Ultrasonic Investigation of Molecular Interactions in Binary Mixtures at 303 K

R. NITHYA, S. NITHIYANANTHAM*,
S. MULLAINATHAN[§] and M. RAJASEKARAN[§]

Department of Physics,
Selvam College of Arts and Science, Namakkal, Tamil nadu, India.

*Department of Physics,
SRM University, Kattankulathur, Tamil nadu India – 603 203.

[§]Department of Physics,
AVC, College of Engineering, Mayiladuthurai, Tamil nadu, India.

s_nithu59@rediffmail.com

Received 27 May 2008; Accepted 20 July 2008

Abstract: The ultrasonic velocity, density and viscosity at 303 K have been measured in the binary systems of toluene with benzene and *o*-xylene with benzene. The acoustical parameters such as adiabatic compressibility, free length, free volume and acoustical impedance are calculated. The results are interpreted in terms of molecular interaction between the components of the mixtures.

Keywords: Ultrasonic velocity, Density, Viscosity, Acoustical parameters

Introduction

In recent years ultrasonic investigation find extensive applications in probing in to the physico-chemical behaviour of binary liquid mixtures leading to an understanding of the liquid state¹⁻³. Ultrasonic technique has been adequately employed to investigate the properties of any substance to understand the nature of molecular interactions in pure liquid¹ liquid mixtures²⁻⁵ and ionic interactions in electrolytic solutions^{6,7}. Though the molecular interactions studies can be best carried out through spectroscopic methods^{8,9} the other non spectroscopic techniques such as dielectric¹⁰ magnetic¹¹ ultrasonic velocity and viscosity¹² measurements have been widely used in field of interactions and structural aspect evaluations studies. The measurements of ultrasonic velocity have been adequately employed in understanding the nature of molecular systems and physicochemical behaviour in liquid mixtures¹³⁻¹⁶.

Experimental

The Ultrasonic Velocity was measured using a single crystal variable path interferometer working at 2MHz by standard procedure. The accuracy of ultrasonic velocity determination

in the solution is $\pm 0.001\%$. The velocities were measured at room temperature 303 K. The density were measured using a corning specific gravity bottle by standard procedure and the viscosity was measured using Oswald's viscometer with an accuracy of $\pm .1\%$.

Results and Discussion

The calculated parameters such as adiabatic compressibility (β), inter molecular free length (L_f), free volume (V_f) and acoustic impedance (Z), are calculated using the following relation (1- 4).

$$\beta = 1/U^2 \rho \quad (1)$$

$$L_f = k_T (\beta)^{1/2} \quad (2)$$

$$V_f = (M_{eff} U / \eta k)^{3/2} \quad (3)$$

and

$$Z = U \rho \quad (4)$$

The measured values such as ultrasonic velocity (U), density (ρ) and viscosity (η) are of *o*-xylone with benzene and toluene with benzene are given in Table 1. It is clearly reveals that all measured parameters, sound velocity, density and viscosity, increasing and decreasing trend for increasing moles of x_2 . The ultrasonic velocity studies carried out in the present investigation reveal that the velocity varies with concentration due to the solute – solvent interactions through molecular association. The existing particle-particle resistance initiates some more interactions and this is supported by the measured parameters.

A keen look at the Table 1 suggest that the range of density, sound velocity, and their variation with concentration of toluene is appreciable, this liquid composition suggests the basis of structural changes as well as interaction between like molecules and unlike molecules. On comparing toluene and *o*-xylone, in general, toluene shows a relatively higher density and viscosity. The shear viscosity increases with increase of concentration once again confirmed that the solute – solvent interaction.

Table 1. Measured (Ultrasonic velocity (U), density (ρ) and viscosity (η) and calculated (adiabatic compressibility (β), free length (L_f), free volume (V_f) and acoustical impedance (Z) parameters for benzene + toluene, *o*-xylone at 303 K.

