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A Study on the Acoustic and Rheological Properties of Polystyrene in Different Solvents

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ABSTRACT

Polystyrene (PS) is a synthetic aromatic hydrocarbon polymer prepared from the monomer styrene. Polystyrene can be foamed or solid. General-purpose polystyrene is hard, clear and rather brittle. It is a low cast resin per unit weight. It is a rather poor barrier to oxygen and water vapour and has a relatively low melting point. Polystyrene is one of the most widely used plastics, the scale of its production being several million tonnes per year. Polystyrene can be naturally transparent, but can be coloured with colourants. Uses include protective packaging (such as packing peanuts and DVD and CD cases), bottles, trays, containers, lids, tumblers, disposable cutlery and in the making of models. In the present study an attempt has been made to compute the viscosity of Polystyrene (M.W: 35000) in toluene and 1,4-Dioxane at different concentrations (0.2%, 0.4%, 0.6%, 0.8% & 1.0%) at different temperatures (303 K, 308 K, 313 K & 318 K). From these experimental data, activation energy is calculated and the effect of solvent is analyzed. Density and ultrasonic velocity have been estimated for the above systems at 303K. From these experimental values, various molecular interaction parameters like free volume, internal pressure, viscous relaxation time, interatomic free length, etc. are calculated and discussed in terms of solute-solvent interactions.

Key Words: Activation energy, Free volume, Internal Pressure, Ultrasonic velocity

INTRODUCTION

Acoustical and molecular interaction studies in polymer solutions have been the subject of research in recent years [1-4]. Ultrasonic and viscometry is the universally accepted technique to study the physical, chemical and thermodynamic properties of the polymeric solutions, liquids, liquid mixtures and electrolytic solutions and polymeric solutions [5-8]. The different acoustical parameters interpret the nature and strength of molecular interaction that exist in the system [9-12].

In the present work, density, viscosity, ultrasonic velocity and related thermodynamic and molecular interaction properties have been determined and the solute-solvent interactions for Polystyrene in toluene and 1,4-Dioxane at different concentrations have been studied at constant frequency (2MHz) at 303K. Measurement of ultrasonic velocity [1-4] has been effectively employed in understanding the molecular interaction properties in polymer solution.

The transmission of ultrasonic wave in a medium is a thermodynamic property and has come to be recognized as a very specific and unique tool for calculating and estimating various physico-chemical properties of the systems under consideration. Since ultrasonic velocity data proves to be a very simple and appropriate tool to determine various thermodynamic properties of polymer solutions, liquids and liquid mixtures not obtained so accurately through other technique.

EXPERIMENTAL DETAILS

Polystyrene (PS 35000) (SPECTRUM grade) is purchased from Sri Ganapathy Scientific Company, Kanchipuram, India. The polymer solution was prepared by dissolving the polymer in toluene and 1,4-Dioxane (SPECTRUM grade). The concentration range chosen in the solution are 0.2%, 0.4%, 0.6%, 0.8% and 1.0% w/v.

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The relative viscosity studies of the polymer solutions were performed at four different temperatures (303K, 308K, 313K & 318K) for different concentrations using digital viscometer [BROOKFIELD make, accuracy ±0.01 cP]. The density values are measured using specific gravity method. The mass of the liquid was measured using a K-ROY make Electronic balance, with an accuracy of ±0.001gm. The ultrasonic velocity measurements are performed using Mittal make single frequency Ultrasonic interferometer at 2 MHz (F-81 model) (uncertainty ± 0.01m/s). The temperature of viscometer and interferometer are maintained at 303K by circulating water from a thermostat with a thermal stability of ± 0.5 K.

RESULTS AND DISCUSSION

Activation Energy Studies

Viscosity measurements are performed for Polystyrene in toluene and 1,4-Dioxane in the concentrations range from 0.2% to 1.0% in steps of 0.2% at various temperatures 303K, 308K, 313K and 318K. In all the cases, the relative viscosity increases with the increase in concentration and decreases with the increase in temperature (Fig. 1 & Fig. 2). The reason for this behavior may be due to the development of large frictional force between the layers of the solution [3]. Arrhenius expression [1] is valid for pure solvents and also for dilute polymer solutions. Activation energy is obtained from Arrhenius expression.

