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Viscosities of binary mixtures of ethanenitrile with benzene and several substituted benzenes

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Abstract−Viscosities (η) and densities (ρ) of five binary mixtures of ethanenitrile with benzene and several substituted benzenes viz methylbenzene, 1,4-dimethylbenzene, chlorobenzene and 1,2-dichlorobenzene have been experimentally determined at 308.15 K. Viscosity deviations ($\Delta\eta$) from the linear blending rule have been evaluated for all the mixtures studied. These are small with a maximum negative deviation of about 6% for binary mixture with benzene and maximum positive deviation of about 3% for mixture with 1,4-dimethylbenzene. $\Delta\eta$ Values are fitted into Redlich - Kister equation and standard deviations in $\Delta\eta$ values, $\sigma(\Delta\eta)$ have been evaluated. The correlating performance of several viscosity models such as Grunberg - Nissan, Katti and Chaudhari, Hind-McLaughlin - Ubbelohde and Sedgwick has been evaluated. Grunberg-Nissan viscosity model is suitable for viscosities of several binary systems studied. The results are discussed in terms of molecular interactions between the components of binary mixtures.

Key words: Molecular Interactions, Liquid Mixtures, Hydrocarbons, Viscosity Model

INTRODUCTION

Studies on binary liquid mixtures of a variety of polar aliphatic molecules [1-5], namely ketones, nitroalkanes, haloalkanes and dihaloalkanes with non-polar hydrocarbon solvents, have been carried out in our laboratory employing viscosity measurements. Nitriles are a very important class of compounds due to their importance in organic synthesis and removal of coloring matters from petroleum hydrocarbons. However, little attention [6,7] has been given to the study of binary mixtures containing nitriles as one of the components. Binary mixtures of ethanenitrile and ethanol [8] at 298.15 K and of formic acid with ethanenitrile [9] at 303.15 K have been studied by viscosity measurements. It has been suggested that dipole - dipole interactions are present in the former case while non-specific dipolar interactions are present in the latter. Oswal et al. [10] have measured viscosities of binary mixtures of acrylonitrile with ethanenitrile and several esters at 303.15 K and data have been correlated with several viscosity equations.

In view of the above, viscosities of five binary mixtures of ethanenitrile with benzene, successive methylated and chlorinated benzenes, i.e., methylbenzene, 1,4-dimethylbenzene, chlorobenzene and 1,2-dichlorobenzene, have been measured to access the suitability of viscometric method for the study the molecular interactions present in such mixtures and to demonstrate the effect of different types of substituents present on benzene over such interactions.

EXPERIMENTAL

Ethanenitrile (Merck, 99%), benzene (s.d. fine chem. Ltd. HPLC & spectroscopy grade 99.8%), methylbenzene (Merck, 99%), 1,4-dimethylbenzene (s.d. fine chem. Ltd LR grade, 98.5%), chlorobenzene (Merck, 99%) and 1,2-dichlorobenzene (Merck, 98%) were used for sample preparation after fractional distillation over a one-meter long column and middle fractions were only collected. Purities of the liquids used were checked by density measurements. Samples of binary mixtures for complete mole fraction range were prepared by weight. The components of the mixtures were injected into sealed vials by means of syringe employing 24 number needle to avoid evaporation losses during sample preparation. Viscosities of component liquids and their binary mixtures were determined within uncertainty of $\pm 0.0001\times 10^{-3}$ $Nm^{-2}s$ with a Tuan and Fuoss viscometer. Time of flow was measured using an electronic stop watch (Racer) within ±0.01 s. Densities were determined by making buoyancy correction [11] employing single stem pycnometer within uncertainty of $\pm 0.0001\times 10^{3}$ kg m^{-3}. Glass stoppers were placed at the opening of the viscometer and pycnometer to prevent the loss due to evaporation during viscosities and densities measurements. All weights were measured within $\pm 0.00001\times 10^{-3}$ kg employing a single pan analytical balance (Model K-15 Deluxe, K.Roy Instruments Pvt. Ltd., Varanasi). All measurements were made at 308.15± 0.03 K with a water thermostat.

