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EXPERIMENTAL AND THEORETICAL PREDICTIONS OF VISCOSITY IN BINARY LIQUID MIXTURES CONTAINING QUINOLINE WITH ARENES (BENZENE, TOLUENE AND MESITYLENE) AT TEMPERATURE T=303.15K : A COMPARATIVE STUDY

Sk. Fakruddin Babavali[*,1,4], Ch. Srinivasu[2], K. Narendra[1] and Ch.Sridhar Yesaswi[3]

[1] Department of Physics, V.R. Siddhartha Engineering College, Vijayawada (A.P), India.
[2] Department of Physics, Andhra Loyola College, Vijayawada (A.P), India.
[3]Department of Mechanical Engineering, K.L.University,Vaddeswaram,Vijayawada (A.P), India.
[4] Research Scholar, Department of Physics, Rayalaseema University, Kurnool (A.P), India.
*E-mail: fakruddinspl@gmail.com

ABSTRACT

Theoretical viscosities have been calculated for three binary liquid mixtures quinoline with arenes [quinoline +benzene, +toluene, +mesitylene] at 303.15 K using Bingham relation, Kendall-Munroe relation, Arrhenius- Eyring relation, Croenaurer-Rothfus-Kermore relation and Gambrill relation. The validity of these theories has been checked by estimating average percentage deviations between calculated values and experimental values. The results of all the theories are comparatively good agreement with experimental results. Among the reported theories, Bingham relation gives the best results.

Keywords: Viscosity, quinoline, arenes, benzene, toluene, mesitylene.

INTRODUCTION

Transport and thermo acoustic properties of binary liquid mixtures provide a lot of knowledge about molecular interactions occurring in liquid mixtures. Viscosity is an important transport property[1] for process design in chemical and other industries involving fluid transportation, mixing, agitation, filtration, heat exchange and concentration. Therefore, viscosities of binary liquid mixtures have been determined using experimental methods[2-8] and theoretical methods[9-11] (Bingham relation, Kendall-Munroe relation, Arrhenius- Eyring relation, Croenaurer-Rothfus-Kermore relation and Gambrill relation) by several workers. These viscosity models have been proposed especially for binary and non-electrolytic solutions[12]**.** For computing the viscosities of liquid mixtures, experimental values of viscosity ,molar volumes of pure liquids are required. In the present study, theoretical viscosity of three binary liquid mixtures (quinoline + benzene, +toluene, +mesitylene) at temperature T=303.15K have been calculated using Bingham relation, Kendall-Munroe relation, Arrhenius- Eyring relation, Croenaurer-Rothfus-Kermore relation and Gambrill relation.

EXPERIMENTAL

In the present investigation the chemicals used are of AR grade (Quinoline obtained from SDFCL chemical distribution company with 98% of purity, whereas benzene toluene and mesitylene are obtained from MERCK chemical distribution company with 99% of purity) and they are purified by standard procedure[13]**.**The different concentrations of the liquid mixture are prepared by varying mole fractions with respect to Job's method of continuous variation. Stoppard conical flasks are used for preserving the

prepared mixtures and the flasks are left undisturbed to attain thermal equilibrium. The temperature of the pure liquids or liquid mixtures is done by using temperature controlled water bath by circulating water around the liquid cell which is present in interferometer. Specific gravity bottle is used for the measurement of densities of pure liquids and liquid mixtures. An electronic weighing balance (Shimadzu AUY220, Japan), with a precision of + /- 0.1 mg is used for the measurements of mass of pure liquids or liquid mixtures. Average of 4 to 5 measurements is taken for each sample. Ostwald's viscometer is used for the measurement of viscosity of pure liquids or liquid mixtures. The time of flow of liquid in the viscometer is measured with an electronic stopwatch with a precision of 0.01s.

Theory

The viscosity of the binary liquid mixtures, undertaken for the present study, has been calculated using Bingham relation, Kendall-Munroe relation, Arrhenius- Eyring relation, Croenaurer-Rothfus-Kermore relation and Gambrill relation are as follows-

Bingham relation: $\eta_m = \sum x_i \eta_i$ (1)

Kendall-Munroe relation: $\log \eta_m = \sum x_i \log\eta_i$ (2)

Arrhenius-Eyring relation: $\log (\eta_m V_m) = \sum x_i \log(V_i\eta_i)$ (3)

Croenauer-Rothfus-Kermore relation: $\log \nu_m = \sum x_i \log(\nu_i)$ (4)

Gambrill relation: $\nu_m^{1/3} = \sum x_i \nu_i^{1/3}$ (5)

Where, η_m, Vm and ν_m respectively are viscosity, molar volume and kinematic viscosity of mixture. Whereas x_i, η_i, Vi and ν_i respectively are mole fraction, viscosity, molar volume and kinematic viscosity of individual pure liquids.

