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Ultrasonic Study of Cyclohexane with *o*-Xylene at Different Temperatures

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Molecular interactions have been studied in binary liquid mixtures of cyclohexane and *o*-xylene by ultrasonic velocity (u), density (ρ) and viscosity (η) measurements at 303.15, 308.15, 313.15 and 318.15 K and at different mole fractions. Acoustical parameters such as adiabatic compressibility (β), intermolecular free length (L_f), free volume (V_m), internal pressure (π) were calculated from the experimental data. The investigations on the binary mixture containing non-polar, non-polar liquids shows weak induced dipole-induced dipole attractions.

Key Words: Binary mixtures, Cyclohexane, *o*-Xylene, Interactions, Induced dipole, Mole fractions, Ultrasonics, Viscosity.

INTRODUCTION

Ultrasonic study of liquid and liquid mixtures has gained much importance during the last two decades in assessing the nature of molecular interactions in pure binary liquid mixtures[1-3] and investigating the physico-chemical behaviour of such systems. In binary mixtures containing non-polar components there can be only induced dipole-induced dipole interactions, which arise due to polarizability aspects. The forces of attraction due to induced dipole-induced dipole are very weak and optical methods cannot be used to detect and access these interactions. Literature survey showed that few studies have been done on the induced dipole-induced dipole interactions in binary liquid mixtures. Hence, an attempt has been made to measure the ultrasonic velocity, density and viscosity in order to assess the weak dispersion interactions existing between the molecules of the components in binary liquid mixtures.

EXPERIMENTAL

The chemicals were redistilled and purified by the standard methods[4,5]. Liquid mixtures of different known compositions were prepared by mixing measured amounts of the pure liquids in cleaned and dried flasks. Ultrasonic velocity was measured by a single crystal variable path interferometer (Mittal enterprises, Model F-80X) at a frequency of 3 MHz. The working principle used in the measurement of speed of sound through medium was based on the accurate determination of the wavelength of ultrasonic waves of known frequency produced by quartz crystal in the measuring cell[6,7]. The apparatus is standardized first with distilled water then with benzene at various temperatures, the results obtained are found to be in good agreement with reported values in the literature. An electronically digital operated constant temperature bath has been used to circulate water through the double walled measuring cell made up of steel containing the experimental solution at the desired temperature. The accuracy of the velocity measurements is ± 5 ms^{-1}. The densities of pure liquids and liquid mixtures were measured by employing a 25 mL specific gravity bottle at all the temperatures and weights were taken to an accuracy of ± 0.1mg.

The measurements were made at all the temperatures with the help of thermostat with an accuracy of ± 0.1 K.

Acoustical parameters such as adiabatic compressibility (β), intermolecular free length (L_f), molar volume (V_m), enthalpy (H) and internal pressure (π) were calculated using standard equations.

Theory: The adiabatic compressibility has been determined by using the experimentally measured ultrasonic velocity (U) and density (ρ) by the following formula:

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

The molar volumes of the binary mixtures were calculated using the equation:

$$V = (X_1M_1 + X_2M_2)/\rho \quad (2)$$

Inter molecular free length (L_f) was calculated by using the relation:

$$L_f = K(\beta_{ad})^{1/2} \quad (3)$$

where K is temperature dependent Jacobson's constant.

Enthalpy (H) is calculated using the relation:

$$H = \Pi \cdot V_m \quad (4)$$

Internal pressure (Π) is calculated using the formula:

$$\pi = bRT\frac{(K\eta)^{1/2}}{U}(\rho^{2/3}\cdot\eta^{7/6}) \quad (5)$$

RESULTS AND DISCUSSION

The plots of ultrasonic velocity against mole fraction of *o*-xylene at different temperatures are shown in Fig. 1. These plots are almost linear with either positive or negative slope indicating the existence of very weak intermolecular attractions in the system and there is a little deviation from ideal behaviour. These forces may be of induced dipole-induced dipole type. Similar type of deviations was referred by Kannappan and Santhi[8].