The viscometer was calibrated with liquids of known viscosity using a two-term equation

$$\nu = \eta/\rho = a\,t - b/t \tag{1}$$

where ν, η, ρ, and t are kinematic viscosity, dynamic viscosity, density and time of flow, respectively. The constants of the viscometer at experimental temperature were a=0.00465 and b=0.11502.

RESULTS AND DISCUSSION

Experimental values of densities (ρ), viscosities (η) for the binary mixtures of ethanenitrile with benzene, methylbenzene, 1,4-dimeth-

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Table 1. Mole fractions of hydrocarbons (x_1), densities (ρ), viscosities (η) and deviation in viscosities from the additive viscosity values ($\Delta\eta$) for binary mixtures of ethanenitrile+hydrocarbon systems at 308.15 K

x_1	$\rho\times10^{-3}$/kg m^{-3}	$\eta\times10^{3}$/Nm^{-2}s	$\Delta\eta\times10^{3}$/Nm^{-2}s
Benzene (x_1)+Ethanenitrile (x_2)			
0.0000	0.7672	0.3180	0.0000
0.1018	0.7821	0.3278	−0.0111
0.2042	0.7956	0.3407	−0.0192
0.3030	0.8081	0.3576	−0.0226
0.4008	0.8188	0.3780	−0.0223
0.4892	0.8278	0.3939	−0.0245
0.5921	0.8362	0.4163	−0.0233
0.6906	0.8445	0.4413	−0.0185
0.8017	0.8523	0.4762	−0.0065
0.8951	0.8579	0.4954	−0.0062
1.0000	0.8634	0.5234	0.0000
Methylbenzene (x_1)+Ethanenitrile (x_2)			
0.0000	0.7672	0.3180	0.0000
0.1038	0.7838	0.3334	−0.0027
0.2037	0.7972	0.3498	−0.0037
0.2993	0.8082	0.3692	−0.0010
0.3885	0.8171	0.3887	0.0029
0.4673	0.8236	0.4020	0.0025
0.5986	0.8337	0.4240	0.0016
0.6907	0.8401	0.4457	0.0073
0.7946	0.8451	0.4617	0.0052
0.8925	0.8504	0.4789	0.0053
1.0000	0.8533	0.4923	0.0000
1,4-Dimethylbenzene (x_1)+ Ethanenitrile (x_2)			
0.0000	0.7672	0.3180	0.0000
0.1008	0.7844	0.3403	0.0006
0.2001	0.7975	0.3636	0.0025
0.2981	0.8089	0.3915	0.0093
0.3964	0.8178	0.4147	0.0113
0.4985	0.8252	0.4387	0.0134
0.5923	0.8315	0.4603	0.0148
0.6937	0.8374	0.4799	0.0125
0.7907	0.8415	0.4989	0.0106
0.9051	0.8455	0.5199	0.0070
1.0000	0.8488	0.5334	0.0000
Chlorobenzene (x_1)+Ethanenitrile (x_2)			
0.0000	0.7672	0.3180	0.0000
0.1038	0.8268	0.3520	−0.0023
0.2009	0.8738	0.3871	−0.0013
0.3059	0.9168	0.4245	−0.0007
0.3949	0.9486	0.4591	0.0028
0.4943	0.9800	0.4944	0.0032
0.5946	1.0073	0.5309	0.0046
0.6984	1.0299	0.5671	0.0043
0.7956	1.0547	0.6032	0.0063
0.8961	1.0728	0.6352	0.0031
1.0000	1.0907	0.6685	0.0000
1,2-Dichlorobenzene (x_1)+Ethanenitrile (x_2)			
0.0000	0.7672	0.3180	0.0000
0.1003	0.8678	0.3803	−0.0167
0.2063	0.9544	0.4569	−0.0238
0.3069	1.0232	0.5299	−0.0301
0.4058	1.0785	0.6077	−0.0303
0.4918	1.1213	0.6760	−0.0299
0.5925	1.1656	0.7617	−0.0235
0.6956	1.2017	0.8443	−0.0222
0.7945	1.2463	0.9395	−0.0050
0.9016	1.2655	1.0269	−0.0021
1.0000	1.2904	1.1066	0.0000

