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Research paper

Ultrasonic study of molecular interactions in binary mixtures of methyl methacrylate(MMA) with toluene and dimethylacetamide at 318 K

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Abstract

The ultrasonic velocity, density and viscosity at 318K have been measured in the binary systems of Methyl methacrylate + Toluene and Methyl methacrylate + Dimethylacetamide. In this work an attempt has been made for the first time to investigate the behavior of binary solutions of Methylmethacrylate(MMA) in Toluene and Dimethylacetamide(DMAC) with regard to acoustical parameters such as adiabatic compressibility(β), intermolecular free length(l_f), free volume(V_f), Rao's constant(R), Wada's constant(W) and specific acoustical impedance(Z) from ultrasonic measurements at 318 K were calculated. The results are interpreted in terms of molecular interaction between the components of mixtures.

Keywords: *Acoustical Impedance; Acoustical Parameters; Free Volume; Rao's Constant; Ultrasonic Velocity; Wada's Constant.*

1. Introduction

Ultrasonic technique has been adequately employed to investigate the properties of any substance to understand the nature of molecular interactions in pure liquid, liquid mixtures and ionic interactions in electrolytic solutions. Though the molecular interaction studies can be best carried out through spectroscopic methods, the other non-spectroscopic methods such as dielectric, magnetic, ultrasonic velocity and viscosity measurements have been widely used in the field of interactions and structural aspect evaluations studies. Understanding the nature of molecular systems, physiochemical behavior and molecular interactions in liquid mixtures, the measurement of ultrasonic velocity has been extensively applied.

2. Experimental method

Methyl methacrylate solutions in two different organic solvents (Toluene and Dimethyl Acetamide) were prepared in the concentration range 0% to 100% in steps of 10%. The samples were added to the solvent taken in bottles with air tight bids. The content of the bottle were shaken periodically and allow dissolving at the required temperature. Enough time was given for MMA to dissolve and clear solutions were obtained. All measurements were made within 2 or 3 days of preparation. The binary mixtures were prepared by using analytical regent grade of Toluene and Dimethylacetamide with different concentration of Methyl methacrylate from 0% to 100% in steps of 10%. The density of pure liquids and mixtures are measured using a 10ml specific gravity bottle. The specific gravity bottle with the experimental liquid is immersed in a temperature controlled water bath. The viscosities of MMA + Toluene and DMAC were determined using an Ubbelohode viscometer. The ultrasonic velocity was measured at a frequency of 1MHZ at temperature 318 K. Its accuracy is ±5m/s.

3. Results and discussion

Various acoustical parameters such as adiabatic compressibility (M.Aravinthraj et al. 2011, p. 6), acoustical Impedance, intermolecular free length, free volume, Wada's constant and Rao's constant (S.Mullainathan and S.Nithiyanantham 2010, p. 354) were calculated using the experimental data of ultrasonic velocity, density and viscosity.

The measured parameters viz., ultrasonic velocity (U), density (ρ) and viscosity (η) are given in table-1. In MMA+Toluene system, the values of viscosity increases linearly with concentration. The density values in this system increases with the increase in concentration of MMA. The velocity decreases with increase in concentration of MMA. In MMA + DMAC system, the values of viscosity decreases linearly with concentration. The density values in this system decreases with the increase in concentration of MMA. The velocity decreases with increase in concentration of MMA. The study of density and viscosity shows there may be structural changes in the molecules of MMA + Toluene [16]. The computed other parameters like adiabatic compressibility, acoustical impedance, free length, free volume, Wada's constant (W) and Rao's Constant(R) are given in table-2 and table-3. Tables -2, 3 show that, in MMA + Toluene system, acoustic impedance decreases with increase in concentration. Adiabatic compressibility increases with increase in concentration of MMA. Free length increases with concentration. Free volume decreases with increase in concentration of MMA, which shows there is solute-solvent interaction in MMA+Toluene system [9-13]. Rao's constant decreases with increase in concentration of MMA. Wada's constant called molecular compressibility decreases with increase in concentration of MMA. In MMA+DMAC system, acoustical impedance decreases with increase in concentration. Adiabatic compressibility increases with increase in concentration of MMA. Free length increases with concentration of MMA. Rao's constant and Wada's constant increases with increase in concentration of MMA. Free Volume in MMA + DMAC system increases with increase in concentration of MMA, which are also evidenced from figures.