Table-1: Theoretical values of viscosities calculated using Bingham relation(η_B), Kendall-Munroe relation(η_{KM}), Arrhenius- Eyring relation(η_{AE}), Croenaurer-Rothfus-Kermore relation(η_{CRK}) and Gambrill relation(η_G) along with experimental values(η_{EXP}) in all the three binary liquid mixtures at temperature T=303.15K.

Mole fraction of quinoline (X_1)	η_{EXP} 10^{-3} Nsm^{-2}	η_B 10^{-3} Nsm^{-2}	η_{KM} 10^{-3} Nsm^{-2}	η_{AE} 10^{-3} Nsm^{-2}	η_{CRK} 10^{-3}Nsm^{-2}	η_G 10^{-3} Nsm^{-2}
(Quinoline + Benzene)						
0.0000	0.6200	0.6200	0.6200	0.6200	0.6200	0.6200
0.0779	0.8490	0.8000	0.6997	0.6974	0.6896	0.7219
0.1596	1.0780	0.9891	0.7945	0.7898	0.7891	0.8407
0.2457	1.3070	1.1880	0.9081	0.9008	0.9076	0.9795
0.3362	1.5360	1.3974	1.0453	1.0354	1.0497	1.1418
0.4318	1.7650	1.6183	1.2126	1.2001	1.2216	1.3320
0.5327	1.9940	1.8515	1.4184	1.4036	1.4313	1.5552
0.6394	2.2230	2.0982	1.6741	1.6579	1.6894	1.8178
0.7524	2.4520	2.3596	1.9956	1.9795	2.0103	2.1274
0.8724	2.6810	2.6371	2.4045	2.3915	2.4135	2.4934
1.0000	2.9320	2.9320	2.9320	2.9320	2.9320	2.9320
(Quinoline + Toluene)						
0.0000	0.5910	0.5910	0.5910	0.5910	0.5910	0.5910
0.0904	0.8490	0.8027	0.6831	0.6873	0.6908	0.7113
0.1828	1.0780	1.0190	0.7920	0.8014	0.8088	0.8514
0.2772	1.3070	1.2400	0.9213	0.9374	0.9486	1.0141
0.3737	1.5360	1.4658	1.0752	1.0998	1.1148	1.2024

0.4723	1.7650	1.6966	1.2591	1.2944	1.3129	1.4196
0.5731	1.9940	1.9326	1.4797	1.5287	1.5496	1.6694
0.6762	2.2230	2.1740	1.7454	1.8118	1.8334	1.9560
0.7817	2.4520	2.4209	2.0665	2.1235	2.1425	2.2504
0.8896	2.6810	2.6735	2.4563	2.4904	2.5027	2.5728
1.0000	2.9320	2.9320	2.9320	2.9320	2.9320	2.9320
(Quinoline + Mesitylene)						
0.0000	0.6213	0.6213	0.6213	0.6213	0.6213	0.6213
0.1160	0.9089	0.8893	0.7438	0.7420	0.7421	0.7671
0.2280	1.2002	1.1480	0.8849	0.8819	0.8823	0.9319
0.3361	1.4719	1.3978	1.0465	1.0401	1.0406	1.1128
0.4405	1.7314	1.6392	1.2306	1.2206	1.2212	1.3121
0.5415	1.9700	1.8725	1.4393	1.4130	1.4137	1.5167
0.6392	2.2010	2.0983	1.6749	1.6366	1.6373	1.7448
0.7337	2.4140	2.3168	1.9395	1.8828	1.8833	1.9850
0.8253	2.6148	2.5283	2.2356	2.1522	2.1525	2.2359
0.9140	2.7950	2.7333	2.5654	2.4822	2.4821	2.5333
1.0000	2.9320	2.9320	2.9320	2.9320	2.9320	2.9320

Table-2: Percentage deviations of theoretical values of viscosities with that of experimental values in all the three binary liquid mixtures at temperature T=303.15K.