ylbenzene, chlorobenzene and 1,2-dichlorobenzene with mole fraction of hydrocarbon solvents at experimental temperature 308.15 K are recorded in Table 1. Experimental viscosities are used to evaluate deviation in viscosities ($\Delta\eta$) from the linear blending rule for the mixtures by equation

$$\Delta\eta=\eta-\sum_{i=1}^{2}x_i\eta_i \tag{2}$$

where η_i and x_i are the viscosity of component i and mole fraction of component i in the mixture, respectively. The evaluated values of $\Delta\eta$ at experimental temperature for all the systems studied are also recorded in Table 1 with mole fractions of hydrocarbon solvents. Variations of η and $\Delta\eta$ with mole fractions of hydrocarbon solvents for all the binary mixtures studied are shown in Figs. 1 and 2, respectively. $\Delta\eta$ values for all the mixtures studied are fitted into Redlich-Kister equation of the type

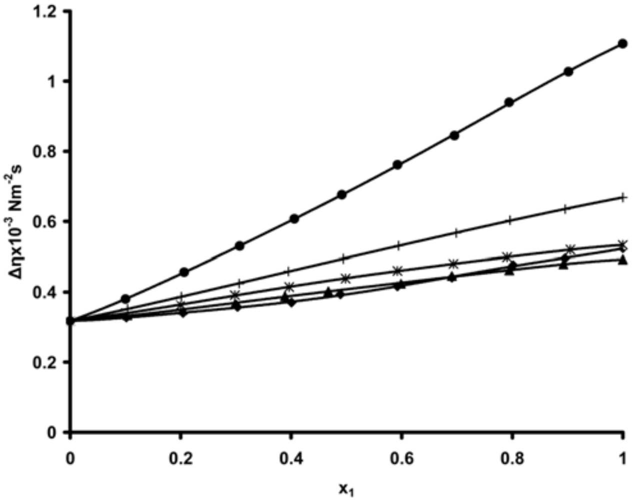

Fig. 1. Viscosities (η) of Ethanenitrile+hydrocarbon solvents versus mole fractions of hydrocarbons (x_1) (■ Benzene, ▲ methylbenzene, ⚹ 1,4-dimethylbenzene, + chlorobenzene and ● 1,2-dichlorobenzene) at 308.15 K.

$$\Delta\eta=x_1x_2\,[A+B\,(x_1-x_2)+C\,(x_1-x_2)^2] \tag{3}$$

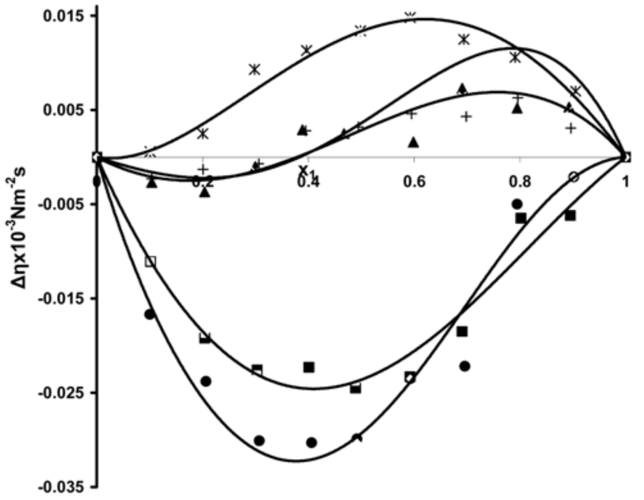

Fig. 2. Deviations in viscosities ($\Delta\eta$) from additive viscosities values of Ethanenitrile+hydrocarbon solvents versus mole fractions of hydrocarbons (x_1) (■ Benzene, ▲ methylbenzene, ✱ 1,4-dimethylbenzene, + chlorobenzene and ● 1,2-dichlorobenzene) at 308.15 K.

where x_1 and x_2 are the mole fractions of the components 1 and 2, respectively. A, B, C the coefficients of the polynomial and standard deviations $\sigma(\Delta\eta)$ are recorded in Table 2.

