Asian Journal of Chemistry; Vol. 30, No. 11 (2018), 2557-2566

ASIAN JOURNAL OF CHEMISTRY

https://doi.org/10.14233/ajchem.2018.21598

Prediction of Interactions between Binary Mixtures of Aliphatic Amines and Aliphatic Acetates

PARTIBHA[1], KRISHAN KUMAR[1,*], MANJU RANI[2] and VINITA BHANKAR[3]

[1]Department of Chemistry, Deenbandhu Chhotu Ram University of Science and Technology, Murthal-131 039, India
[2]Department of Chemical Engineering, Deenbandhu Chhotu Ram University of Science and Technology, Murthal-131 039, India
[3]Department of Biochemistry, Kurukshetra University, Kurukshetra-136 119, India

*Corresponding author: E-mail: mehra.krishan25@gmail.com

Received: 20 July 2018; *Accepted*: 31 August 2018; *Published online*: 27 September 2018; AJC-19111

The refractive indices (n) of aliphatic amines and aliphatic acetates were measured at different temperatures (293.15, 298.15, 303.15, 308.15 and 313.15 K) on the entire composition as CO_2 capture is a fast-developing field with amine based technologies due to their reversible reaction with CO_2. The aliphatic amines selected were diethylenetriamine, dibutylamine and tributylamineand methyl acetate, ethyl acetate, propyl acetate, butyl acetate and pentyl acetate respectively. All the possible binary mixtures of these aliphatic amines and acetates were taken for determining the experimental refractive indices and various empirical correlations like Arago-Biot, Gladstone-Dale, Lorentz-Lorenz, Heller, Weiner, Newton and Erying-John were applied to experimental data for estimating theoretical value of refractive indices. To evaluate the standard deviation, Redlich-Kister polynomial equation was applied to the measured refractive indices data.

Keywords: Refractive Indices, Aliphatic amines, Aliphatic acetates, Correlations.

INTRODUCTION

The Inter-governmental Panel on Climate Change (IPCC) reports shows that greenhouse gas (GHG) emissions will increase global temperature from 1.1 to 6.4 ºC at the average. As a result of this, during recent years more draughts, extreme weather mishap and floods are increasing day by day. The chemical absorption of carbon dioxide by amine solutions has been investigated over the last decades. Post combustion of CO_2 became necessity with amine based technology because of increasing global warming due to greenhouse gas emissions [1]. In past various parameters of binary mixtures were studied [2-18]. The alkyl amines are important organic bases because of their strong electron donating capabilities, further primary and secondary amines are self associated and tertiary amines are weakly polar.

Amines have important applications to our daily lives like development of crop protection chemicals, medication and water purification. Esters are moderately polar solvent relatively non-hygroscopic and non-toxic. Due to lack of an acidic proton esters are poor hydrogen bond acceptor. In many pharmaceutical industries they are important component in extractants for the concentration and purification of antibiotics. Esters are also work as intermediate in synthesis for drugs.

Hence, the extensive information on various thermophysical as well as thermochemical properties of binary liquid mixtures of aliphatic amines and aliphatic acetates are important from industrial point of view. In the present work, the molecular interaction are explored with the help of measured refractive index data for the binary mixtures of aliphatic amines [diethylenetriamine (DETA), dibutylamine (DBA) and tributylamine (TBA)] and aliphatic acetates (C_1-C_5) (methyl acetate to pentyl acetate) from 293.15 to 313.15 K over the entire composition range. Refractive index is a great tool to understand the structure and characterization along with non-ideal behaviour for the binary liquid mixtures as molar refractivity measures the ability to form instantaneous dipoles. Various empirical expressions such as Arago-Biot, Gladstone-Dale, Lorentz-Lorenz, Weiner, Heller, Newton and Erying-John were applied to measure the refractive index data for theoretical estimation of refractive index [19-21]. No comparable data for the binary liquid mixtures studied are available in literature.

TABLE-1
SAMPLE INFORMATION

S. No.	Sample	CAS No.	Make	Initial mass fraction purity
1	Diethylenetriamine (DETA)	111-40-0	Merck, India	≥ 0.990
2	Dibutylamine (DBA)	108-18-9	Merck, India	≥ 0.990
3	Tributylamine (TBA)	102-82-9	Merck, India	≥ 0.990
4	Methyl acetate (MA)	79-2-0-9	Merck, India	≥ 0.995
5	Ethyl acetate (EA)	141-78-6	Fisher Scientific, India	≥ 0.995
6	Propyl acetate (PA)	109-60-4	S.D. Fine Chemicals, India	≥ 0.980
7	Butyl acetate (BA)	123-86-4	Merck, India	≥ 0.995
8	Pentyl acetate (PENA)	628-63-7	Merck, India	≥ 0.990

EXPERIMENTAL

All the purchased chemicals were purified by standard procedures [22,23] and their complete details are given in Table-1. Purity of these solvents ascertained by comparing their experimental data of densities and refractive indices at 298.15 to 308.15 K with the available literature values [24-26] (Table-2). Refractive indices were measured with a refractometer (Abbemat-200) with temperature controlled within ± 0.01 K having accuracy up to ± 1 × 10^{-4}. The binary mixtures of aliphatic amines and aliphatic acetates (C_1-C_5) at different temperatures (293.15 to 313.15 K) on the entire composition range were prepared. For weighing appropriate quantity specially designed air tight stopper bottles and electronic balance (CAUW 220 D) with a precision of ± 0.005 mg was used.

TABLE-2
EXPERIMENTAL AND LITERATURE VALUES OF DENSITIES, ρ^* AND REFRACTIVE INDEX OF PURE LIQUID COMPONENTS AT (298.15, 303.15 AND 313.15) K AND ATMOSPHERIC PRESSURE

Component	Density × 10^{-3} (kg m^{-3})		Refractive index (n)	
	Expt.	Lit.	Expt.	Lit.
		298.15 K		
DETA	0.945842	0.945548 [24]	1.4814	1.4815 [25]
DBA	0.755664	0.755553 [26]	1.4167	1.4169 [26]
TBA	0.773283	0.773910 [26]	1.4272	1.4277 [26]
Methyl acetate	0.928458	0.928500 [27]	1.3594	1.3597 [27]
Ethyl acetate	0.894790	0.894710 [27]	1.3698	1.3700 [27]
Propyl acetate	0.883369	0.883100 [27]	1.3818	1.3821 [27]
Butyl acetate	0.876399	0.876260 [27]	1.3920	1.3922 [27]
Pentyl acetate	0.87132	0.871460 [27]	1.4049	1.4050 [27]
		303.15 K		
DETA	0.941630	0.941315 [24]	1.4788	1.4788 [25]
DBA	0.751562	0.751445 [26]	1.4139	1.4143 [26]
TBA	0.769550	0.770460 [26]	1.4249	1.4256 [26]
Methyl acetate	0.921854	0.921800 [27]	1.3564	1.3567 [27]
Ethyl acetate	0.888656	0.888550 [27]	1.3672	1.3673 [27]
Propyl acetate	0.877422	0.877400 [27]	1.3791	1.3794 [27]
Butyl acetate	0.871235	0.870840 [27]	1.3894	1.3897 [27]
Pentyl acetate	0.865782	0.866420 [27]	1.4028	1.4030 [27]
		313.15 K		
DETA	0.937415	0.937092 [24]	1.4764	1.4764 [25]
DBA	0.747450	0.747329 [26]	1.4111	1.4118 [26]
TBA	0.765810	0.766950 [26]	1.4229	1.4232 [26]
Methyl acetate	0.915156	0.915200 [27]	1.3534	1.3538 [27]
Ethyl acetate	0.882475	0.882500 [27]	1.3644	1.3647 [27]
Propyl acetate	0.871784	0.871800 [27]	1.3764	1.3767 [27]
Butyl acetate	0.860840	0.865470 [27]	1.3868	1.3872 [27]
Pentyl acetate	0.860581	0.861440 [27]	1.4002	1.4004 [27]

RESULTS AND DISCUSSION

Deviation in refractive index has been calculated as:

$$\Delta n = n_D - \sum_{i=1}^{2} x_i n_{Di} \quad (1)$$

where n_{Di} and x_i symbols represent the refractive index and mole fraction of the i^{th} component, respectively and n_D is the refractive index of binary mixtures. Experimental n_D and Δn data of binary systems are given in Tables 3-5. The Δn values were also fitted with Redlich-Kister polynomial equation.

$$\Delta n = x_1(1-x_1)\left(\sum_{n=1}^{4} A^{(j)}(2x_1-1)^{(j-1)}\right) \quad (2)$$

where $A^{(j)}$ are the adjustable parameters and calculated by fitting Δn data in eqn. 2 and standard deviations $\sigma(\Delta n)$ were recorded in Table-6. Experimental deviation in refractive index data for the studied system together with smoothing curves from eqn. 2 is shown in Fig. 1(a-c).

