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Study of temperature change on ultrasonic velocity and some acoustic parameters of binary liquid mixture of DMSO+ Chlorobenzene

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ABSTRACT

The Ultrasonic velocity, density and viscosity have been measured for binary liquid mixture of DMSO + Chlorobenzene of fixed equal volumes of the mixtures at temperatures of 298K, 303K, 308K, 313K and 318K. The experimental measured values of ultrasonic velocity, density and viscosity are used to calculate some acoustic and thermodynamic parameters such as adiabatic compressibility, acoustic impedance, free length, relaxation time, free volume and internal pressure. It was observed that ultrasonic velocity (U), density (ρ) and viscosity (η) decreased with increase in temperature. The adiabatic compressibility (β), free length (L_f) and free volume (V_f) increases with increase in temperature, whereas acoustic impedance (Z), relaxation time (τ) and internal pressure (π_i) decreased with increase in temperature. Some probable reasons on the increase or decrease of acoustic and thermodynamic parameters with temperature change are presented.

Keywords: Binary mixtures, Density, Relaxation time, quartz crystal.

INTRODUCTION

The ultrasonic study of liquids is of most important in understanding the nature and strength of molecular interactions. The biological activity of drug molecules and the activation energy of the metabolic process basically depend on the type and strength of the intermolecular interactions.

Thermodynamic and transport properties of liquids mixtures have been used to study the departure of a real liquid mixture behavior from ideality. From the literature, the nature and degree of molecular interactions in different solutions depend upon the nature of solvent, the structure of solute molecule and extent of solutes taking place in the solution [1]. In recent years ultrasonic investigations find large number of applications in characterizing of thermosdynamic and physicochemical aspect of binary liquid mixtures. The thermodynamic and acoustical parameter have been used to study different kinds of associations, molecular motion and various types of interaction and their strengths influenced by the size of pure component and the mixtures [2].

Ultrasonic investigation of liquid mixture with components is of considerable importance in understanding intermolecular interaction between the component molecules which finds application in several industrial and technological processes. Ultrasonic velocity, density, viscosity and the derived acoustical parameters like adiabatic compressibility, free length, free volume, acoustic impedance, relaxation time, internal pressure, etc., provide valuable information about the molecular environments. This has been studied for various binary and ternary mixtures with respect to variation in concentration of the liquids and temperatures [3].

In this paper, variation of some acoustic and thermosdynamic parameters of binary liquid mixture of Dimethylsulphoxide and Chlorobenzene with tempera-ture has been studied for a fixed concentration of equal volumes of the individual liquids making up the mixture.

METHODOLOGY

A concentration in volume fraction of mixture was prepared by taking liquids of DMSO and Chlorobenzene (Merck, AR grade Germany, 99.5%). The volume fractions of the component liquids making the mixture were kept constant in the ratio of 1:1 through-out the variation of temperature. The ultrasonic velocity, density and viscosity were measured as a function of temperature of the binary liquid mixture at 2MHz and at temperatures of 298K, 303K, 308K, 313K and 318K.

The density of the mixture at different temperatures were measured by using a specific gravity bottle with an accuracy of ± 0.5% and viscosity of the system at different temperatures were measured using an Ostwald's viscometer. The flow time was determined using a digital stopwatch with an accuracy of ± 0.01sec. The ultrasonic velocity of the liquid mixture was measured using ultrasonic interferometer at 2MHz. The required temperature of the liquid mixture was maintained constant by circulating water from a thermostatically controlled water bath with an accuracy of ±0.1K. Some acoustic and thermodynamic parameters were calculated [4]

1) Adiabatic compressibility (β)

$$\beta_{ad} = \frac{1}{U^2 \rho} \quad (1)$$

2) Acoustic impedance (Z)

$$Z = \rho U \quad (2)$$

3) Free length (L_f)

$$L_f = KT\, \beta^{1/2} \quad (3)$$

4) Relaxation time (τ)

$$\tau = \frac{3}{4}\, \eta\, \beta_{ad} \quad (4)$$

5) Free volume (V_f)

$$V_f = [\, M_{eff}\, U / K\eta]^{3/2} \quad (5)$$

6) Internal pressure (π_i)

$$\pi_i = bRT[(K\eta/U)^{1/2}(\rho^{2/3} M^{7/6})] \quad (6)$$

Where U is ultrasonic velocity, ρ is density of the mixture, f is the frequency of ultrasonic wave, K_T is temperature dependent constant known as Jacobson's constant (K_T = 2.131x10^{-6} at 318K), Meff is the effective molecular weight of the mixture, k is a temperature independent constant which is equal to 4.281x10^{9} for all liquids, η is the viscosity of the mixture, b stand for cubic packing, which is 2 for all liquids, T is the absolute temperature in Kelvin, R is the universal gas constant, k_B is Boltzmann's constant, h is Planck's constant.