X_2	U ms^{-1}	ρ Kgm^{-3}	$\eta \times 10^3$ Nsm^{-2}	$\beta \times 10^{10}$ $N^{-1}m^2$	$L_f \times 10^{11}$ m	$V_f \times 10^8$ m^3mol^{-1}	$Z \times 10$ $kgm^{-2}s^{-1}$
Benzene + Toluene							
0.0936	1289	861.51	0.6932	6.986	5.276	1.0379	1.1105
0.1882	1301	857.91	0.7396	6.886	5.237	1.0005	1.1161
0.2887	1285	855.34	0.7865	7.080	5.311	0.9465	1.0991
0.3915	1294	855.01	0.7469	6.985	5.275	1.0222	1.1064
0.5015	1270	854.46	0.7464	7.256	5.377	1.0195	1.0852
Benzene + <i>o</i> -xylone							
0.0957	1280	861.22	0.6929	7.087	5.314	1.0556	1.1024
0.1953	1290	860.85	0.7322	6.981	5.274	1.0489	1.1105
0.3023	1296	860.57	0.7320	6.918	5.250	0.9736	1.1153
0.4118	1303	860.48	0.7319	6.845	5.222	1.1452	1.1213
0.5376	1320	860.39	0.7318	6.844	5.221	1.0685	1.1357

On comparing toluene and *o*-xylone, the zigzag values are obtained for β , but for *o*-xylone the increasing trend is observed, it shows that the interaction is higher in the second system. The intermolecular free lengths L_f has been calculated by using semi empirical relation given by Jacobson¹⁷. The values of L_f reflects the same trend as that of β . According to Eyring and Kincaid¹⁸, the ultrasonic velocity increases, if the L_f decreases and vice – a – versa in a result of mixing components. The decrease or increase in the values of L_f can be explained on the basis of interactions between the solute and solvent molecules.

The values of V_f is decrease in trend of both these system suggest that there is a specific interaction between the components of the mixtures. The specific acoustic impedance Z is varied linearly with concentration of solution.

References

1. Sheshagiri Rao M G, *Indian J Pure Appl Phys.*, 1971, **9**, 169.
2. Sheshagiri K and Reddy K C, *Acustica* (Germany), 1973, **29**, 59.
3. Ramamoorthy K and Varadachari P S, *Indian J pure Appl phys.*, 1973, **11**, 238.
4. Kaulgud M V and Patil K J, *Indian J pure Appl Phys.*, 1975, **13**, 322.
5. Tiwari V and Pandey J D, *Indian J Pure Appl Phys.*, 1980, **18**, 51.
6. Satya Narayanamurthy M, *Current science*, 1964, **33**, 364.
7. Soitkar V S and Jajoo S N, *Acoust Lett.*, 1984, **7(12)**, 1991.
8. Suryanarayana C V, *J Acoust Soc Ind.*, 1983, **13**, XI.
9. Fletcher A, *J Phys Chem.*, 1969, **73**, 2217.
10. Pimental G C and Maclellan A L, *The Hydrogen bond*, (WH Freeman and Co, san Fransisco) 1960.
11. Hobbs M E and Bates W W, *J Am Chem Soc.*, 1952, **74**, 746.
12. Lin W and Tsay S J, *J Phys Chem.*, 1970, **74**, 1037.
13. Manisha Gupta and Shukla J P, *Indian J Pure Appl Phys.*, 1996, **34**, 772.
14. Pandey J D Rai R D Shukla A K and Misra N, *Indian J pure Appl Phys.*, 1993, **31**, 84.
15. Pankaj and Sharma C, *Ultrasonics*, 1991, **29**, 344.
16. Velmourougane S, Nambinarayanan TK, Srinivasa Rao A and Krishnan B, *Indian J Phys.*, 1987, **61B**, 105.
17. Jacobson B, *Acta Chem Scaud.*, 1952, **6**, 1485.
18. Eyring H and Kincaid J F, *J Chem Phys*, 1938, **6**, 620.