Mole fraction of quinoline (X_1)	% $\Delta\eta_B$	% $\Delta\eta_{KM}$	% $\Delta\eta_{AE}$	% $\Delta\eta_{CRK}$	% $\Delta\eta_G$
(Quinoline + Benzene)					
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0779	0.0490	0.1493	0.1516	0.1594	0.1271
0.1596	0.0889	0.2835	0.2882	0.2889	0.2373
0.2457	0.1190	0.3989	0.4062	0.3994	0.3275
0.3362	0.1386	0.4907	0.5006	0.4863	0.3942
0.4318	0.1467	0.5524	0.5649	0.5434	0.4330
0.5327	0.1425	0.5756	0.5904	0.5627	0.4388
0.6394	0.1248	0.5489	0.5651	0.5336	0.4052
0.7524	0.0924	0.4564	0.4725	0.4417	0.3246
0.8724	0.0439	0.2765	0.2895	0.2675	0.1876
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000
(Quinoline + Toluene)					
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0904	0.0463	0.1659	0.1617	0.1582	0.1377
0.1828	0.0590	0.2860	0.2766	0.2692	0.2266
0.2772	0.0670	0.3857	0.3696	0.3584	0.2929
0.3737	0.0702	0.4608	0.4362	0.4212	0.3336
0.4723	0.0684	0.5059	0.4706	0.4521	0.3454
0.5731	0.0614	0.5143	0.4653	0.4444	0.3246
0.6762	0.0490	0.4776	0.4112	0.3896	0.2670
0.7817	0.0311	0.3855	0.3285	0.3095	0.2016
0.8896	0.0075	0.2247	0.1906	0.1783	0.1082
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000
(Quinoline + Mesitylene)					
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.1160	0.0196	0.1651	0.1669	0.1668	0.1418
0.2280	0.0522	0.3153	0.3183	0.3179	0.2683
0.3361	0.0741	0.4254	0.4318	0.4313	0.3591

0.4405	0.0922	0.5008	0.5108	0.5102	0.4193
0.5415	0.0974	0.5306	0.5569	0.5563	0.4533
0.6392	0.1027	0.5261	0.5644	0.5637	0.4562
0.7337	0.0972	0.4745	0.5312	0.5306	0.4290
0.8253	0.0865	0.3793	0.4626	0.4623	0.3790
0.9140	0.0617	0.2295	0.3127	0.3128	0.2617
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table-3: Average Percentage Deviation (APD) values of viscosities calculated using Bingham relation(APD_B), Kendall-Munroe relation(APD_{KM}),Arrhenius- Eyring relation(APD_{AE}), Croenaurer-Rothfus-Kermore relation(APD_{CRK}) and Gambrill relation(APD_G) in all the three binary liquid mixtures at temperature T=303.15K.

Binary Liquid Mixture	APD_B	APD_{KM}	APD_{AE}	APD_{CRK}	APD_G
Quinoline + Benzene	0.0860	0.3393	0.3481	0.3362	0.2614
Quinoline + Toluene	0.0418	0.3097	0.2828	0.2711	0.2034
Quinoline + Mesitylene	0.0621	0.3224	0.3505	0.3503	0.2880

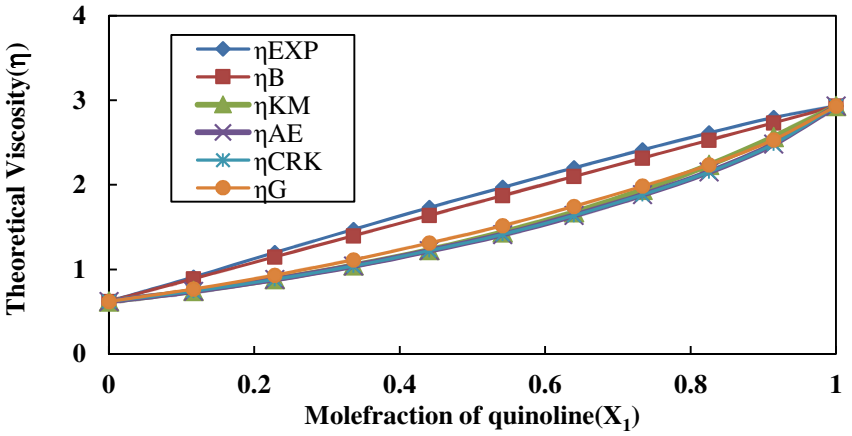

Fig-1: Variation of theoretical viscosity values and experimental values(η_{EXP}) with respect to molefraction of quinoline in (quinoline + benzene) liquid mixture at temperature T=303.15K.