RESULT AND DISCUSSION

The experimental data related to ultrasonic velocity, density and viscosity at indicated temperatures for frequency 2MHz, for the given liquid mixture have been presented in Table 1. The calculated values of adiabatic compressibility, acoustic impedance, intermolecular free length, relaxation time, free volume and internal pressure are presented in Table 2.

Table 1: The values of Ultrasonic Velocity (U), Density (ρ) and Viscosity (η) of DMSO + Chlorobenzene at 298⁰K, 303⁰K, 308⁰K, 313⁰K and 318⁰K.

T(K)	Ultrasonic Velocity U(ms^{-1})	Density (kg m^{-3})	Viscosity 10^3 ($Nm^{-2}s$)
298⁰K	1372.00	1094.70	0.1361
303⁰K	1355.36	1089.43	0.1164
308⁰K	1337.05	1086.30	0.0981
313⁰K	1321.05	1081.58	0.0818
318⁰K	1302.10	1076.42	0.0622

Table -2 The values of adiabatic compressibility (β), acoustic impedance (Z), free length (L_f), relaxation time (τ), free volume (V_f), internal pressure (π_i) of DMSO + chlorobenzene at 298⁰K, 303⁰K, 308⁰K, 313⁰K and 318⁰K.

T(K)	β $\times10^{-10}$ ms^2 kg^{-1}	Z$\times10^6$kg $m^{-2}s^{-1}$	L_f $\times10^{-9}$m	τ$\times10^{-12}$ sec	V_f $\times10^{-6}$ (ml)	π_i ($\times10^3$ Nm^{-2})
298	4.853	1.502	0.453	88.06	10.9275	3.535
303	4.997	1.477	0.464	77.55	13.5413	3.338
308	5.149	1.452	0.475	67.35	17.1224	3.133
313	5.298	1.429	0.486	57.78	22.0338	2.921
318	5.479	1.402	0.499	45.44	32.4442	2.602