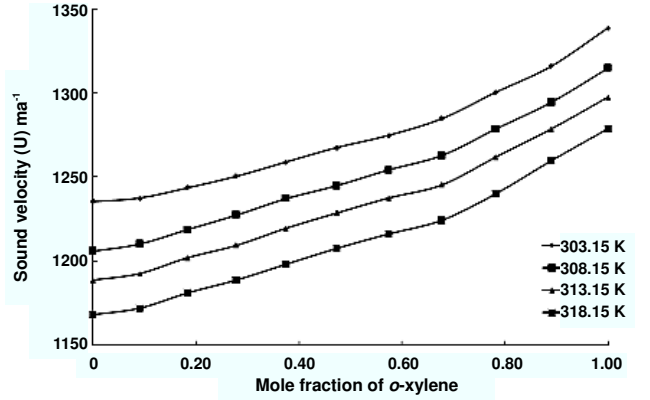

Fig. 1. Variation of ultrasonic velocity with mole fraction of *o*-xylene at different temperatures

Adiabatic compressibility (β), intermolecular free length (L_f), molar volume (V_m), enthalpy (H) and internal pressure (π) values are calculated for the sytem investigated. The trend in adiabatic compressibility with concentration is the reverse of the trend in ultrasonic velocity with concentrations at all the four temperatures, since adiabatic compressibility is inversely proportional to u^2. The plots of adiabatic compressibility against mole fraction of *o*-xylene at different temperatures are shown in Fig. 2.

The intermolecular free length in binary liquid mixtures can be used to assess the attraction between the component molecules. The values of intermolecular free length in a binary mixture depend on concentration and temperature. At a given concentration for binary systems intermolecular free length increases with increase in temperature. This may be due to the weakening of intermolecular attraction due to thermal agitation. At a given temperature intermolecular free length either increases or decreases with concentration depending upon the components of the liquid mixture. This is true at all the temperatures. The plots of intermolecular free length against molefraction of *o*-xylene at different temperatures are shown in Fig. 3.

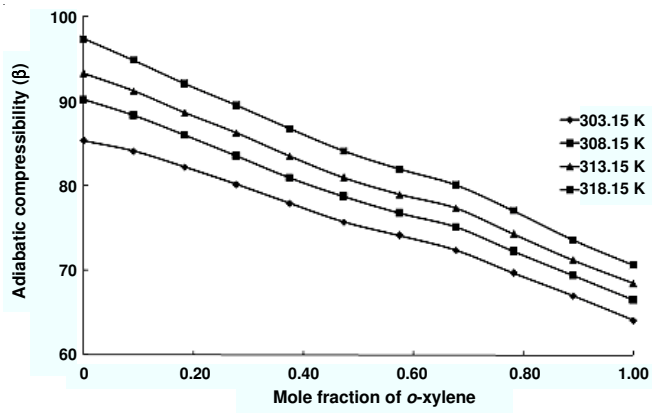

Fig. 2. Variation of adiabatic compressibility with mole fraction of *o*-xylene at different temperatures

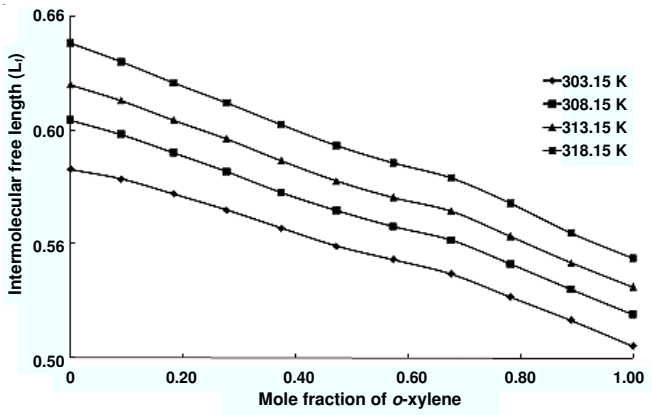

Fig. 3. Variation of intermolecular free length with mole fraction of *o*-xylene at different temperatures

The molar volume increases when *o*-xylene is added to cyclohexane. It is observed from the Fig. 4 that the curves are almost linear at different temperatures and for different mole fractions.