For quantitative determination of refractive indices following mixing relations were used:

Arago-Biot (A-B):

$$n_D = n_{D1}\phi_1 + n_{D2}\phi_2 \quad (3)$$

Gladstone-Dale (G-D):

$$n_D - 1 = (n_{D1} - 1)\phi_1 + (n_{D2} - 1)\phi_2 \quad (4)$$

Lorentz-Lorenz (L-L):

$$\frac{n_D^2 - 1}{n_D^2 + 2} = \left(\frac{n_{D1}^2 - 1}{n_D^2 + 2}\right)\phi_1 + \left(\frac{n_{D2}^2 - 1}{n_D^2 + 1}\right)\phi_2 \quad (5)$$

Heller (H):

$$\frac{n_D - 1}{n_D} = \frac{3}{2}\left(\frac{(n_{D2}/n_{D1})^2 - 1}{(n_{D2}/n_{D1})^2 + 2}\right)\phi_2 \quad (6)$$

Weiner (W):

$$\frac{n_D^2 - n_{D1}^2}{n_D^2 + 2n_{D2}^2} = \left(\frac{n_{D2}^2 - n_{D1}^2}{n_{D2}^2 + 2n_{D2}^2}\right)\phi_2 \quad (7)$$

Newton (Nw):

$$n_D^2 - 1 = (n_{D1}^2 - 1)\phi_1 + (n_{D2}^2 - 1)\phi_2 \quad (8)$$

Eyring and John (E-J):

$$n_D = n_{D1}\phi_1^2 + 2(n_{D1}n_{D2})^{1/2}\phi_1\phi_2 + n_{D2}\phi_2^2 \quad (9)$$

In all above equations, n_D is the refractive index for the binary mixture n_{D1} and n_{D2} are the refractive index of its pure components, respectively. ϕ_1 and ϕ_2 represent the volume fraction of pure components and given by

TABLE-3
REFRACTIVE INDEX (n) AND DEVIATION IN REFRACTIVE INDEX (n^E) FOR THE BINARY SYSTEM DETA + (C_1–C_5) ACETATES At T = (293.15 to 313.15) K

