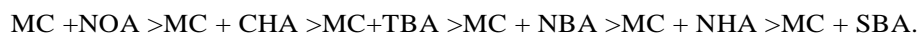
From the Fig -2 , it is also observed that the negative excess volumes of normal amines with MC increase with increase in chain length of amines, this can be explained by considering amines as proton acceptors and MC as proton donor. As the chain length of normal amines increases proton accepting ability of these amines increase and electron density will be more and more on nitrogen atom of NH_2 group due to inductive effect. So, as the chain length of the amines increase, the interaction ability (hydrogen bonding ability) of amines increase with increase in MC component. In the case of branched amines, negative V^E values increase with increase in branching. This is very clear that as the amines become more and more branched, the proton accepting ability increases due to the increase in $-CH_3$ groups on the carbon atom attached to amine group. However, the slight positive V^E values are observed at higher MC mole fraction in case of NOA&CHA indicating lesser specific interactions at these mole fractions. A similar observation was made by Haraschita.et.al. [45] from the V^E studies of γ- Picoline + sec-butanol and + tert-butanol.

In the case of cyclohexylamine, V^E values are less positive than the corresponding normal hexyl amine, which may be due to steric and other effects because of cyclic nature of cyclohexylamine.

From Figure -3, it is noticed that of η^E values are positive over the whole composition range for all the systems under study. A correlation between the signs of η^E and V^E has been observed for a number of binary systems [45-46] where η^E being Positive and V^E is negative and vice-versa. In general, for systems where dispersion and dipolar interactions are operating η^E values are found to be negative whereas charge transfer and hydrogen bonding interactions lead to the formation of complex species between unlike molecules thereby resulting in positive ηE values. The positive values of ηE for the mixtures of MC + amines fall in the order.

MC+NBA >MC +SBA >MC + TBA > MC + CHA > MC + NHA>MC>NOA
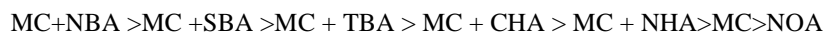
It can be predicted that in view of the strong proton donating ability of MC and strong proton accepting ability of amines, the overall negative V^E values and overall positive η^E values in all these systems may be regarded as an evidence for the formation of two sets of hydrogen bonds between MC and amines. Among them the first set of hydrogen bond formation is between N atom of amino group of amine and H atom of – OH group of 2-(2-Methoxy ethoxy) ethanol

H
|
R –N------- HO⁻C₂H₄⁻O⁻C₂H₄⁻O⁻CH₃
|
H

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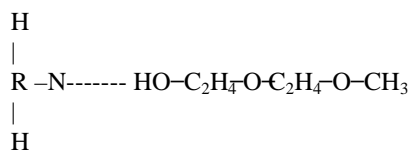
(MC) and second set of hydrogen bond formation is between H atom of amino group of amines and oxygen atom of etheric group of 2-(2-Methoxy ethoxy) ethanol (MC).Among the two the first set of hydrogen bond formation predominates.

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    H -------O─CH₃
    |        |
R –N       C₂H₄─O─C₂H₄─OH
    |
    H
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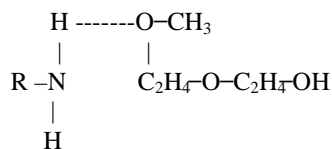
From the table 1&Fig-4, it is also observed that the values of G^{*E} are found to be positive which is an indication of the presence of strong specific interactions between the unlike molecules and are in the following order

MC+ SBA >MC +NBA >MC + TBA >MC + NOA >MC +CHA >MC + NHA

Fort and Moore [47]and Ramana Moorthy[48]reported that for any binary liquid mixture, the positive value of d^1 indicates the presence of strong interactions and the negative value of d^1 indicates the presence of weak interactions between the components On this basis the d^1values in the present study for all the systems confirm the presence of strong interactions between the component molecules. A similar observation was made by Subha et.al.[3]from the d^1 values of the binary liquid mixtures of propionic acid with alcohols.