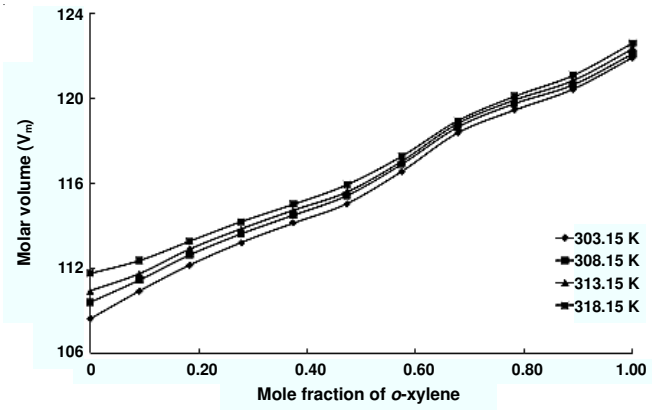

Fig. 4. Variation of molar volume with mole fraction of *o*-xylene at different temperatures

Fig. 5 shows the variation of enthalpy with mole fraction at different temperatures. As the mole fraction increases the enthalpy decreases. The corresponding curves at four temperatures are similar. All the values are observed to be positive confirms the weak interaction.

Internal pressure is binary liquid mixtures can be used to assess the inter molecular attraction between the components.

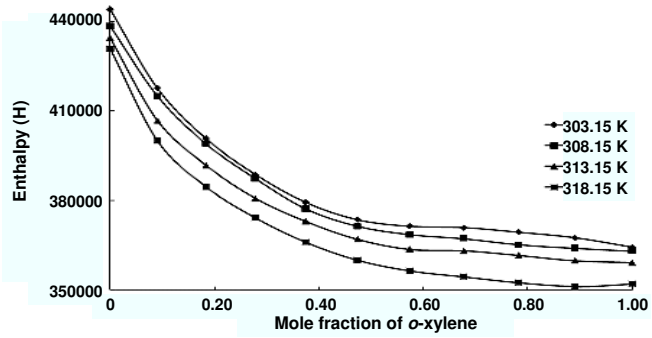

Fig. 5. Variation of enthalpy with mole fraction of *o*-xylene at different temperatures

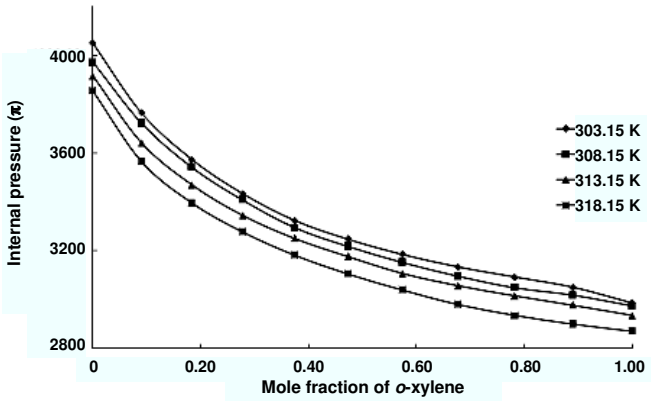

Fig. 6. Variation of internal pressure with mole fraction of *o*-xylene at different temperatures

The variation of internal pressure with mole fraction at different temperatures is shown in Fig. 6. As the mole fraction increases the internal pressure decreases, at all four temperatures. The internal pressure values are observed to be less in mixtures containing high mole fraction of the aromatic compound, *o*-xylene. This suggests the presence of weak interactions between cyclohexane and *o*-xylene.

Conclusion

There are weak induced dipole-induced dipole interactions in the binary mixture chosen for investigation.

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