x_1	293.15 K		298.15 K		303.15 K		308.15 K		313.15 K	
	n_D	Δn	n_D	Δn	n_D	Δn	n_D	Δn	n_D	Δn
DETA + Methyl acetate										
0.0000	1.3613	0.00000	1.3594	0.00000	1.3564	0.00000	1.3534	0.00000	1.3505	0.00000
0.0525	1.3629	-0.00493	1.3597	-0.00610	1.3563	-0.00652	1.3531	-0.00675	1.3496	-0.00734
0.1009	1.3659	-0.00796	1.3627	-0.00901	1.3593	-0.00945	1.3561	-0.00971	1.3526	-0.01028
0.2230	1.3727	-0.01636	1.3695	-0.01710	1.3661	-0.01759	1.3629	-0.01792	1.3594	-0.01846
0.3030	1.3768	-0.02223	1.3736	-0.02277	1.3702	-0.02329	1.367	-0.02367	1.3635	-0.02418
0.4101	1.3874	-0.02496	1.3842	-0.02523	1.3808	-0.02580	1.3776	-0.02624	1.3741	-0.02672
0.5011	1.3967	-0.02699	1.3935	-0.02703	1.3901	-0.02763	1.3869	-0.02814	1.3834	-0.02858
0.6300	1.4139	-0.02583	1.4107	-0.02556	1.4073	-0.02621	1.4041	-0.02679	1.4006	-0.02720
0.7277	1.4281	-0.02380	1.4249	-0.02328	1.4215	-0.02397	1.4183	-0.02461	1.4148	-0.02499
0.8503	1.4471	-0.02006	1.4439	-0.01923	1.4405	-0.01997	1.4373	-0.02068	1.4338	-0.02103
0.9087	1.4589	-0.01553	1.4557	-0.01456	1.4523	-0.01532	1.4491	-0.01607	1.4456	-0.01640
1.0000	1.4858	0.00000	1.4814	0.00000	1.4788	0.00000	1.4764	0.00000	1.4732	0.00000
DETA + Ethyl acetate										
0.0000	1.3722	0.00000	1.3698	0.00000	1.3672	0.00000	1.3644	0.00000	1.3619	0.00000
0.0505	1.3746	-0.00334	1.3714	-0.00404	1.3680	-0.00484	1.3648	-0.00526	1.3613	-0.00622
0.1638	1.3811	-0.00971	1.3779	-0.01018	1.3745	-0.01098	1.3713	-0.01144	1.3678	-0.01233
0.2592	1.3881	-0.01354	1.3849	-0.01382	1.3815	-0.01462	1.3783	-0.01513	1.3748	-0.01595
0.3072	1.3921	-0.01500	1.3889	-0.01519	1.3855	-0.01599	1.3823	-0.01651	1.3788	-0.01729
0.4072	1.4010	-0.01746	1.3978	-0.01745	1.3944	-0.01825	1.3912	-0.01881	1.3877	-0.01952
0.5001	1.4100	-0.01902	1.4068	-0.01882	1.4034	-0.01962	1.4002	-0.02022	1.3967	-0.02087
0.5916	1.4199	-0.01950	1.4167	-0.01912	1.4133	-0.01992	1.4101	-0.02055	1.4066	-0.02114
0.7164	1.4346	-0.01898	1.4314	-0.01835	1.4280	-0.01915	1.4248	-0.01984	1.4213	-0.02033
0.8205	1.4499	-0.01551	1.4467	-0.01467	1.4433	-0.01547	1.4401	-0.01620	1.4366	-0.01663
0.9132	1.4657	-0.01024	1.4625	-0.00922	1.4591	-0.01002	1.4559	-0.01078	1.4524	-0.01114
1.0000	1.4858	0.00000	1.4814	0.00000	1.4788	0.00000	1.4764	0.00000	1.4732	0.00000
DETA + Propyl acetate										
0.0000	1.3838	0.00000	1.3818	0.00000	1.3791	0.00000	1.3764	0.00000	1.3738	0.00000
0.0599	1.3850	-0.00491	1.3828	-0.00497	1.3804	-0.00467	1.3782	-0.00419	1.3750	-0.00481
0.1581	1.3901	-0.00983	1.3879	-0.00965	1.3855	-0.00936	1.3833	-0.00891	1.3801	-0.00946
0.2505	1.3943	-0.01505	1.3921	-0.01465	1.3897	-0.01438	1.3875	-0.01395	1.3843	-0.01445
0.3283	1.3987	-0.01858	1.3965	-0.01800	1.3941	-0.01773	1.3919	-0.01733	1.3887	-0.01778
0.4951	1.4149	-0.01940	1.4127	-0.01841	1.4103	-0.01816	1.4081	-0.01781	1.4049	-0.01816
0.5537	1.4205	-0.01977	1.4183	-0.01865	1.4159	-0.01840	1.4137	-0.01807	1.4105	-0.01838
0.6014	1.4250	-0.02015	1.4228	-0.01890	1.4204	-0.01866	1.4182	-0.01834	1.4150	-0.01863
0.7104	1.4370	-0.01927	1.4348	-0.01776	1.4324	-0.01753	1.4302	-0.01724	1.4270	-0.01747
0.8035	1.4481	-0.01765	1.4459	-0.01592	1.4435	-0.01571	1.4413	-0.01545	1.4381	-0.01561
0.9338	1.4716	-0.00745	1.4694	-0.00541	1.4670	-0.00520	1.4648	-0.00498	1.4616	-0.00507
1.0000	1.4858	0.00000	1.4814	0.00000	1.4788	0.00000	1.4764	0.00000	1.4732	0.00000
DETA + Butyl acetate										
0.0000	1.3942	0.00000	1.3920	0.00000	1.3894	0.00000	1.3868	0.00000	1.3843	0.00000
0.0572	1.3943	-0.00514	1.3921	-0.00502	1.3897	-0.00482	1.3875	-0.00443	1.3843	-0.00514
0.1037	1.3963	-0.00740	1.3941	-0.00717	1.3917	-0.00697	1.3895	-0.00659	1.3863	-0.00727
0.2019	1.4011	-0.01160	1.3989	-0.01115	1.3965	-0.01095	1.3943	-0.01059	1.3911	-0.01120
0.3760	1.4138	-0.01484	1.4116	-0.01401	1.4092	-0.01381	1.4070	-0.01349	1.4038	-0.01397
0.4775	1.4216	-0.01634	1.4194	-0.01529	1.4170	-0.01509	1.4148	-0.01479	1.4116	-0.01520
0.5171	1.4248	-0.01676	1.4226	-0.01563	1.4202	-0.01543	1.4180	-0.01513	1.4148	-0.01552
0.6397	1.4363	-0.01650	1.4341	-0.01509	1.4317	-0.01489	1.4295	-0.01462	1.4263	-0.01492
0.7318	1.4454	-0.01584	1.4432	-0.01423	1.4408	-0.01403	1.4386	-0.01377	1.4354	-0.01401
0.8038	1.4533	-0.01452	1.4511	-0.01276	1.4487	-0.01256	1.4465	-0.01232	1.4433	-0.01250
0.9607	1.4744	-0.00780	1.4722	-0.00569	1.4698	-0.00549	1.4676	-0.00528	1.4644	-0.00535
1.0000	1.4858	0.00000	1.4814	0.00000	1.4788	0.00000	1.4764	0.00000	1.4732	0.00000
DETA + Pentyl acetate										
0.0000	1.4068	0.00000	1.4049	0.00000	1.4028	0.00000	1.4002	0.00000	1.3976	0.00000
0.0530	1.4085	-0.00248	1.4063	-0.00265	1.4039	-0.00293	1.4017	-0.00254	1.3985	-0.00315
0.1065	1.4111	-0.00411	1.4089	-0.00415	1.4065	-0.00439	1.4043	-0.00402	1.4011	-0.00460
0.2041	1.4149	-0.00803	1.4127	-0.00782	1.4103	-0.00801	1.4081	-0.00766	1.4049	-0.00818
0.3065	1.4191	-0.01191	1.4169	-0.01145	1.4145	-0.01159	1.4123	-0.01125	1.4091	-0.01172
0.4159	1.4255	-0.01415	1.4233	-0.01341	1.4209	-0.01351	1.4187	-0.01319	1.4155	-0.01359
0.5016	1.431	-0.01543	1.4288	-0.01447	1.4264	-0.01452	1.4242	-0.01422	1.4210	-0.01457
0.6251	1.4405	-0.01568	1.4383	-0.01442	1.4359	-0.01441	1.4337	-0.01413	1.4305	-0.01441
0.7166	1.4481	-0.01531	1.4459	-0.01382	1.4435	-0.01376	1.4413	-0.01351	1.4381	-0.01373
0.8077	1.4574	-0.01321	1.4552	-0.01149	1.4528	-0.01139	1.4506	-0.01115	1.4474	-0.01131
0.9596	1.4769	-0.00571	1.4747	-0.00361	1.4723	-0.00343	1.4701	-0.00322	1.4669	-0.00330
1.0000	1.4858	0.00000	1.4814	0.00000	1.4788	0.00000	1.4764	0.00000	1.4732	0.00000

TABLE-4
REFRACTIVE INDEX (n) AND DEVIATION IN REFRACTIVE INDEX (n^E) FOR THE BINARY SYSTEM DBA + (C_1–C_5) ACETATES At T = (293.15 to 313.15) K