It is evident from Fig. 1 that η values for the binary mixtures of ethanenitrile with benzene and with methylbenzene are comparable. However, η values for mixtures with methylbenzene are higher than that for mixture with benzene at lower mole fractions of the hydrocarbons. At higher mole fractions around 0.8 of the hydrocarbons, η values for the latter mixture become higher than for the former mixture. This is quite expected in view of higher η value of benzene than methylbenzene. Values of η at a fixed composition for all the binary mixtures studied follow the order:

Methylbenzene≃benzene<1,4-dimethylbenzene<chlorobenzene
<1,2-dichlorobenzene

Table 1 shows that $\Delta\eta$ values for all the systems are small. A perusal of Fig. 2 reveals that $\Delta\eta$ values for binary mixture of ethanenitrile+1,2-dichlorobenzene for the whole range of concentrations are negative. Binary mixtures of ethanenitrile+benzene have lesser negative values (higher values) of $\Delta\eta$ than the mixture of ethanenitrile+1,2-dichlorobenzene. All $\Delta\eta$ values for binary mixtures of ethanenitrile+1,4-dimethylbenzene are positive. However, the evaluation of percentage deviation in viscosities from the linear blending rule shows that maximum negative deviation of about 6% is for binary mixture of ethanenitrile with benzene and maximum positive deviation of about 3% is for binary mixture with 1,4-dimethylbenzene. $\Delta\eta$ values for binary mixtures of ethanenitrile with either methylbenzene or chlorobenzene are negative at lower mole fractions of the hydrocarbons up to about 0.30 and positive at higher mole fractions of the hydrocarbons. Comparison of $\Delta\eta$ values at equimolar mixture of ethanenitrile with several hydrocarbon solvents suggests that the values follow the order:

1,2-dichlorobenzene<benzene<methylbenzene<chlorobenzene
<1,4-dimethylbenzene

It has been suggested [12,13] that negative $\Delta\eta$ values show the presence of weak interactions between the components of binary mixtures. $\Delta\eta$ values tend to become less negative and then increasingly positive as the strength of interaction between unlike molecules increases. The negative $\Delta\eta$ values for ethanenitrile+benzene system in our case may be due to dipole-induced dipole interaction as ethanenitrile is a polar molecule (gas phase dipole moment=3.97 D) [14] and benzene has polarizable π-electrons. The positive values of $\Delta\eta$ for binary mixtures of ethanenitrile with 1,4-dimethylbenzene, methylbenzene and chlorobenzene suggest the presence of strong unlike interaction, while the negative values $\Delta\eta$ for binary mixtures of ethanenitrile with benzene and 1,2-dichlorobenzene show the presence of comparatively weaker unlike interactions. Rastogi et al. [15] have suggested that observed excess property is a combination of an interaction and non-interaction part:

$$\gamma^E_{(observed)}=\gamma^E_{(interaction)}+\gamma^E_{(size\ effect)} \tag{4}$$

Homer et al. [16] have also suggested that the substituents over the interacting components affect the interactions either by blocking the mutual approach of the interacting components or by locking one component into the other. It seems that in the binary mixtures of ethanenitrile+1,2-dichlorobenzene the blocking effect dominates, causing weak unlike interactions between the components.

Several viscosity models, Grunberg and Nissan, [17] Katti and Chaudhari, [18] Hind - McLaughlin - Ubbelohde [19] and Sedgwick [20], have been suggested time to time for binary mixture viscosities. To test the suitability of these viscosity models the Grunberg-Nissan equation with single disposable parameter for viscosities of liquid mixtures given below is analyzed:

$$\ln \eta = x_1 \ln \eta_1 + x_2 \ln \eta_2 + 2\, x_1\, x_2\, d \tag{5}$$

where η is the viscosity of the mixture; x_1, x_2, and η_1, η_2 are the mole fractions and viscosities of the components 1 and 2, respectively; d is proportional to w/RT, where w is the interchange energy. The interaction parameter d approximately measures the strength of interactions. Nigam et al. [21] have indicated that positive and large in magnitude of $\Delta\eta$ and d values show the presence of strong specific