Table:2:Values of Density (ρ), Viscosity (η), Excess viscosity (η^E), Molar volume (V), Excess molar volume (V^E), Excess Gibbs free energy of activation of viscous flow (G^{*E}) and Grunberg-Nissan interaction parameter (d^1) for the binary liquid mixtures of Methyl carbitol (MC) + Amines at 308.15 K						
Mole fraction of Methyl carbitol (X_{MC})	ρ x 10⁻³ Kg m⁻³	η x 10³ Kg m⁻¹ s⁻¹	η^E x 10³ Kg m⁻¹ s⁻¹	V^E x10⁵ m³ mol⁻¹	G^{*E} x 10³ N mol⁻¹	d^1
Methyl carbitol (MC) + N-Butyl amine (NBA)						
0.0000	0.7241	0.4248	0.0000	0.0000	0.0000	---
0.0754	0.7524	0.6270	0.0422	0.0046	153.5778	3.6482
0.1551	0.7807	0.8392	0.0853	0.0082	243.1822	3.0762
0.2393	0.8090	1.0514	0.1188	0.0106	287.9341	2.6245
0.3286	0.8373	1.2636	0.1415	0.0174	302.1603	2.2739
0.4233	0.8656	1.4758	0.1527	0.0204	293.3867	1.9961
0.5241	0.8939	1.6881	0.1511	0.0220	265.5892	1.7687
0.6314	0.9222	1.9002	0.1355	0.0145	221.1652	1.5783
0.7460	0.9505	2.1124	0.1045	0.0079	161.3846	1.4139
0.8685	0.9788	2.3246	0.0568	0.0044	86.9413	1.2627
1.0000	1.0073	2.5469	0.0000	0.0000	0.0000	---
Methyl carbitol (MC) + Sec-Butyl amine (SBA)						
0.0000	0.7084	0.3994	0	0	0	---
0.0877	0.7383	0.6142	0.0265	0.0016	164.5909	3.3487
0.1778	0.7682	0.8290	0.0478	0.0045	246.4497	2.7425
0.2705	0.7981	1.0438	0.0635	0.0048	282.7056	2.3291
0.3658	0.8280	1.2586	0.0736	0.0058	289.3862	2.0267
0.4639	0.8579	1.4734	0.0778	0.0065	274.6760	1.7933
0.5648	0.8878	1.6882	0.0759	0.0079	243.4884	1.6076
0.6688	0.9177	1.9030	0.0674	0.0069	198.6715	1.4547
0.7758	0.9476	2.1178	0.0524	0.0040	142.4288	1.3276
0.8862	0.9775	2.3326	0.0301	0.0020	75.8645	1.2193
1.0000	1.0073	2.5469	0	0	0	---
Methyl carbitol (MC) + Tert-Butyl amine (TBA)						
0.0000	0.6809	0.4122	0	0	0	---
0.0909	0.7135	0.6257	0.0195	0.0005	154.5473	3.0479
0.1837	0.7461	0.8392	0.0349	0.0001	231.1164	2.5106
0.2784	0.7787	1.0527	0.0462	0.0018	264.5185	2.1438
0.3751	0.8113	1.2662	0.0533	0.0025	269.9079	1.8739
0.4737	0.8439	1.4797	0.0563	0.0028	255.4136	1.6666
0.5745	0.8765	1.6932	0.0546	0.0031	225.5368	1.5001
0.6775	0.9091	1.9067	0.0482	0.0037	183.3255	1.3633
0.7826	0.9417	2.1202	0.0374	0.0038	130.9417	1.2495
0.8901	0.9743	2.3337	0.0214	0.0035	69.5801	1.1525
1.0000	1.0073	2.5469	0	0	0	---