x_1	293.15 K		298.15 K		303.15 K		308.15 K		313.15 K	
	n_D	Δn	n_D	Δn	n_D	Δn	n_D	Δn	n_D	Δn
DBA + Methyl acetate										
0.0000	1.3613	0.00000	1.3594	0.00000	1.3564	0.00000	1.3534	0.00000	1.3505	0.00000
0.0510	1.3641	-0.00012	1.3609	-0.00142	1.3582	-0.00113	1.3545	-0.00184	1.3519	-0.00157
0.1109	1.3651	-0.00255	1.3631	-0.00266	1.3604	-0.00238	1.3557	-0.00410	1.3531	-0.00387
0.2203	1.3682	-0.00570	1.3662	-0.00583	1.3635	-0.00557	1.3588	-0.00731	1.3562	-0.00715
0.2941	1.3705	-0.00762	1.3685	-0.00775	1.3658	-0.00751	1.3611	-0.00927	1.3585	-0.00915
0.4009	1.3745	-0.00973	1.3725	-0.00987	1.3698	-0.00965	1.3651	-0.01143	1.3625	-0.01137
0.5104	1.3802	-0.01029	1.3782	-0.01045	1.3755	-0.01025	1.3698	-0.01305	1.3672	-0.01306
0.6008	1.3849	-0.01077	1.3829	-0.01093	1.3807	-0.01025	1.3743	-0.01377	1.3718	-0.01373
0.7308	1.3937	-0.00940	1.3917	-0.00957	1.3890	-0.00942	1.3828	-0.01277	1.3802	-0.01290
0.8204	1.4015	-0.00672	1.3995	-0.00691	1.3968	-0.00677	1.3911	-0.00963	1.3885	-0.00983
0.9143	1.4115	-0.00210	1.4095	-0.00229	1.4068	-0.00217	1.4021	-0.00405	1.3995	-0.00430
1.0000	1.4185	0.00000	1.4167	0.00000	1.4139	0.00000	1.4111	0.00000	1.4088	0.00000
DBA + Ethyl acetate										
0.0000	1.3722	0.00000	1.3698	0.00000	1.3672	0.00000	1.3644	0.00000	1.3619	0.00000
0.0496	1.3723	-0.00220	1.3703	-0.00183	1.3676	-0.00192	1.3649	-0.00182	1.3623	-0.00193
0.1130	1.3729	-0.00453	1.3709	-0.00420	1.3682	-0.00428	1.3655	-0.00418	1.3629	-0.00430
0.2141	1.3755	-0.00661	1.3735	-0.00634	1.3708	-0.00640	1.3681	-0.00630	1.3655	-0.00644
0.3622	1.3808	-0.00817	1.3788	-0.00799	1.3761	-0.00802	1.3734	-0.00792	1.3708	-0.00809
0.4220	1.3832	-0.00854	1.3812	-0.00839	1.3785	-0.00841	1.3758	-0.00831	1.3732	-0.00849
0.5317	1.3883	-0.00852	1.3863	-0.00843	1.3836	-0.00843	1.3809	-0.00833	1.3783	-0.00853
0.6403	1.3938	-0.00805	1.3918	-0.00803	1.3891	-0.00800	1.3864	-0.00790	1.3838	-0.00813
0.7204	1.3981	-0.00745	1.3961	-0.00749	1.3934	-0.00744	1.3907	-0.00734	1.3881	-0.00759
0.8110	1.4039	-0.00585	1.4019	-0.00593	1.3992	-0.00587	1.3965	-0.00577	1.3939	-0.00603
0.9206	1.4115	-0.00332	1.4095	-0.00348	1.4068	-0.00339	1.4041	-0.00329	1.4015	-0.00358
1.0000	1.4185	0.00000	1.4167	0.00000	1.4139	0.00000	1.4111	0.00000	1.4088	0.00000
DBA + Propyl acetate										
0.0000	1.3838	0.00000	1.3818	0.00000	1.3791	0.00000	1.3764	0.00000	1.3738	0.00000
0.0503	1.3841	-0.00144	1.3821	-0.00145	1.3794	-0.00145	1.3767	-0.00144	1.3741	-0.00146
0.1294	1.3855	-0.00279	1.3835	-0.00281	1.3808	-0.00280	1.3781	-0.00279	1.3755	-0.00283
0.2566	1.3890	-0.00371	1.3870	-0.00376	1.3843	-0.00373	1.3816	-0.00371	1.3790	-0.00378
0.3504	1.3913	-0.00466	1.3893	-0.00473	1.3866	-0.00470	1.3839	-0.00466	1.3813	-0.00477
0.4443	1.3939	-0.00532	1.3919	-0.00541	1.3892	-0.00536	1.3865	-0.00532	1.3839	-0.00545
0.5038	1.3959	-0.00538	1.3939	-0.00548	1.3912	-0.00543	1.3885	-0.00538	1.3859	-0.00553
0.6407	1.4012	-0.00483	1.3992	-0.00496	1.3965	-0.00490	1.3938	-0.00483	1.3912	-0.00502
0.7542	1.4061	-0.00387	1.4041	-0.00402	1.4014	-0.00395	1.3987	-0.00387	1.3961	-0.00410
0.8377	1.4103	-0.00257	1.4083	-0.00274	1.4056	-0.00265	1.4029	-0.00257	1.4003	-0.00282
0.9182	1.4141	-0.00156	1.4121	-0.00175	1.4094	-0.00165	1.4067	-0.00156	1.4041	-0.00184
1.0000	1.4185	0.00000	1.4167	0.00000	1.4139	0.00000	1.4111	0.00000	1.4088	0.00000
DBA + Butyl acetate										
0.0000	1.3942	0.00000	1.3920	0.00000	1.3894	0.00000	1.3868	0.00000	1.3843	0.00000
0.0735	1.3945	-0.00148	1.3925	-0.00131	1.3898	-0.00140	1.3871	-0.00148	1.3845	-0.00160
0.1500	1.3949	-0.00294	1.3929	-0.00280	1.3902	-0.00287	1.3875	-0.00294	1.3849	-0.00307
0.2061	1.3952	-0.00401	1.3932	-0.00389	1.3905	-0.00395	1.3878	-0.00401	1.3852	-0.00415
0.2854	1.3962	-0.00493	1.3942	-0.00485	1.3915	-0.00489	1.3888	-0.00493	1.3862	-0.00509
0.4604	1.3998	-0.00559	1.3978	-0.00557	1.3951	-0.00558	1.3924	-0.00559	1.3898	-0.00578
0.5201	1.4011	-0.00574	1.3991	-0.00575	1.3964	-0.00574	1.3937	-0.00574	1.3911	-0.00594
0.6620	1.4052	-0.00509	1.4032	-0.00515	1.4005	-0.00512	1.3978	-0.00509	1.3952	-0.00532
0.7260	1.4074	-0.00444	1.4054	-0.00453	1.4027	-0.00449	1.4000	-0.00444	1.3974	-0.00469
0.8205	1.4106	-0.00354	1.4086	-0.00367	1.4059	-0.00360	1.4032	-0.00354	1.4006	-0.00380
0.9068	1.4142	-0.00203	1.4122	-0.00220	1.4095	-0.00212	1.4068	-0.00203	1.4042	-0.00232
1.0000	1.4185	0.00000	1.4167	0.00000	1.4139	0.00000	1.4111	0.00000	1.4088	0.00000
DBA + Pentyl acetate										
0.0000	1.4068	0.00000	1.4049	0.00000	1.4028	0.00000	1.4002	0.00000	1.3976	0.00000
0.0610	1.4071	-0.00041	1.4051	-0.00052	1.4024	-0.00108	1.3997	-0.00116	1.3971	-0.00118
0.1029	1.4073	-0.00070	1.4053	-0.00081	1.4026	-0.00134	1.3999	-0.00142	1.3973	-0.00145
0.2042	1.4079	-0.00129	1.4059	-0.00141	1.4032	-0.00187	1.4005	-0.00193	1.3979	-0.00199
0.2430	1.4082	-0.00144	1.4062	-0.00157	1.4035	-0.00200	1.4008	-0.00205	1.3982	-0.00212
0.4086	1.4096	-0.00198	1.4076	-0.00212	1.4049	-0.00244	1.4022	-0.00245	1.3996	-0.00258
0.5024	1.4106	-0.00208	1.4086	-0.00223	1.4059	-0.00248	1.4032	-0.00248	1.4006	-0.00263
0.6013	1.4118	-0.00204	1.4098	-0.00220	1.4071	-0.00237	1.4044	-0.00235	1.4018	-0.00253
0.7047	1.4132	-0.00184	1.4112	-0.00202	1.4085	-0.00212	1.4058	-0.00208	1.4032	-0.00229
0.8035	1.4147	-0.00150	1.4127	-0.00168	1.4100	-0.00172	1.4073	-0.00166	1.4047	-0.00190
0.9041	1.4164	-0.00098	1.4144	-0.00117	1.4117	-0.00114	1.4090	-0.00106	1.4064	-0.00133
1.0000	1.4185	0.00000	1.4167	0.00000	1.4139	0.00000	1.4111	0.00000	1.4088	0.00000

TABLE-5
REFRACTIVE INDEX (n) AND DEVIATION IN REFRACTIVE INDEX (n^E) FOR THE BINARY SYSTEM TBA + (C_1–C_5) ACETATES At T = (293.15 to 313.15) K