Table 2. The values of coefficients of the Redlich-Kister equation A, B, and C and standard deviations in viscosities, $\sigma(\Delta\eta)$ for different systems of ethanenitrile and hydrocarbon solvents at 308.15 K

Systems	A	B	C	$\sigma(\Delta\eta)\times10^3$/Nm^{-2}s
Benzene (x_1)+Ethanenitrile (x_2)	−0.0945	0.0417	0.0105	±0.0026
Methylbenzene (x_1)+Ethanenitrile (x_2)	0.0114	0.0478	0.0057	±0.0018
1,4-Dimethyl Benzene (x_1)+Ethanenitrile (x_2)	0.0535	0.0406	−0.0194	±0.0009
Chlorobenzene (x_1)+Ethanenitrile (x_2)	0.0146	0.0712	0.0400	±0.0045
1,2-Dichloro benzene (x_1)+Ethanenitrile (x_2)	−0.1115	0.0923	0.0275	±0.0032

Table 3. Mole fractions of hydrocarbons (x_1), interactions parameters (d), (K_{12}), (H_{12}) and (C), interaction energies (w_{visc}) and excess free energy of activation for viscous flow (G^{*E}) for all the systems at 308.15 K

x_1	d	K_{12}	H_{12}	C	w_{visc}/ (J mol^{-1})	$G^{*E}\times10^{-2}$/ (J mol^{-1})
Benzene (x_1)+Ethanenitrile (x_2)						
0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00
0.1018	−0.1109	−0.0553	0.3601	0.3550	−141.73	−0.13
0.2042	−0.1009	−0.0444	0.3615	0.3535	−113.83	−0.19
0.3030	−0.0795	−0.0137	0.3671	0.3562	−35.18	−0.07
0.4008	−0.0557	−0.0266	0.3702	0.3610	68.25	0.16
0.4892	−0.0592	0.0126	0.3716	0.3557	32.31	0.08
0.5921	−0.0532	0.0226	0.3724	0.3537	57.82	0.14
0.6906	−0.0381	0.0447	0.3774	0.3570	114.60	0.24
0.8017	−0.0137	0.1419	0.4004	0.3834	364.54	0.58
0.8951	−0.0020	0.0872	0.3876	0.3652	224.20	0.21
1.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00
Methylbenzene (x_1)+Ethanenitrile (x_2)						
0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00
0.1038	0.0110	0.2951	0.3909	0.3834	756.03	0.75
0.2037	0.0196	0.3133	0.3938	0.3854	802.66	1.30
0.2993	0.0442	0.3476	0.4029	0.3935	890.25	1.87
0.3885	0.0650	0.3766	0.4114	0.4017	864.74	2.30
0.4673	0.0604	0.3592	0.4102	0.4007	920.20	2.29
0.5986	0.0542	0.3426	0.4086	0.3993	877.62	2.11
0.6907	0.0838	0.3766	0.4223	0.4145	964.83	2.06
0.7946	0.0782	0.3586	0.4210	0.4136	918.67	1.50
0.8925	0.1005	0.3890	0.4327	0.4276	996.70	0.96
1.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00
1,4-Dimethylbenzene (x_1)+Ethanenitrile (x_2)						
0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00
0.1008	0.0868	0.6209	0.4291	0.4146	1590.62	1.44
0.2001	0.0955	0.6099	0.4335	0.4187	1562.46	2.50
0.2981	0.1285	0.6450	0.4479	0.4322	1652.38	3.45
0.3964	0.1264	0.6175	0.4493	0.4346	1582.11	3.79
0.4985	0.1280	0.6020	0.4524	0.4390	1541.66	3.86
0.5923	0.1318	0.5910	0.4563	0.4018	1514.02	3.66
0.6937	0.1243	0.5567	0.4551	0.4444	1426.35	3.03
0.7907	0.1251	0.5463	0.4576	0.4485	1399.47	2.31
0.9051	0.1367	0.5592	0.4662	0.4500	1432.70	1.23
1.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00