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Methyl carbitol (MC) + N-Hexyl amine (NHA)						
0.0000	0.7522	0.6001	0	0	0	---
0.1113	0.7777	0.7948	-0.0220	-0.0010	73.9875	1.2145
0.2199	0.8032	0.9895	-0.0387	-0.0011	112.3684	1.0625
0.3258	0.8287	1.1842	-0.0502	-0.0042	128.8472	0.9506
0.4291	0.8542	1.3789	-0.0566	-0.0050	130.7410	0.8642
0.5299	0.8797	1.5736	-0.0581	-0.0060	122.4173	0.7951
0.6284	0.9052	1.7683	-0.0552	-0.0085	106.6088	0.7380
0.7246	0.9307	1.9630	-0.0478	-0.0069	85.2828	0.6901
0.8185	0.9562	2.1577	-0.0359	-0.0045	59.8448	0.6499
0.9103	0.9817	2.3524	-0.0199	-0.0027	31.1908	0.6152
1.0000	1.0073	2.5469	0	0	0	---
Methyl carbitol (MC) + N-Octyl amine (NOA)						
0.0000	0.7704	0.9263	0	0	0	---
0.1351	0.7941	1.0884	-0.0568	-0.0011	18.8911	0.2107
0.2600	0.8178	1.2505	-0.0972	-0.0043	29.1702	0.1930
0.3759	0.8415	1.4126	-0.1229	-0.0061	33.6304	0.1782
0.4837	0.8652	1.5747	-0.1355	-0.0082	34.1029	0.1658
0.5843	0.8888	1.7368	-0.1364	-0.0093	31.8219	0.1549
0.6783	0.9126	1.8989	-0.1267	-0.0096	27.4558	0.1456
0.7663	0.9363	2.0610	-0.1072	-0.0109	21.8000	0.1379
0.8490	0.9600	2.2231	-0.0791	-0.0081	15.1293	0.1307
0.9267	0.9837	2.3852	-0.0429	-0.0047	7.8273	0.1258
1.0000	1.0073	2.5469	0	0	0	---
Methyl carbitol (MC) + Cyclohexyl amine (CHA)						
0.0000	0.8525	1.3245	0	0	0	---
0.0977	0.8680	1.4467	0.0028	-0.0034	14.9256	0.2765
0.1960	0.8835	1.5689	0.0048	-0.0044	25.2339	0.2614
0.2947	0.8990	1.6911	0.0064	-0.0074	31.6409	0.2486
0.3939	0.9145	1.8133	0.0073	-0.0104	34.6377	0.2370
0.4936	0.9300	1.9355	0.0076	-0.0133	34.6424	0.2265
0.5939	0.9455	2.0577	0.0072	-0.0145	31.9662	0.2166
0.6946	0.9610	2.1799	0.0063	-0.0177	26.9511	0.2079
0.7959	0.9765	2.3021	0.0047	-0.0193	19.7725	0.1995
0.8977	0.9920	2.4243	0.0025	-0.0173	10.6596	0.1912
1.0000	1.0073	2.5469	0	0	0	---

Table 3: The Co-efficient of a_i of the Redlich-Kister type polynomial equation (6) and the corresponding standard deviations $\sigma(Y^E)$ for the binary liquid mixtures of MC+Amines at 308.15K.