x_1	293.15 K		298.15 K		303.15 K		308.15 K		313.15 K	
	n_D	Δn	n_D	Δn	n_D	Δn	n_D	Δn	n_D	Δn
TBA + Methyl acetate										
0.0000	1.3613	0.00000	1.3594	0.00000	1.3564	0.00000	1.3534	0.00000	1.3505	0.00000
0.0501	1.3674	0.00271	1.3654	0.00261	1.3627	0.00287	1.3600	0.00312	1.3574	0.00339
0.1009	1.3725	0.00436	1.3705	0.00426	1.3678	0.00449	1.3651	0.00468	1.3625	0.00491
0.2003	1.3816	0.00672	1.3796	0.00662	1.3769	0.00678	1.3742	0.00688	1.3716	0.00704
0.2941	1.3895	0.00826	1.3875	0.00816	1.3848	0.00825	1.3821	0.00826	1.3795	0.00835
0.4009	1.3976	0.00912	1.3956	0.00902	1.3929	0.00904	1.3902	0.00894	1.3876	0.00896
0.5004	1.4046	0.00937	1.4026	0.00927	1.3999	0.00922	1.3972	0.00902	1.3946	0.00897
0.6008	1.4107	0.00867	1.4087	0.00857	1.406	0.00845	1.4033	0.00814	1.4007	0.00802
0.7008	1.4156	0.00679	1.4136	0.00669	1.4109	0.00650	1.4082	0.00610	1.4056	0.00591
0.8004	1.4201	0.00454	1.4181	0.00444	1.4154	0.00418	1.4127	0.00368	1.4101	0.00342
0.9003	1.4244	0.00206	1.4224	0.00196	1.4197	0.00163	1.4176	0.00163	1.4152	0.00150
1.0000	1.4291	0.00000	1.4272	0.00000	1.4249	0.00000	1.4229	0.00000	1.4207	0.00000
TBA + Ethyl acetate										
0.0000	1.3722	0.00000	1.3698	0.00000	1.3672	0.00000	1.3644	0.00000	1.3619	0.00000
0.0502	1.3760	0.00095	1.374	0.00132	1.3713	0.00121	1.3686	0.00127	1.3660	0.00115
0.1040	1.3801	0.00198	1.3781	0.00233	1.3754	0.00220	1.3727	0.00222	1.3701	0.00209
0.2041	1.3870	0.00319	1.385	0.00348	1.3823	0.00332	1.3796	0.00326	1.3770	0.00310
0.3022	1.3934	0.00400	1.3914	0.00425	1.3887	0.00406	1.3860	0.00392	1.3834	0.00373
0.4020	1.3998	0.00473	1.3978	0.00492	1.3951	0.00470	1.3924	0.00448	1.3898	0.00426
0.5017	1.4059	0.00516	1.4039	0.00531	1.4012	0.00505	1.3985	0.00475	1.3959	0.00450
0.6003	1.4116	0.00524	1.4096	0.00534	1.4069	0.00506	1.4042	0.00468	1.4016	0.00440
0.7004	1.4168	0.00475	1.4148	0.00480	1.4121	0.00449	1.4094	0.00403	1.4068	0.00372
0.8009	1.4215	0.00373	1.4195	0.00373	1.4168	0.00339	1.4141	0.00284	1.4115	0.00250
0.9011	1.4255	0.00203	1.4235	0.00198	1.4208	0.00161	1.4185	0.00139	1.4161	0.00122
1.0000	1.4291	0.00000	1.4272	0.00000	1.4249	0.00000	1.4229	0.00000	1.4207	0.00000
TBA + Propyl acetate										
0.0000	1.3838	0.00000	1.3818	0.00000	1.3791	0.00000	1.3764	0.00000	1.3738	0.00000
0.0509	1.3875	0.00139	1.3855	0.00139	1.3828	0.00137	1.3801	0.00133	1.3775	0.00131
0.1204	1.3925	0.00325	1.3905	0.00324	1.3878	0.00319	1.3851	0.00310	1.3825	0.00306
0.2066	1.3976	0.00444	1.3956	0.00442	1.3929	0.00434	1.3902	0.00419	1.3876	0.00411
0.3060	1.4029	0.00524	1.4009	0.00521	1.3982	0.00508	1.3955	0.00487	1.3929	0.00475
0.4043	1.4079	0.00579	1.4059	0.00575	1.4032	0.00558	1.4005	0.00530	1.3979	0.00514
0.5015	1.4125	0.00598	1.4105	0.00593	1.4078	0.00573	1.4051	0.00538	1.4025	0.00518
0.6007	1.4170	0.00599	1.415	0.00593	1.4123	0.00569	1.4096	0.00527	1.4070	0.00503
0.7102	1.4216	0.00563	1.4196	0.00556	1.4169	0.00527	1.4142	0.00478	1.4116	0.00449
0.8007	1.4248	0.00473	1.4228	0.00465	1.4201	0.00433	1.4174	0.00377	1.4148	0.00345
0.9008	1.4278	0.00319	1.4258	0.00310	1.4231	0.00274	1.4204	0.00211	1.4178	0.00175
1.0000	1.4291	0.00000	1.4272	0.00000	1.4249	0.00000	1.4229	0.00000	1.4207	0.00000
TBA + Butyl acetate										
0.0000	1.3942	0.00000	1.3920	0.00000	1.3894	0.00000	1.3868	0.00000	1.3843	0.00000
0.0535	1.3965	0.00043	1.3945	0.00062	1.3918	0.00050	1.3891	0.00037	1.3866	0.00035
0.1100	1.3991	0.00106	1.3971	0.00123	1.3944	0.00110	1.3917	0.00093	1.3891	0.00080
0.2003	1.4027	0.00151	1.4007	0.00165	1.3980	0.00149	1.3953	0.00127	1.3927	0.00111
0.3239	1.4073	0.00180	1.4053	0.00190	1.4026	0.00170	1.3999	0.00141	1.3974	0.00131
0.4004	1.4101	0.00193	1.4081	0.00201	1.4054	0.00179	1.4027	0.00145	1.4002	0.00133
0.5020	1.4137	0.00198	1.4117	0.00203	1.4090	0.00178	1.4064	0.00148	1.4039	0.00133
0.5920	1.4168	0.00194	1.4148	0.00196	1.4121	0.00168	1.4095	0.00133	1.4071	0.00125
0.7201	1.4211	0.00177	1.4191	0.00175	1.4164	0.00144	1.4138	0.00100	1.4116	0.00109
0.8002	1.4236	0.00147	1.4216	0.00143	1.4189	0.00109	1.4164	0.00071	1.4143	0.00087
0.9065	1.4267	0.00086	1.4247	0.00079	1.4220	0.00042	1.4199	0.00037	1.4178	0.00050
1.0000	1.4291	0.00000	1.4272	0.00000	1.4249	0.00000	1.4229	0.00000	1.4207	0.00000
TBA + Pentyl acetate										
0.0000	1.4068	0.00000	1.4049	0.00000	1.4028	0.00000	1.4002	0.00000	1.3976	0.00000
0.0575	1.4090	0.00092	1.4070	0.00082	1.4045	0.00043	1.4018	0.00029	1.3992	0.00027
0.1106	1.4108	0.00153	1.4088	0.00143	1.4061	0.00085	1.4034	0.00069	1.4008	0.00064
0.2013	1.4134	0.00211	1.4114	0.00201	1.4087	0.00145	1.4060	0.00123	1.4034	0.00115
0.3229	1.4166	0.00260	1.4146	0.00250	1.4119	0.00196	1.4092	0.00167	1.4066	0.00154
0.4109	1.4187	0.00274	1.4167	0.00264	1.4140	0.00212	1.4113	0.00177	1.4087	0.00161
0.5032	1.4209	0.00288	1.4189	0.00278	1.4162	0.00228	1.4135	0.00188	1.4109	0.00168
0.6202	1.4234	0.00277	1.4214	0.00267	1.4187	0.00219	1.4160	0.00172	1.4134	0.00147
0.7403	1.4258	0.00249	1.4238	0.00239	1.4211	0.00194	1.4184	0.00139	1.4158	0.00110
0.8105	1.4269	0.00203	1.4249	0.00193	1.4222	0.00149	1.4197	0.00110	1.4171	0.00078
0.9205	1.4285	0.00117	1.4265	0.00107	1.4238	0.00066	1.4216	0.00051	1.4191	0.00024
1.0000	1.4291	0.00000	1.4272	0.00000	1.4249	0.00000	1.4229	0.00000	1.4207	0.00000