Table 3. Continued

x_1	d	K_{12}	H_{12}	C	w_{visc}/ (J mol^{-1})	$G^{*E}\times10^{-2}$/ (J mol^{-1})
Chlorobenzene (x_1)+Ethanenitrile (x_2)						
0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00
0.1038	0.1328	0.5137	0.4809	0.4515	1316.10	1.22
0.2009	0.1481	0.5122	0.4894	0.4578	1312.21	2.19
0.3059	0.1450	0.5152	0.4915	0.4885	1320.02	2.80
0.3949	0.1548	0.5267	0.4990	0.4667	1349.26	3.22
0.4943	0.1484	0.5034	0.4997	0.4678	1289.69	3.22
0.5946	0.1470	0.4932	0.5027	0.4718	1263.56	3.05
0.6984	0.1415	0.4845	0.5097	0.4734	1241.19	2.61
0.7956	0.1508	0.5036	0.5153	0.4869	1390.18	2.09
0.8961	0.1400	0.4570	0.5098	0.4833	1170.89	1.09
1.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00
1,2-Dichlorobenzene (x_1)+Ethanenitrile (x_2)						
0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00
0.1003	0.2996	0.9450	0.6197	0.5291	2421.13	2.19
0.2063	0.3214	0.9644	0.6397	0.5328	2470.76	4.05
0.3069	0.3009	0.9000	0.6415	0.5242	2305.76	4.90
0.4058	0.2938	0.8749	0.6495	0.5231	2241.41	5.40
0.4918	0.2818	0.8369	0.6925	0.5190	2144.13	5.36
0.5925	0.2790	0.8145	0.6636	0.5259	2086.59	5.04
0.6956	0.2577	0.7681	0.6598	0.5120	1967.87	4.17
0.7945	0.2837	0.7497	0.6971	0.5685	1920.75	4.18
0.9016	0.2690	0.7703	0.7011	0.5728	1973.50	1.75
1.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00

interactions, negative $\Delta\eta$ and positive d values show the presence of weak specific interactions, and large negative $\Delta\eta$ and d values show the absence of any specific interaction between component molecules. In our case, calculated d values given in Table 3 are positive for binary mixtures except for the ethanenitrile+benzene system, where it is negative. For binary mixtures of ethanenitrile with either benzene or monosubstituted benzenes the d values follow similar trends as $\Delta\eta$ values. Large positive values of d and large negative values of $\Delta\eta$ for ethanenitrile+1,2-dichlorobenzene may be due to the presence of weak specific interactions.

Katti and Chaudhri equation for mixture viscosity is

$$\ln \eta V = x_1 \ln \eta_1 V_1 + x_2 \ln \eta_2 V_2 + x_1 x_2 K_{12} \tag{6}$$

where V is molar volume of the mixture, K_{12} is the interaction parameter and equal to w_{visc}/RT where w_{visc}, R and T are interaction energy term, gas constant and experimental temperature, respectively; x_1, x_2 and V_1, V_2 are mole fractions and molar volumes of the components respectively. Hind - McLaughlin - Ubbelohde viscosity model is

$$\eta = x_1^2 \eta_1 + x_2^2 \eta_2 + 2 x_1 x_2 H_{12} \tag{7}$$

where H_{12} is the interaction parameter. The Sedgwick model of mixture viscosity is

$$\eta^2 = x_1^2 \eta_1^2 + x_2^2 \eta_2^2 + 2 x_1 x_2 C^2 \tag{8}$$

where C is the interaction parameter.