The variation of activation energy with concentration of Polystyrene in toluene and 1,4-Dioxane is shown in Fig 3. In these systems, for Polystyrene in 1,4-Dioxane, it is observed that there is a sudden decrease in the activation energy after 0.6% concentration. In most cases, activation energy for the viscous flow of polymer solution increases continuously with increasing polymer concentration, except in particular cases of critical mixtures [13]. The reason being the activation energy for the viscous flow of polymer solutions in poor solvent decreases with polymer concentration at high dilution and this is ascribed to the temperature dependence of the limiting viscosity number [14]. For Polystyrene in toluene, it is observed that the activation energy increases with increase in concentration. This reveals that as concentration increases, more amount of energy is required to move the molecules into the structure. Similar results are observed by few researchers [15, 16]. From this it may be concluded that toluene is a better solvent compared to 1,4-Dioxane for Polystyrene.

Molecular Interaction Studies

Various molecular interaction parameters (Table 1) like adiabatic compressibility, inter molecular free length, free volume, internal pressure and viscous relaxation time are calculated by measuring density, viscosity and ultrasonic velocity values (Fig. 4 & Fig. 5).

It is evident from the Table 1 that decrease in adiabatic compressibility, and as well as in intermolecular free length is observed in all the two systems, with the increasing concentration of Polystyrene. This trend indicates the formation of strong hydrogen bonding between polymer and solvent molecules [3]. A reverse trend of viscosity with free volume is observed in both cases. Also observed that the free volume decreases with increase in internal pressure in both systems. The molecular interaction of the liquid is understood from the knowledge of the internal pressure of the liquid. As the concentration of polyethylene glycol increases the internal pressure of the system also increases. This increase in the internal pressure of the polymer may be due the presence of strong attractive force between the polymer and solvent molecules [3]. The increase in viscous relaxation indicates that viscous forces play a dominant role in the relaxation process. This indicates that the solution is highly ordered due to outstanding hydration and such solution generally absorbs more ultrasonic energy [1, 5].

CONCLUSION

Viscosity studies are performed for Polystyrene in toluene and 1,4-Dioxane in the concentration range from 0.2% to 1.0 % at various temperatures (303K, 308K, 313K and 318K). From these values, activation energy is calculated. From activation energy values, it may be concluded that toluene is a better solvent compared to 1,4-Dioxane. From density and ultrasonic velocity values the molecular interaction properties are analysed. The variation of molecular interaction parameters suggests that the presence of strong interaction between polymer and solvent at higher concentrations. This helps to analyse the effect of concentration on the systems taken for study.

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Conflicts of Interest

There are no conflicts of interest to declare.

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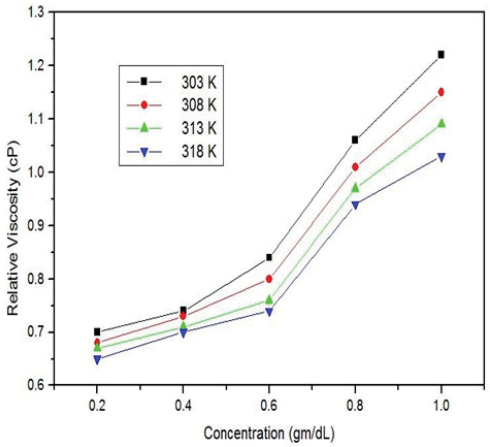

Figure 1: Variation of Relative Viscosity against concentration (Polystyrene + Toluene).

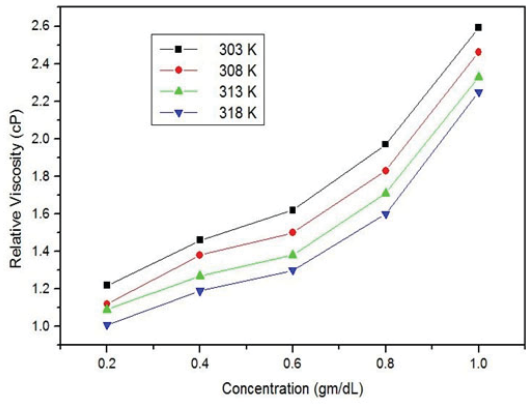

Figure 2: Variation of Relative Viscosity against concentration (Polystyrene + 1,4-Dioxane).