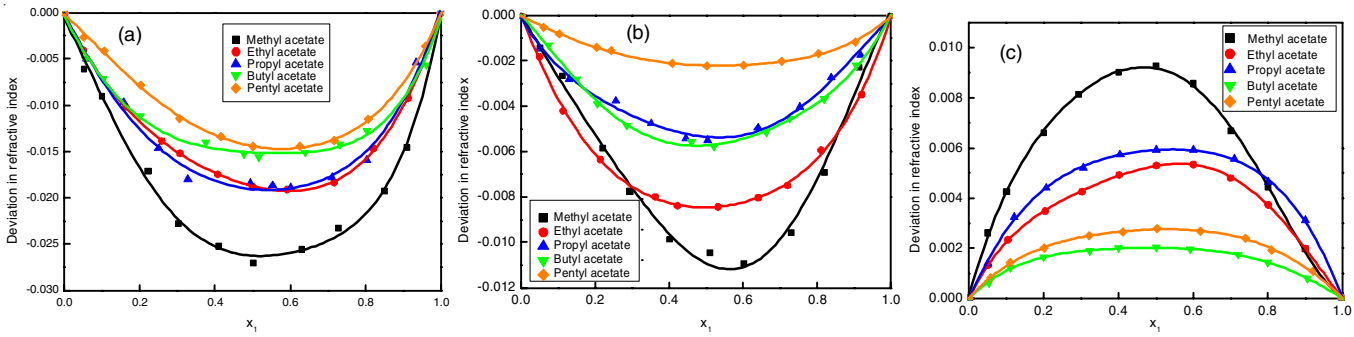

Fig. 1. Deviation in refractive index against mole fractions of x_1 DETA + x_2 alkyl acetate (C_1-C_5) (a); x_1 DBA + x_2 alkyl acetate (C_1-C_5) (b) and x_1 TBA + x_2 alkyl acetate (C_1-C_5) (c) at 298.15 K. The smoothing of the curve has been drawn from Redlich-Kister polynomial equation

TABLE-6
COEFFICIENTS OF A_i OF REDLICH-KISTER POLYNOMIAL EQUATION AND STANDARD DEVIATIONS (σ) FOR THE BINARY MIXTURES AT DIFFERENT TEMPERATURES

Excess property	Temperature (K)	A_1	A_2	A_3	A_4	σ
DETA (1) + Methyl acetate (2)	293.15	-0.10460	-0.00808	-0.04280	-0.07480	0.00070
	298.15	-0.10460	-0.00571	-0.04460	-0.05570	0.00080
	303.15	-0.10670	-0.00664	-0.05090	-0.05670	0.00090
	308.15	-0.10850	-0.00767	-0.05610	-0.05960	0.00090
	313.15	-0.11000	-0.00778	-0.06120	-0.05580	0.00100
DETA (1) + Ethyl acetate (2)	293.15	-0.07560	-0.02230	-0.03270	-0.01670	0.00020
	298.15	-0.07480	-0.02050	-0.03140	-0.00130	0.00010
	303.15	-0.07770	-0.02120	-0.03960	0.00111	0.00030
	308.15	-0.07980	-0.02210	-0.04560	-0.00028	0.00040
	313.15	-0.08210	-0.02220	-0.05260	0.00727	0.00050
DETA (1) + Propyl acetate (2)	293.15	-0.08000	-0.01070	-0.03660	-0.02960	0.00070
	298.15	-0.07640	-0.00858	-0.02630	-0.01020	0.00090
	303.15	-0.07550	-0.00852	-0.02360	-0.01130	0.00090
	308.15	-0.07430	-0.00855	-0.01990	-0.01420	0.00090
	313.15	-0.07550	-0.00832	-0.02370	-0.00875	0.00090
DETA (1) + Butyl acetate (2)	293.15	-0.06390	-0.00241	-0.06180	-0.04480	0.00100
	298.15	-0.06020	-0.00329	-0.04750	-0.01980	0.00060
	303.15	-0.05950	-0.00353	-0.04520	-0.01940	0.00060
	308.15	-0.05840	-0.00392	-0.04190	-0.02070	0.00050
	313.15	-0.05980	-0.00331	-0.04600	-0.01450	0.00060
DETA (1) + Pentyl acetate (2)	293.15	-0.06060	-0.01560	-0.02390	-0.03960	0.00040
	298.15	-0.05760	-0.01500	-0.01120	-0.01410	0.00020
	303.15	-0.05780	-0.01480	-0.01150	-0.00923	0.00030
	308.15	-0.05680	-0.01490	-0.00812	-0.01090	0.00020
	313.15	-0.05800	-0.01460	-0.01190	-0.00533	0.00030
DBA (1) + Methyl acetate (2)	293.15	-0.04360	-0.01290	0.01900	0.00537	0.00060
	298.15	-0.04380	-0.01590	0.01400	0.01570	0.00040
	303.15	-0.04250	-0.01400	0.01480	0.00967	0.00050
	308.15	-0.05300	-0.02730	0.00183	0.02540	0.00040
	313.15	-0.05290	-0.02750	0.00177	0.01990	0.00040
DBA (1) + Ethyl acetate (2)	293.15	-0.03420	0.00109	-0.01500	0.00029	0.00010
	298.15	-0.03380	0.00055	-0.01380	-0.00456	0.00010
	303.15	-0.03380	0.00073	-0.01380	-0.00299	0.00010
	308.15	-0.03350	0.00074	-0.01280	-0.00312	0.00010
	313.15	-0.03420	0.00054	-0.01490	-0.00442	0.00010
DBA (1) + Propyl acetate (2)	293.15	-0.02100	-0.00266	-0.00067	0.01060	0.00020
	298.15	-0.02140	-0.00287	-0.00166	0.00928	0.00020
	303.15	-0.02120	-0.00276	-0.00117	0.01000	0.00020
	308.15	-0.02100	-0.00266	-0.00067	0.01060	0.00020
	313.15	-0.02150	-0.00298	-0.00216	0.00860	0.00020
DBA (1) + Butyl acetate (2)	293.15	-0.02290	0.00267	-0.00178	-0.00592	0.00009
	298.15	-0.02290	0.00229	-0.00175	-0.00875	0.00009
	303.15	-0.02290	0.00248	-0.00176	-0.00734	0.00009
	308.15	-0.02290	0.00267	-0.00178	-0.00592	0.00009
	313.15	-0.02360	0.00241	-0.00365	-0.00712	0.00008

DBA (1) + Pentyl acetate (2)	293.15	-0.00826	-0.00058	-0.00140	-0.00245	0.00002
	298.15	-0.00880	-0.00081	-0.00287	-0.00273	0.00003
	303.15	-0.00964	-0.00048	-0.00556	0.00340	0.00009
	308.15	-0.00963	-0.00031	-0.00562	0.00492	0.00010
	313.15	-0.01020	-0.00071	-0.00703	0.00312	0.00010
TBA (1) + Methyl acetate (2)	293.15	0.03700	-0.00507	-0.00355	-0.01830	0.00010
	298.15	0.03670	-0.00517	-0.00458	-0.01790	0.00010
	303.15	0.03650	-0.00588	-0.00478	-0.02310	0.00010
	308.15	0.03540	-0.00837	-0.00318	-0.02320	0.00020
	313.15	0.03510	-0.00953	-0.00230	-0.02610	0.00030
TBA (1) + Ethyl acetate (2)	293.15	0.02060	0.00552	0.00196	-0.00651	0.00005
	298.15	0.02110	0.00519	0.00373	-0.01080	0.00003
	303.15	0.02020	0.00466	0.00128	-0.01220	0.00003
	308.15	0.01890	0.00271	0.00067	-0.01260	0.00003
	313.15	0.01800	0.00174	-0.00071	-0.01170	0.00005
TBA (1) + Propyl acetate (2)	293.15	0.02390	0.00204	0.01350	0.00144	0.00008
	298.15	0.02370	0.00190	0.01300	0.00086	0.00008
	303.15	0.02300	0.00135	0.01110	-0.00147	0.00008
	308.15	0.02170	0.00040	0.00786	-0.00554	0.00009
	313.15	0.02100	-0.00015	0.00599	-0.00787	0.00010
TBA (1) + Butyl acetate (2)	293.15	0.007912	0.000105	0.003683	-0.000218	0.000051
	298.15	0.008085	-0.000155	0.004278	-0.002599	0.000031
	303.15	0.007191	-0.000586	0.001810	-0.004173	0.000055
	308.15	0.005746	-0.001868	0.001189	-0.001752	0.000059
	313.15	0.005297	-0.001035	0.002481	-0.000221	0.000030
TBA (1) + Pentyl acetate (2)	293.15	0.01130	0.00074	0.00601	-0.00180	0.00004
	298.15	0.01100	0.00072	0.00496	-0.00166	0.00003
	303.15	0.00916	0.00122	0.00021	-0.00107	0.00003
	308.15	0.00747	-0.00064	-0.00064	0.00130	0.00003
	313.15	0.00672	-0.00131	-0.00220	-0.00034	0.00003

$$\phi_1 = \frac{x_1 V_1}{\sum x_i V_i} \text{ and } \phi_2 = \frac{x_2 V_2}{\sum x_i V_i} \quad (10)$$

From these mixing rules standard deviation were also calculated and reported in Table-7. It is concluded that all mixing rules have good results for all the binary mixtures.