| Excess Property	A_0	A_1	A_2	A_3	A_4	σ
Methyl carbitol (MC)+ N- Butyl amine (NBA)						
η^E x 10^3 (Kg m^{-1} s^{-1})	-0.00102	0.64896	-0.57047	-0.36031	0.28281	0.0013
V^E x 10^6 (m^3 mol^{-1})	-0.00294	-6.91548	11.83324	-6.55798	1.64487	0.00392
G^{*E} x 10^3 (N mol^{-1})	-0.000301	2618.1684	-8634.34	11927.24621	9798.74683	0.04256
Methyl carbitol (MC)+ Sec-Butyl amine (SBA)						
η^E x 10^3 (Kg m^{-1} s^{-1})	-0.000018	0.33725	-0.39904	0.08154	-0.01971	0.000054
V^E x 10^6 (m^3 mol^{-1})	0.000707	-0.06148	0.26214	-0.4612	0.25915	0.00149
G^{*E} x 10^3 (N mol^{-1})	-0.000047	2643.17802	-11215.3680	34833.76	-87963.08	0.01211
Methyl carbitol (MC)+ Tert-Butyl amine (TBA)						
η^E x 10^3 (Kg m^{-1} s^{-1})	0.000007	0.2349	-0.27198	0.04537	-0.01186	0.00009
V^E x 10^6 (m^3 mol^{-1})	-0.00237	0.16859	-0.64978	1.23175	-0.74501	0.00524
G^{*E} x 10^3 (N mol^{-1})	0.0001374	2392.2543	-9786.2227	29700.09452	-75174.1899	0.03817
Methyl carbitol (MC)+ N-Hexyl amine (NHA)						
η^E x 10^3 (Kg m^{-1} s^{-1})	0.000013	-0.22028	0.19661	0.02041	0.00327	0.00007
V^E x 10^6 (m^3 mol^{-1})	-0.00092	0.05871	-0.24412	0.43913	-0.25149	0.00194
G^{*E} x 10^3 (N mol^{-1})	0.0000084	883.7606	-2372.5638	4449.2148	-8737.6206	0.01945
Methyl carbitol (MC)+ N-Octyl amine (NOA)						
η^E x 10^3 (Kg m^{-1} s^{-1})	-0.0000006	-0.46795	0.34018	0.07184	0.056	0.00008
V^E x 10^6 (m^3 mol^{-1})	0.00155	-0.10482	0.5089	-0.84415	0.43604	0.00637
G^{*E} x 10^3 (N mol^{-1})	0.000016	173.0691	-259.4579	121.2605	-317.9294	0.04846
Methyl carbitol (MC)+ Cyclohexyl amine (CHA)						
η^E x 10^3 (Kg m^{-1} s^{-1})	0.000028	0.0303	-0.02738	-0.00902	0.00605	0.000057
V^E x 10^6 (m^3 mol^{-1})	0.0007048	-0.07531	0.32318	-0.64254	0.39215	0.00269
G^{*E} x 10^3 (N mol^{-1})	0.0000254	179.99809	-296.72935	176.42425	179.6763	0.01094