Table 1: Valuesof Density, Viscosity and Ultrasonic Velocity at 318 K

Concentration of MMA (In Vol. %)	Density(ρ) $X10^3$ kgm^{-3}		Viscosity(η) $X10^{-3}$Nsm^{-2}		Velocity(U) ms^{-1}	
	Toluene	DMAC	Toluene	DMAC	Toluene	DMAC
0	0.8718	0.9547	5.1966	9.4240	1397	1384
10	0.8789	0.9544	5.3018	9.0568	1218	1367
20	0.8844	0.9543	5.3771	8.6008	1199	1354
30	0.8939	0.9542	5.4562	8.1449	1189	1318
40	0.9004	0.9541	5.5388	7.9165	1182	1297
50	0.9063	0.9540	5.6183	7.6428	1170	1273
60	0.9121	0.9536	5.6978	7.5713	1164	1230
70	0.9194	0.9509	5.7872	6.9151	1144	1206
80	0.9279	0.9490	5.8850	6.6071	1140	1174
90	0.9375	0.9450	5.9906	6.3539	1131	1143
100	0.9416	0.9416	6.0617	6.0617	1118	1118

Table 2: Valuesof Adiabatic Compressibility, Acoustical Impedance and Free Length

Concentrationof MMA (In Vol. %)	AcousticalImpedance(Z) $X10^6$kgm^{-2}s^{-1}		AdiabaticCompressibility(β) $X10^{-10}$Nsm^{-2}		FreeLength(l_f) $\times10^{-11}$m	
	Toluene	DMAC	Toluene	DMAC	Toluene	DMAC
0	1.2183	1.3212	5.8737	5.4696	4.9339	4.7612
10	1.0701	1.3048	7.6751	5.6058	5.6400	4.8201
20	1.0605	1.2924	7.8633	5.7133	5.7087	4.8661
30	1.0630	1.2579	7.9111	6.0302	5.7260	4.9992
40	1.0644	1.2377	7.9473	6.2277	5.7391	5.0804
50	1.0601	1.2147	8.0645	6.4653	5.7813	5.1764
60	1.0612	1.1732	8.0989	6.9281	5.7936	5.3585
70	1.0518	1.1471	8.3108	7.2269	5.8689	5.4728
80	1.0579	1.1141	8.2904	7.6453	5.8617	5.6290
90	1.0598	1.0801	8.3462	8.0998	5.8814	5.7939
100	1.0527	1.0527	8.4966	8.4966	5.9341	5.9341

Table 3: Valuesof Free Volume, Rao's Constant and Wada's Constant

Concentration of MMA (In Vol. %)	FreeVolume(V_f) $X10^{15}$m^{3}mol.$^{-1}$		Rao'sConstant(R) $X10^{-3}$mol.$^{-1}$ ms^{-1}		Wada'sConstant(W) $X10^{-3}$m^{3}mol.$^{-1}$	
	Toluene	DMAC	Toluene	DMAC	Toluene	DMAC
0	1.3427	0.4981	1.1816	1.0169	2.2037	1.9222
10	1.0734	0.5203	1.1291	1.0145	2.1220	1.9187
20	1.0404	0.5751	1.1259	1.0365	2.1196	1.9612
30	1.0180	0.6115	1.1203	1.0413	2.1131	1.9726
40	0.9989	0.6357	1.1193	1.0499	2.1139	1.9905
50	0.9746	0.6653	1.1174	1.0580	2.1134	2.0076
60	0.9584	0.6544	1.1175	1.0611	2.1160	2.0167
70	0.9243	0.7436	1.1177	1.0723	2.1089	2.0391
80	0.9078	0.7813	1.1091	1.0803	2.1073	2.0564
90	0.8833	0.8134	1.1036	1.0910	2.1007	2.0781
100	0.8639	0.8639	1.1036	1.1036	2.1031	2.1031