Experimental values of mixture viscosities and the viscosities of their components are used in Eqs. (6), (7), and (8) to evaluate K_{12}, H_{12} and C. These values for all the systems studied are recorded in Table 3 with composition of the mixture. H_{12}, C and K_{12} are positive for all the mixtures and for complete concentration range with exception for ethanenitrile+benzene binary mixture where K_{12} is negative at lower mole fractions and positive at higher mole fractions of hydrocarbon solvent. All interaction parameters d, H_{12}, K_{12} and C are found to vary with composition for the mixtures. To get information about the suitability of the models for these systems a graphical way is as follows. All the models can be represented by either of the following two forms:

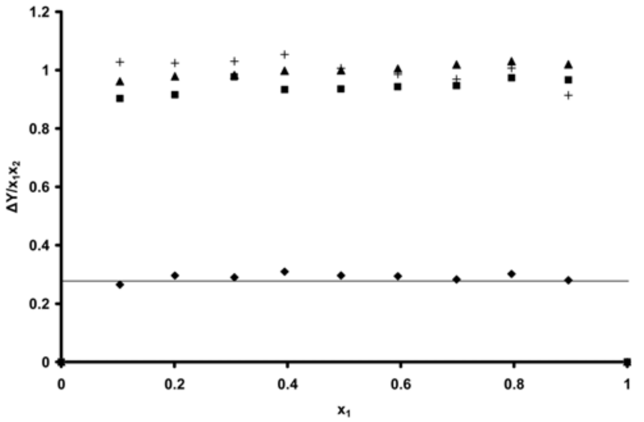

Fig. 3. Plot of ΔY (Δlnη, Δlnη_v, Δη or Δη^2)/x_1x_2 versus composition for several viscosity models for ethanenitrile+chlorobenzene binary system (◆ d, + K_{12}, ▲ H_{12}, ■ C) at 308.15 K.

$$y=a_{11}\,x_1^2+2\,a_{12}\,x_1\,x_2+a_{22}\,x_2^2 \tag{9}$$

or $$y=b_1\,x_1+2\,b_{12}\,x_1\,x_2+b_2\,x_2 \tag{10}$$

where y stands for either ln η, ln η v, η or η^2. a_{11}, a_{12}, a_{22}, b_1, b_{12} and b_2 are coefficients of the polynomial. Thus,

$$\Delta y=y-a_{11}\,x_1^2-a_{22}\,x_2^2=2\,a_{12}\,x_1\,x_2 \tag{11}$$

or $$\Delta y=y-b_1\,x_1-b_2\,x_2=2\,b_{12}\,x_1\,x_2 \tag{12}$$

A plot of $\Delta y/x_1x_2$ (=$2a_{12}$ or $2b_{12}$) versus composition should give a constant and the data points should fall on a horizontal line. The plots of Δy (Δ ln η, Δ ln ηV, Δη or Δη^2)/x_1x_2 versus composition for all viscosity models are made for our systems. A representative plot of this type is shown in Fig. 3 for the ethanenitrile+chlorobenzene binary system. On the basis of such plots it is evident that the Grunberg and Nissan model provides acceptable correlating performance of binary mixtures of nitrile with chlorobenzene, 1,4-dimethylbenzene and 1,2-didichlorobenzene. However, for binary mixtures of ethanenitrile with benzene and methylbenzene Hind-McLauglin-Ubbelohde and Sedgwick models give acceptable correlating performance.

The interaction energy term w_{visc} evaluated from Eq. (6) and excess free energy of activation for viscous flow G^{*E} evaluated by the equation

$$G^{*E}=R\,T\,[\ln \eta V-\Sigma\, x_i \ln \eta_i V_i] \tag{13}$$

are also recorded in Table 3. The values of w_{visc} and G^{*E} for binary mixtures with benzene and monosubstituted benzenes follow a similar trend as that of Δη values. However, disubstituted benzenes have an order reverse to that of the Δη values.

CONCLUSION

Viscometric studies are useful for the study of molecular interactions between ethanenitrile and benzene and substituted benzenes. Maximum negative percentage deviation in viscosity from the linear blending rule is about 6% for the binary mixture of ethanenitrile+benzene, and maximum positive deviation is about 3% for ethanenitrile+1,4-dimethylbenzene system. Grunberg-Nissan viscosity model is suitable for binary mixtures of ethanenitrile and chlorobenzene, 1,2-dichlorobenzene and 1,4-dimethylbenzene.

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