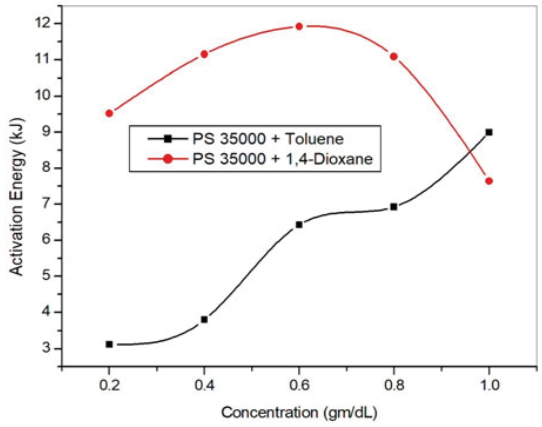

Figure 3: Variation of Activation energy against concentration.

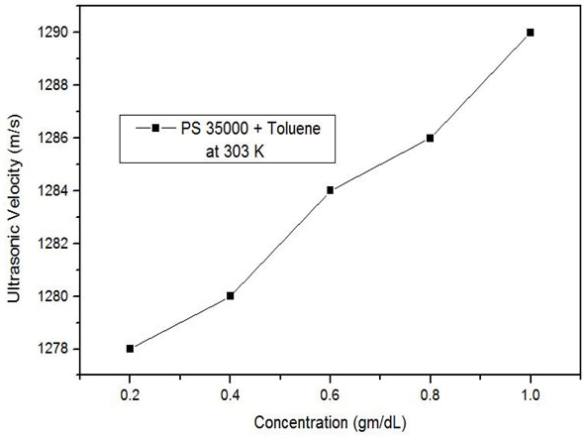

Figure 4: Variation of Ultrasonic velocity against concentration (Polystyrene + toluene).

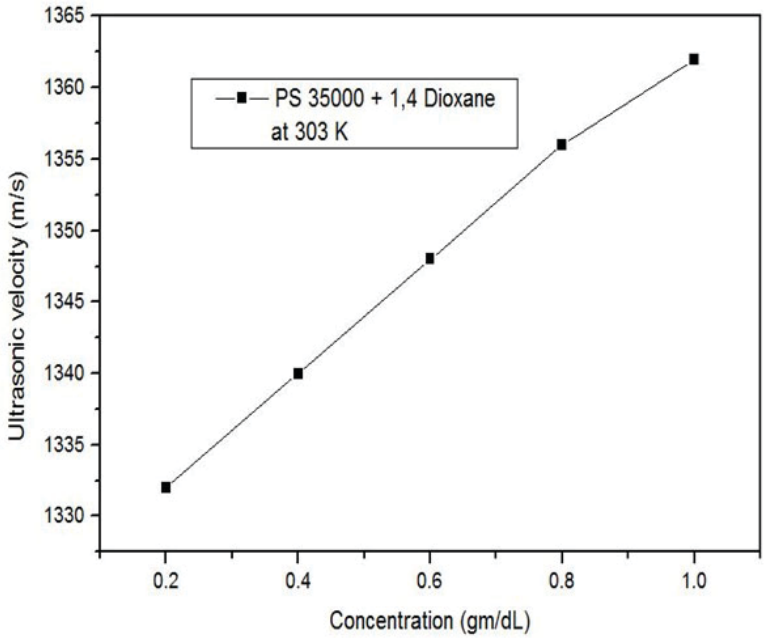

Figure 5: Variation of Ultrasonic velocity against concentration (Polystyrene + 1,4-Dioxane).

Table 1: Various Molecular interaction Parameters of CuO Nanofluid at 303K

Concentration in %	Adiabatic compressibility ($x10^{-10} m^2 N^{-1}$)	Intermolecular free length ($x 10^{-11} m$)	Free Volume ($x 10^{-12} m^3 mol^{-1}$)	Internal pressure ($x10^{10}$ atm)	Relaxation time ($x 10^{-10} s$)
Polystyrene + Toluene					
0.2	7.1071	5.5318	7.7883	1.1318	6.6333
0.4	7.0803	5.5213	7.1823	1.1632	6.9859
0.6	7.0325	5.5027	5.9666	1.2380	7.8764
0.8	6.9957	5.4882	4.2189	1.3914	9.8872
1.0	6.9494	5.4700	3.4227	1.4910	11.3040
Polystyrene + 1,4-Dioxane					
0.2	5.4978	4.8653	3.3697	1.7310	8.9431
0.4	5.4191	4.8304	2.5972	1.8910	10.5490
0.6	5.3531	4.8009	2.2420	1.9865	11.5630
0.8	5.2892	4.7721	1.6868	2.1844	13.8930
1.0	5.2408	4.7504	1.1264	2.4910	18.0980