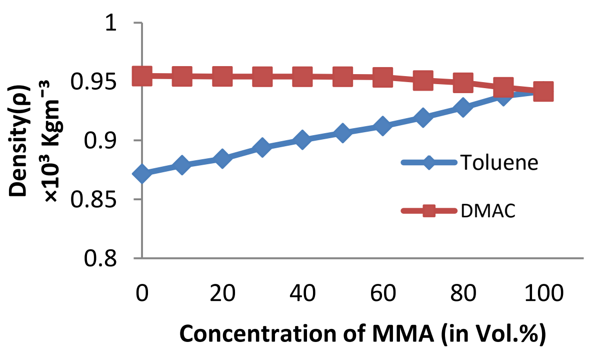

Fig. 1: Concentration Versus Density at 318K.

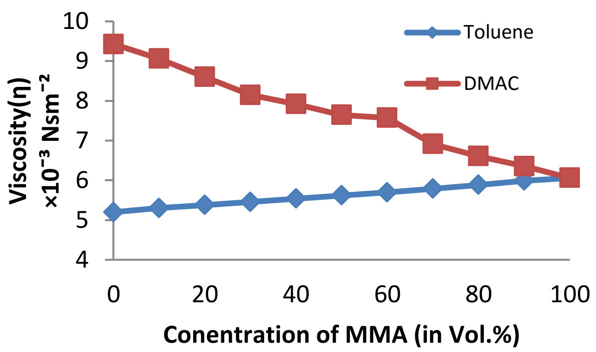

Fig. 2: Concentration Versus Viscosity at 318K

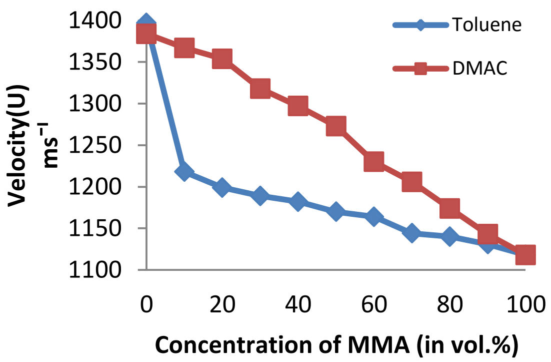

Fig. 3: Concentration Versus Velocity at 318K.

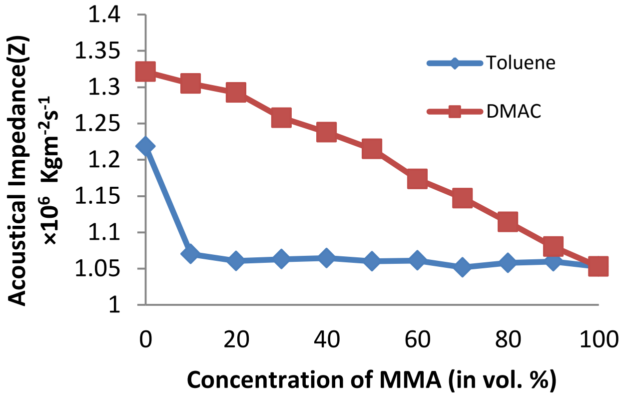

Fig. 4: Concentration Versus Acoustical Impedance at 318K.