Fig. 1(a-c) show deviation in refractive index data *versus* x_1 for various binary systems of aliphatic amines and aliphatic (C_1-C_5) acetates. The deviation in refractive index (Δn) for DETA (1) + (C_1-C_5) acetates (2) and DBA + (C_1-C_5) acetates (2) binary systems are negative while in case of TBA, Δn is positive. The Δn values for DETA and DBA at equimolar mixtures follow the sequence: $C_5 > C_4 > C_3 > C_2 \approx C_1$ while for TBA, the order is $C_1 > C_2 > C3 > C_4 \approx C_5$. Fig. 2 show plot of standard deviation against various correlations used for the binary mixtures of DETA, DBA and TBA with aliphatic acetates at 298.15 K. From

TABLE-7
STANDARD DEVIATION OF CALCULATED VALUES OF REFRACTIVE INDEX USING VARIOUS CORRELATIONS AT 293.15 TO 313.15 K

Binary system	Temp. (K)	Arago-Biot	Gladstone-Dale	Lorentz-Lorenz	Weiner	Heller	Newton	Eyring
DETA (1) + Methyl acetate (2)	293.15	0.0004090	0.0004090	0.0003800	0.0006070	0.0004090	0.0004090	0.0003800
	298.15	0.0004040	0.0004040	0.0003760	0.0005960	0.0004040	0.0004040	0.0003760
	303.15	0.0004200	0.0004200	0.0003920	0.0006180	0.0004200	0.0004200	0.0003920
	308.15	0.0004340	0.0004340	0.0004050	0.0006370	0.0004340	0.0004340	0.0004050
	313.15	0.0004440	0.0004440	0.0004150	0.0006500	0.0004440	0.0004440	0.0004150
DETA (1) + Ethyl acetate (2)	293.15	0.0001660	0.0001660	0.0001500	0.0002880	0.0001660	0.0001660	0.0001500
	298.15	0.0001600	0.0001600	0.0001450	0.0002790	0.0001600	0.0001600	0.0001450
	303.15	0.0001740	0.0001740	0.0001580	0.0002970	0.0001740	0.0001740	0.0001580
	308.15	0.0001840	0.0001840	0.0001680	0.0003120	0.0001840	0.0001840	0.0001680
	313.15	0.0001960	0.0001960	0.0001790	0.0003260	0.0001960	0.0001960	0.0001790
DETA (1) + Propyl acetate (2)	293.15	0.0001260	0.0001260	0.0001150	0.0002140	0.0001260	0.0001260	0.0001150
	298.15	0.0001100	0.0001100	0.0000998	0.0001910	0.0001100	0.0001100	0.0000998
	303.15	0.0001060	0.0001060	0.0000957	0.0001850	0.0001060	0.0001060	0.0000957
	308.15	0.0001000	0.0001000	0.0000904	0.0001780	0.0001000	0.0001000	0.0000904
	313.15	0.0001050	0.0001050	0.0000947	0.0001840	0.0001050	0.0001050	0.0000947
DETA (1) + Butyl acetate (2)	293.15	0.0000571	0.0000571	0.0000512	0.0001110	0.0000571	0.0000571	0.0000512
	298.15	0.0000459	0.0000459	0.0000408	0.0000935	0.0000459	0.0000459	0.0000408
	303.15	0.0000437	0.0000437	0.0000388	0.0000906	0.0000437	0.0000437	0.0000388
	308.15	0.0000407	0.0000407	0.0000359	0.0000864	0.0000407	0.0000407	0.0000359
	313.15	0.0000443	0.0000443	0.0000394	0.0000914	0.0000443	0.0000443	0.0000394