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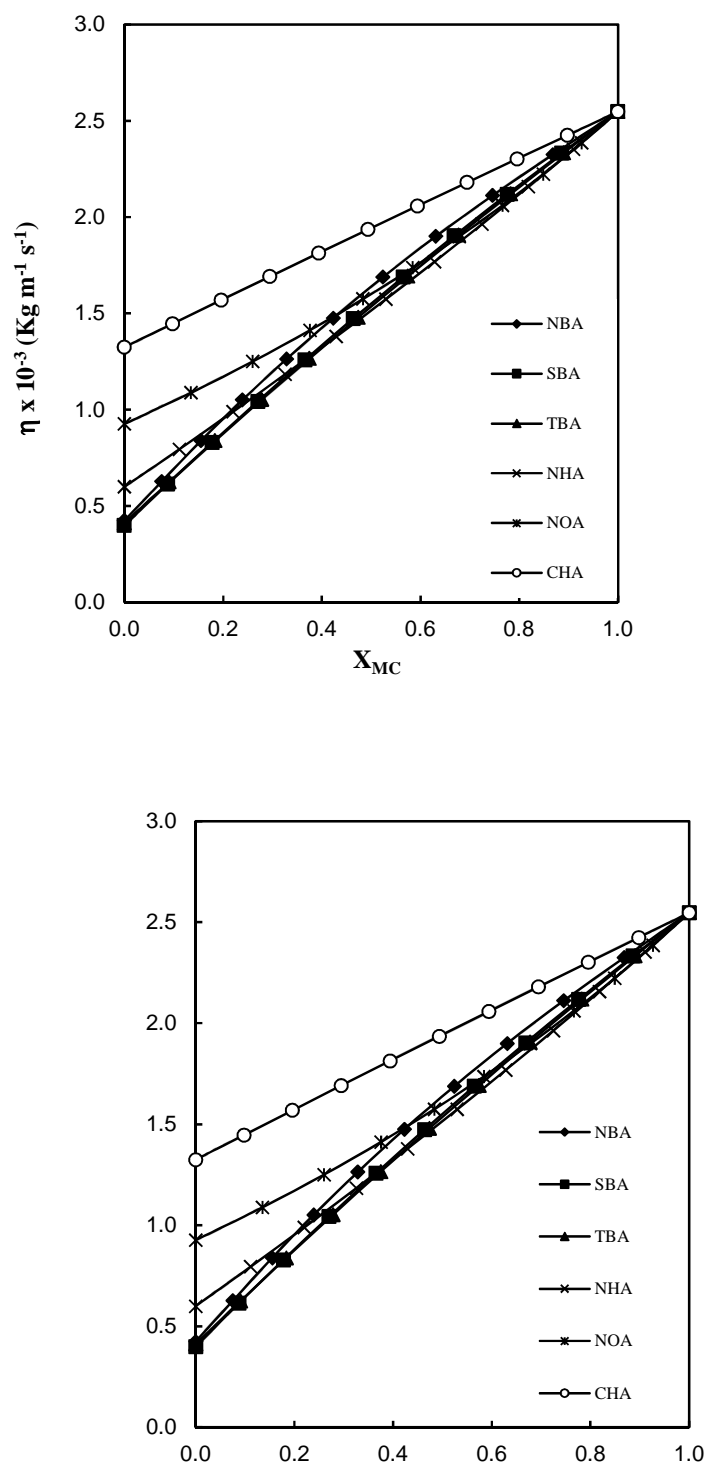
Fig:1: Plots of viscosity (η) vs mole fraction of methyl carbitol (X_{MC}) for binary mixtures of MC + Amines at 308.15 K
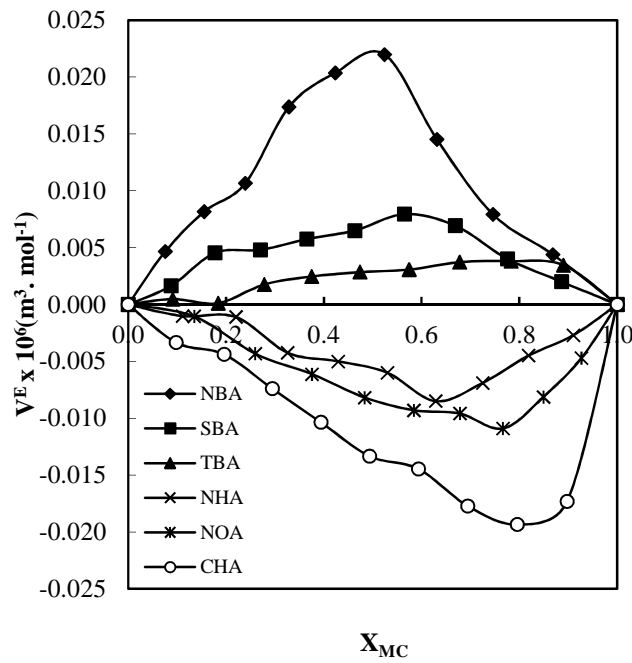
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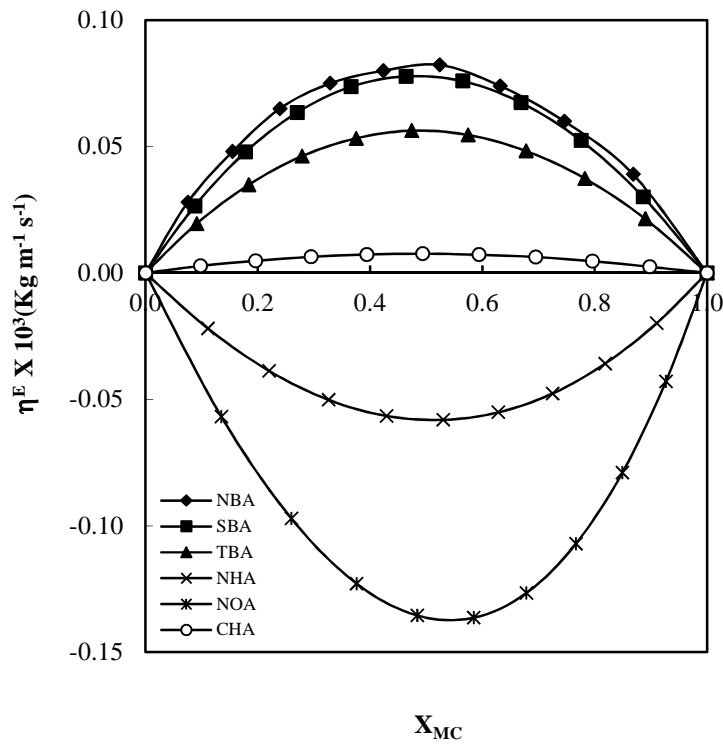**Fig:2: Plots of excess volume (V^E) vs mole fraction of Methyl carbitol(X$_{MC}$) for binary mixtures of MC + Amines at 308.15 K**