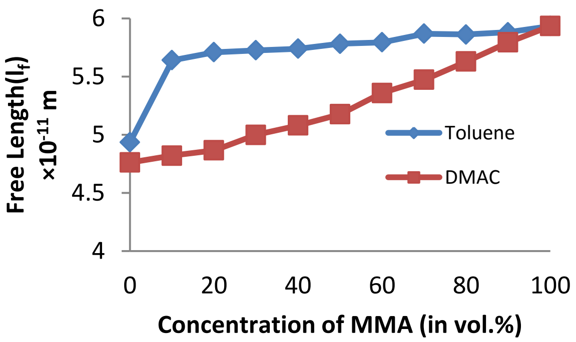

Fig. 5: Concentration Versus Free length at 318K

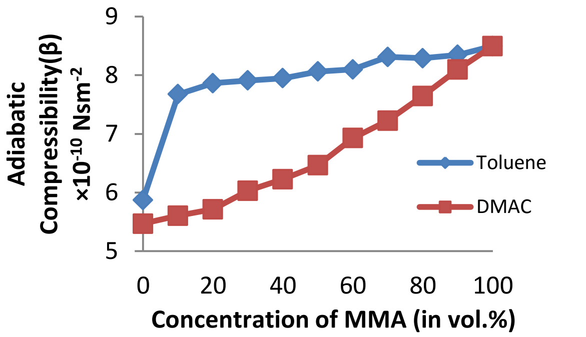

Fig. 6: Concentration Versus Adiabatic compressibility at 318K

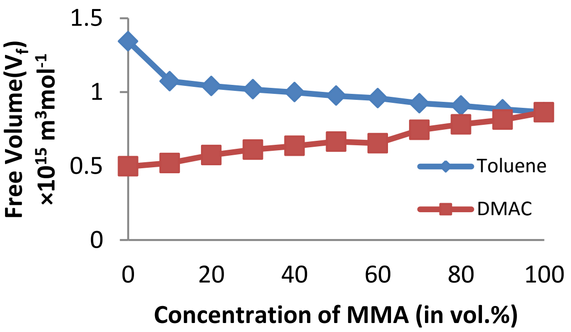

Fig. 7: Concentration Versus Free Volume at 318K.

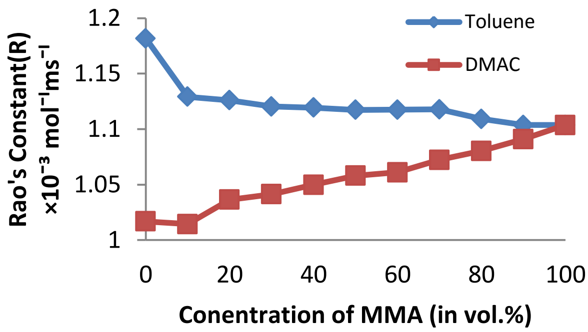

Fig. 8: Concentration Versus Rao's Constant at 318K.

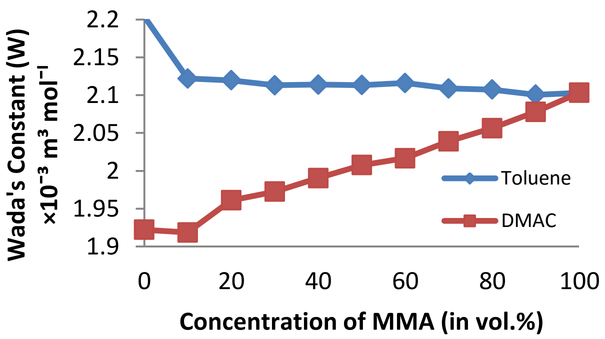

Fig. 9: Concentration Versus Wada's Constant at 318K.

4. Conclusion

The ultrasonic velocity, density, viscosity and other related parameters were calculated. The study of density and viscosity shows there may be structural changes in the molecules of MMA + Toluene. A progressive decrease in free volume in MMA + Toluene mixtures clearly indicates the existence of solute-solvent interaction, due to which the structural arrangement is considerably affected. The existence of type of molecular interaction in solute-solvent is favored in MMA+Toluene system, confirmed from the free volume, viscosity and acoustical impedance values. Toluene is the better solvent compared to DMAC in MMA, even though both are poor solvents.

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