DETA (1) + Pentyl acetate (2)	293.15	0.0000292	0.0000292	0.0000261	0.0000575	0.0000292	0.0000292	0.0000261
	298.15	0.0000229	0.0000229	0.0000203	0.0000478	0.0000229	0.0000229	0.0000203
	303.15	0.0000231	0.0000231	0.0000205	0.0000482	0.0000231	0.0000231	0.0000205
	308.15	0.0000210	0.0000210	0.0000186	0.0000451	0.0000210	0.0000210	0.0000186
	313.15	0.0000233	0.0000233	0.0000207	0.0000485	0.0000233	0.0000233	0.0000207
DBA (1) + Methyl acetate (2)	293.15	0.0001270	0.0001270	0.0001240	0.0001450	0.0001270	0.0001270	0.0001240
	298.15	0.0001300	0.0001300	0.0001270	0.0001490	0.0001300	0.0001300	0.0001270
	303.15	0.0001260	0.0001260	0.0001230	0.0001440	0.0001260	0.0001260	0.0001230
	308.15	0.0001660	0.0001660	0.0001630	0.0001870	0.0001660	0.0001660	0.0001630
	313.15	0.0001670	0.0001670	0.0001630	0.0001890	0.0001670	0.0001670	0.0001630
DBA (1) + Ethyl acetate (2)	293.15	0.0000711	0.0000711	0.0000695	0.0000810	0.0000711	0.0000711	0.0000695
	298.15	0.0000705	0.0000705	0.0000688	0.0000805	0.0000705	0.0000705	0.0000688
	303.15	0.0000701	0.0000701	0.0000685	0.0000801	0.0000701	0.0000701	0.0000685
	308.15	0.0000688	0.0000688	0.0000672	0.0000787	0.0000688	0.0000688	0.0000672
	313.15	0.0000712	0.0000712	0.0000695	0.0000813	0.0000712	0.0000712	0.0000695
DBA (1) + Propyl acetate (2)	293.15	0.0000225	0.0000225	0.0000219	0.0000258	0.0000225	0.0000225	0.0000219
	298.15	0.0000232	0.0000232	0.0000226	0.0000266	0.0000232	0.0000232	0.0000226
	303.15	0.0000228	0.0000228	0.0000222	0.0000261	0.0000228	0.0000228	0.0000222
	308.15	0.0000223	0.0000223	0.0000218	0.0000257	0.0000223	0.0000223	0.0000218
	313.15	0.0000234	0.0000234	0.0000229	0.0000269	0.0000234	0.0000234	0.0000229
DBA (1) + Butyl acetate (2)	293.15	0.0000159	0.0000159	0.0000156	0.0000173	0.0000159	0.0000159	0.0000156
	298.15	0.0000159	0.0000159	0.0000157	0.0000174	0.0000159	0.0000159	0.0000157
	303.15	0.0000159	0.0000159	0.0000157	0.0000173	0.0000159	0.0000159	0.0000157
	308.15	0.0000158	0.0000158	0.0000156	0.0000172	0.0000158	0.0000158	0.0000156
	313.15	0.0000170	0.0000170	0.0000168	0.0000185	0.0000170	0.0000170	0.0000168
DBA (1) + Pentyl acetate (2)	293.15	0.0000018	0.0000018	0.0000018	0.0000019	0.0000018	0.0000018	0.0000018
	298.15	0.0000021	0.0000021	0.0000021	0.0000023	0.0000021	0.0000021	0.0000021
	303.15	0.0000027	0.0000027	0.0000026	0.0000028	0.0000027	0.0000027	0.0000026
	308.15	0.0000027	0.0000027	0.0000027	0.0000028	0.0000027	0.0000027	0.0000027
	313.15	0.0000030	0.0000030	0.0000030	0.0000032	0.0000030	0.0000030	0.0000030
TBA (1) + Methyl acetate (2)	293.15	0.0000230	0.0000377	0.0000231	0.0000264	0.0000230	0.0000377	0.0000231
	298.15	0.0000228	0.0000384	0.0000235	0.0000269	0.0000228	0.0000384	0.0000235
	303.15	0.0000235	0.0000394	0.0000242	0.0000277	0.0000235	0.0000394	0.0000242
	308.15	0.0000253	0.0000421	0.0000261	0.0000298	0.0000253	0.0000421	0.0000261
	313.15	0.0000261	0.0000432	0.0000269	0.0000307	0.0000261	0.0000432	0.0000269
TBA (1) + Ethyl acetate (2)	293.15	0.0000154	0.0000249	0.0000158	0.0000178	0.0000154	0.0000249	0.0000158
	298.15	0.0000147	0.0000240	0.0000151	0.0000171	0.0000147	0.0000240	0.0000151
	303.15	0.0000160	0.0000258	0.0000164	0.0000186	0.0000160	0.0000258	0.0000164
	308.15	0.0000179	0.0000284	0.0000183	0.0000206	0.0000179	0.0000284	0.0000183
	313.15	0.0000193	0.0000303	0.0000198	0.0000222	0.0000193	0.0000303	0.0000198
TBA (1) + Propyl acetate (2)	293.15	0.0000012	0.0000034	0.0000013	0.0000016	0.0000012	0.0000034	0.0000013
	298.15	0.0000012	0.0000034	0.0000013	0.0000017	0.0000012	0.0000034	0.0000013
	303.15	0.0000014	0.0000038	0.0000015	0.0000019	0.0000014	0.0000038	0.0000015
	308.15	0.0000020	0.0000047	0.0000021	0.0000026	0.0000020	0.0000047	0.0000021
	313.15	0.0000024	0.0000053	0.0000024	0.0000030	0.0000024	0.0000053	0.0000024
TBA (1) + Butyl acetate (2)	293.15	0.0000026	0.0000041	0.0000027	0.0000030	0.0000026	0.0000041	0.0000027
	298.15	0.0000025	0.0000040	0.0000026	0.0000029	0.0000025	0.0000040	0.0000026
	303.15	0.0000032	0.0000048	0.0000032	0.0000036	0.0000032	0.0000048	0.0000032
	308.15	0.0000041	0.0000060	0.0000041	0.0000046	0.0000041	0.0000060	0.0000041
	313.15	0.0000043	0.0000064	0.0000044	0.0000049	0.0000043	0.0000064	0.0000044
TBA (1) + Pentyl acetate (2)	293.15	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001
	298.15	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001
	303.15	0.0000000	0.0000002	0.0000000	0.0000001	0.0000000	0.0000002	0.0000000
	308.15	0.0000002	0.0000004	0.0000002	0.0000002	0.0000002	0.0000004	0.0000002
	313.15	0.0000003	0.0000006	0.0000003	0.0000004	0.0000003	0.0000006	0.0000003

these figures, it can be seen that Lorentz-Lorentz correlation is having minimum standard deviation among all the correlations used.

As the Δn values for all the binary mixtures are negative may be due to interstitial structural fitting of ester molecules in the accumulation of amine molecules and increase in volume fraction except TBA + alkyl acetates (C_1-C_5). The negative values show the specific molecular interaction between these two components of binary mixture [27-29]. The negative Δn values decreases for all the binary systems with increase in carbon chain length of acetate group because refractive index depends on speed of light as carbon number increases in the acetate group the system became rarer and the molecular interaction decreases hence the bonding between amine and acetate components becomes weaker due to increase of size of acetate group. In case of TBA, the Δn values are positive which shows there are

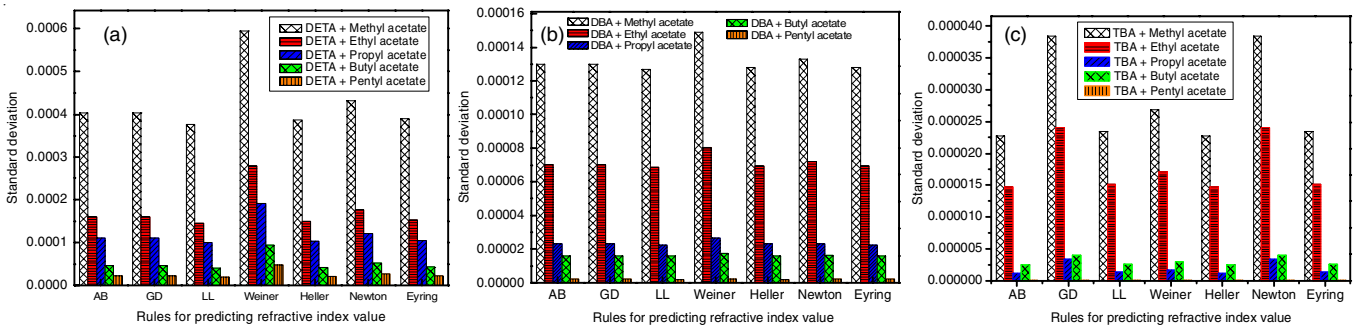

Fig. 2. Standard deviation of calculated values of refractive index using various correlations fractions of x_1 DETA + x_2 alkyl acetate (C_1-C_5) (a); x_1 DBA + x_2 alkyl acetate (C_1-C_5) (b) and x_1 TBA + x_2 alkyl acetate (C_1-C_5) (c) at 298.15 K

weak van der Waal type of interactions between these two components due to bulky butyl groups on nitrogen atom and became more positive as the carbon chain length increased due to steric hindrance.

Temperature also impacts slightly the Δn values. As the temperature is increased the negative Δn values for all the binary mixtures decreases and in case of TBA, the positive Δn values become more positive because as the temperature is increased the molecular interaction decreases between the components. Also when the temperature is increased disorientation of amine and acetate group takes place and the interactions become weak and the system becomes less dense as compare to earlier hence molar refractivity decreases. Furthermore, predicted molar refractivity from all correlations is in well agreement with experimentally measured values. The standard deviations for all correlations used to predict molar refractivity for all the binary mixtures are given in Table-7.

Conclusion

Deviations in refractive index (Δn) for binary liquid mixtures of aliphatic amines and aliphatic acetates were determined at 293.15 to 313.15 K at the interval of 5 K on the entire composition. The Δn results for the binary mixtures of DETA and DBA are negative except in binary mixtures containing TBA. Various mixing rules applied for the theoretical estimation of refractive index and have good results with experimental data for all binary systems. As we move from methyl acetate to pentyl acetate, the interaction decreases. The negative magnitude of values show the presence of specific interaction in case of diethylenetriamine (DETA) and dibutylamine (DBA), but in case of tributylamine (TBA) there are weak forces. The predicted result from various correlation of Δn also supports experimental data.

ACKNOWLEDGEMENTS

Financial assistance provided by Haryana State Council for Science and Technology, Panchkula, India (Ref. No. 1796, dated 23-06-2015) is gratefully acknowledged.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this article.

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