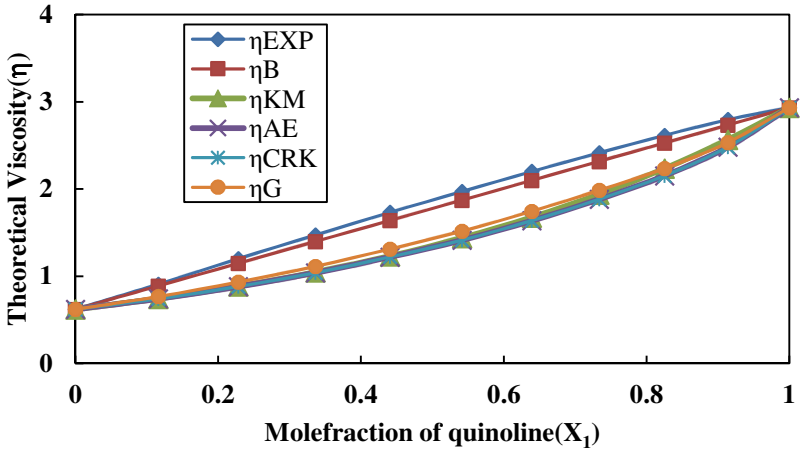

Fig-2: Variation of theoretical viscosity values and experimental values(η_{EXP}) with respect to molefraction of quinoline in (quinoline + toluene) liquid mixture at temperature T=303.15K.

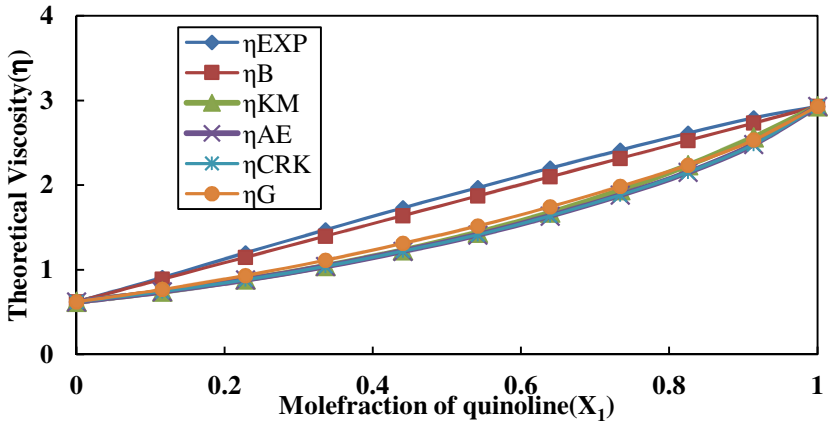

Fig-3: Variation of theoretical viscosity values and experimental values(η_{EXP}) with respect to molefraction of quinoline in (quinoline + mesitylene) liquid mixture at temperature T=303.15K.

RESULTS AND DISCUSSION

The results of theoretical viscosities along with experimental values for all the three binary liquid mixtures are presented in Table-1 and the corresponding variations of theoretical viscosity values with respect to molefraction of quinoline in all the three binary liquid mixtures are represented in Fig.-1 to Fig.-3. The percentage deviations in all the theories in calculating the viscosity with that of experimental results are presented in Table-2. The Validity of these relations has been checked by calculating average percentage deviations (APD) for all the three binary liquid mixtures and the results are shown in Table-3.
From Table-1 and Table-2 it is obvious to say that, the theoretical values of viscosity calculated by using various theories show deviations from experimental values. The limitations and approximations incorporated in these theories are responsible for the deviations.
Further from Table-3 and Fig.-1,2 and 3 it is evident to say that, out of all the theories, Bingham relation gives best results followed by Gambrill relation in all the three binary liquid mixtures at T=303.15K. The results obtained by Bingham relation are good because the relations were developed considering the ideal mixing of solutions.
The order of deviations in all the theories reported is-

Bingham relation < Gambrill relation < Croenaurer-Rothfus-Kermore relation < Arrhenius-Eyring relation < Kendall-Munroe relation.

CONCLUSION

Theoretical estimation of viscosity for all the three binary liquid mixtures are determined and the validity of different theories is checked. It is observed that there are some deviations between theoretical values obtained by various theories and experimental values. However the best correlation method giving the relatively lowest deviation in all the three binary liquid mixtures is Bingham relation.

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