Fig: 3: Plots of excess viscosities(η^E) vs mole fraction of Methyl carbitol (X$_{MC}$) for binary mixtures of MC + Amines at 308.15 K
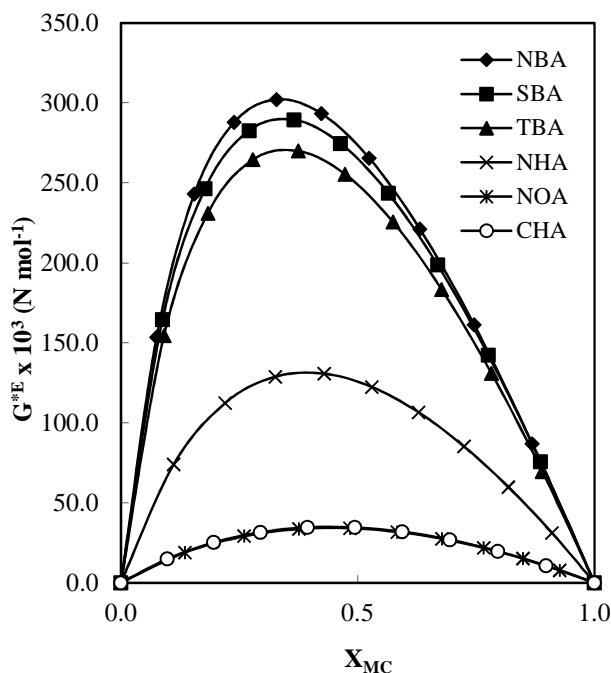
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Fig: 4: Plots of excess Gibbs free energy of activation of viscous flow (G^{*E}) Vs mole fractions of Methyl carbitol (X$_{MC}$) for binary mixtures of MC +Amines at 308.15 K. Methyl carbitol (X$_{MC}$) at 308.15 K

CONCLUSION

The present study reports the volumetric and viscometric properties of2-(2-Methoxy ethoxy) ethanol (MC)with n-butyl amine, sec- butyl amine, tert- butyl amine, n-hexyl amine,

n-octyl amine and cyclo hexyl amine over the entire composition range at 305.15 K. From the results, it is observed that the variation of the properties of the mixtures studied supports the view that the interactions between unlike molecules predominate over the dissociation effects in the individual components. It is also evident that the presence of strong interactions between unlike molecules is predominant and characterized by the negative V^E and positive η^E, G^{*E} and d^1 values

Acknowledgements

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