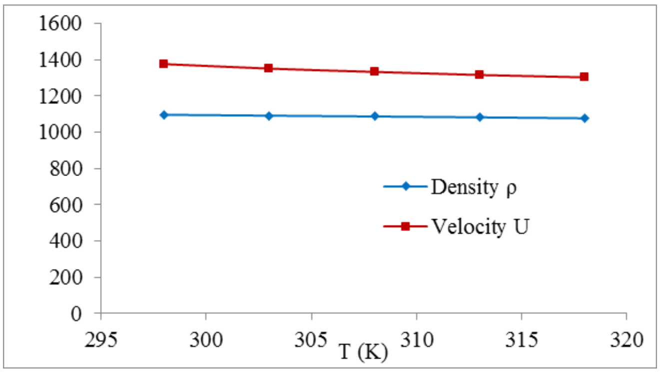

Fig.1

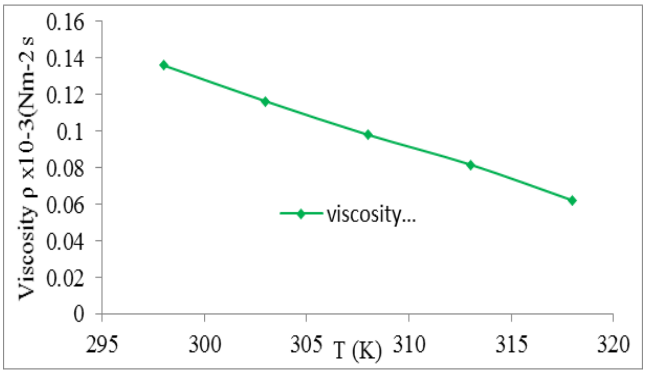

Fig. 2

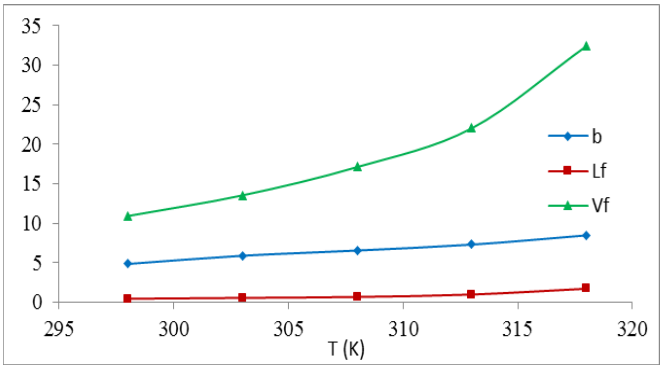

Fig.3

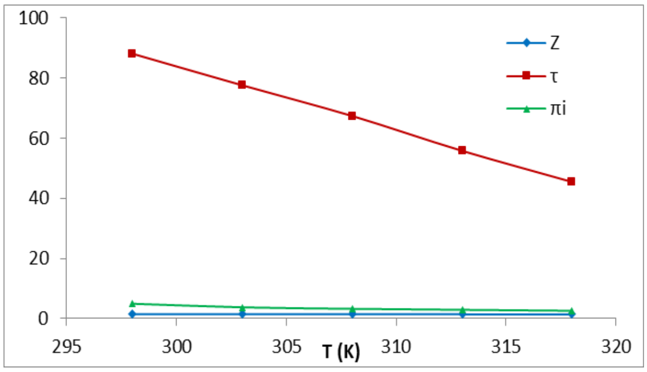

Fig. 4

Fig 1: Variation of Ultrasonic velocity U (m/sec) and density ρ(Kg/m³) with temperature T (K) **Fig 2**: variation of viscosity η with temperature T(K) **Fig 3**: Variation of adiabatic compressibility β, free length L_f and free volume V_f of mixture with temperature **Fig 4**: Variation of acoustic impedance Z, relaxation time **τ** and internal pressure πi of mixture with temperature

From table-1 and figure-1 and 2 it is seen that the ultrasonic velocity, density and viscosity decreases with increase in temperature. The decrease of values with temperature shows decrease in intermolecular forces due to the increase in the thermal energy of the system. The velocity decreases with increase in temperature because as the free length increases with the increase of temperature (Table-2). Thus the association of the interacting molecules varies with the temperature of the ultrasonic wave, cohesive force as well as internal pressure decreases with the increase of temperature[5,6].

From Table 2 and figure 3 it is seen that adiabatic comprssibility (β), free length (Lf) and free volume (Vf) increases with increase in temperature. The free length depends on the adiabatic compressibility and shows a similar behavior to that of compressibility and inverse to that of velocity. It increased with increase in temperature of mixture, indicating that there is a less interaction between solute molecules. Free volume of the mixture increased as the internal pressure decreased (Figure-4) with increase in tempe-rature of the mixture. This is due to the loose packing of the molecules inside the shield, that results in decreasing magnetude of interactions [7]. It is seen from table-2 and figure-4 that acoustic impedance (Z), relaxation time (τ) and internal pressure (пi) decreases with increase in temperature. This is similar to the change found in viscosity, showing that viscous forces play a dominant role in the relaxation process. it is observed that acoustic impedance decreases with increase in temperature, this is in agreement with ultrasonic velocity and density [8].

From figure- 3 and 4, it is observed that adiabatic compressibility (β), free length (Lf) and free volume increases almost linearly with increase in temperature, while acoustic impedance (Z), relaxation time (τ) and internal pressure (пi) decreased almost linearly with increase in temperature. Figure-1 and 2 shows that ultrasonic velocity (U), density (ρ) and viscosity (η) of the system decreases with increase in temperature. The molecules in a liquid are held together much more strongly than in a gas. A force is needed to overcome the mutual attraction of the molecules so that they can be displaced relative to each other. The more strongly the molecules are held together, smaller the flow for a given shearing stress. With increasing temperature, the random kinetic energy of the molecules helps to overcome the molecular forces and reduces the viscosity [9].

CONCLUSION

The adiabatic compressibility, free length and free volume of DMSO+Chlorobenzene mixture increases almost linearly with increase in temperature, while acoustic impedance, relaxation time and internal pressure decreases almost linearly with increase in temperature. As usual, the ultrasonic velocity, density and viscosity decreases with increase in temperature. This is due to the energy obtained to overcome the resistance to flow.the almost linear variation of acoustical parameters with temperature shows that there exist less intermolecular forces between the components of the binary liquid mixture.

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