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Synthesis and Ultrasonic Characterization of Boehmite Nanosuspension in Methanol Base Fluid

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ABSTRACT

Boehmite nanosuspension were synthesized by two step method. In this method Boehmite nano-powder was initially prepared and the powder was dispersed in methanol base fluid. The Nanosuspension exhibits much greater properties as compared to base fluid. Boehmite nanoparticles were synthesized by sol-gel technique. The prepared sample was characterized by X- ray diffraction (XRD), its average particle size has been estimated by using Debye-Scherrer formula. It was found to be 50 nm. Nanosuspension of Boehmite in methanol base fluid were prepared and their thermoacoustic studies were made such that different types of interactions could be assessed. Thermo-acoustical parameters of this nanofluids system were computed from ultrasonic velocities, densities and viscosities. The obtained results of present investigation have been discussed in the light of interactions between the Boehmite nanoparticles and the molecules of methanol-based fluids.

Keywords : Boehmite, XRD, Debye-Scherrer formula, Nanosuspension, Ultrasonic characterization.

Introduction

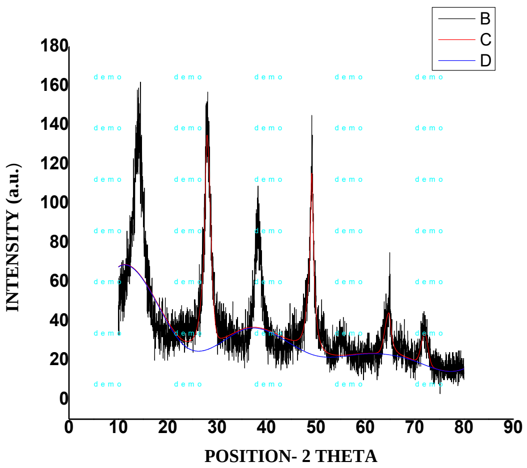
Nanoparticles are mixed with base fluid, some of the particles are remain suspended in the fluid. These suspended particles in the base fluid are considerably changes the transfer characterization and flow of base fluid. The larger surface area of nanoparticles not only increases the thermal transfer but also increases the stability of suspension. The combination of liquid with nanomaterials is also leads to special study as nanosuspension. Recent experiments on nanosuspension have indicated significant increases in thermal conductivity compared with liquids. Cooling is one of the most important technical challenges facing many diverse industries, including microelectronics, transportation, solid-state lighting, and manufacturing. Boehmite nanoparticles have seen a flurry of research in recent years as nanotech researchers, engineers, and manufacturers discover its myriad applications across various fields of interest. As with many nanoparticles, it must be handled with care to avoid issues of toxicity. In this paper, Boehmite nanosuspension were prepared by two step method and their thermodynamic properties were studied by non-destructive technique [1-6].

Synthesis of Boehmite Nanoparticles:

6.49 g of NaOH dissolved in, 50 ml of distilled water and 20 g of $Al(NO_3)_3$ $9H_2O$ dissolved in 30 ml distilled water were prepared. Al $(NO_3)_3$ $9H_2O$ is the source of aluminum. Sodium hydroxide solution is added to aluminium solution at the rate 2.94 ml/min Vigorous stirring up to 17 min [7-8]. Milky mixture was subjected with ultrasonic bath for 3h at room temperature. Mixture filtered and washed with distilled water. The precipitate was kept in 220-degree temp for 10 h. The sample so obtained was grinded to get it in powdered form.

XRD Pattern of Boehmite Nanoparticles:

Figure 1 shows the XRD pattern of AlOOH nanoparticles. The XRD measurement carried out by using "PAN analytical" X-ray diffractometer keeping the parameter constant at start position [°2Th.]: 10.0154 End Position [°2Th.]: 89.9834, Step Size [°2Th.]: 0.0170, Scan Step Time [s]: 5.7150, Scan Type: Continuous, Measurement Temperature [°C]: 25.00 Anode Material: Cu, K-Alpha1 [Å]: 1.54060. It is seen that the materials are well crystalline in nature and well agreed with standard JCPDS file number 021-1307. The estimate size of AlOOH nanoparticles using Debye Scherrer formula is found about 50 nm.



Results and Discussion:

The experimentally measured values of ultrasonic velocity, density and viscosity are used to derive thermo acoustical parameters such as viscosity, adiabatic compressibility, Acoustic impedance, free length, free Volume, internal Pressure, isothermal compressibility, isothermal bulk modulus, molar compressibility, molar sound velocity, molar volume, Poisson ratio, relaxation time, Van der Wall's Constant, volume expansivity and effective mass. These are represented graphically in figures 1 – 16. In this nanosuspension medium there might be nanoparticle fluid interaction favors in increase in ultrasonic velocity. Rise in ultrasonic velocity may concluded as the strong interaction between nanoparticles of Boehmite and microsize molecules of methanol hence there is agglomerisation of Boehmite nanoparticles due to polar nature of methanol base fluid. Therefore sound will travel faster through the more compact structure by means of longotudinal waves [9-13].

Ultrasonic velocity gets increases with increasing the molar concentration of the Boehmite nanoparticles in methanol this shows that the physical parameters of the sample changes by increasing the molar concentration. Nanoparticles suspensions do not settle which provides a long self- life which imparts ultrasonic velocity to them. For Boehmite nanoparticle the velocity of the nanosuspension is higher than methanol and also by increasing the molar concentration of the Boehmite nanoparticle the velocity gets increases beyond 0.4 and maximum at 0.7 and then decreases, it is represented in the figure 1. Peak at molar concentration 0.7 represents the strong aggregation of Boehmite nano suspension in the medium. Nonlinear variation of ultrasonic velocity may due to the Brownian motion of Boehmite nanoparticles.

Figure 2 shows the variation of density with molar concentration of Boehmite nanoparticles in methanol. Nanosuspension Boehmite has more density than methanol. Increase in density indicates the close packing between the Boehmite nanoparticles in methanol base fluid. Nonlinear variation of density may be due to Brownian motion of Boehmite nanoparticle in methanol. Dip at molar concentration 0.7 shows the weaking of interactions between the components in the medium.

When Boehmite nanoparticles suspended in methanol-based fluid, motion of particle becomes more rapid, lighter the particles, faster the motion and denser the particles slower the motion. Also suspended nanoparticles do not settle and they have long self-life. Hence, they can be easily suspended despite high solid density.

The plot of viscosity (η) versus molar concentrations clearly shows that viscosity slightly increases with increase in molar concentration of Boehmite nanoparticles in methanol base fluid. As the motion of nanoparticles becomes more rapid when the temperature of the medium was raised which lowers the viscosity of the medium as the size of the particles was reduced. Hence viscosity of nanosuspension decreases with increase in temperature. The viscosity of Boehmite nanoparticle strongly depends on structure of Boehmite nanoparticles and consequently interactions between the Boehmite nanoparticles and molecules of the fluid. Thus, the viscosity depends on interactions between components of nanosuspension as well as on the size and shape of the Boehmite nanoparticles. Measurements of viscosity yield some reliable information in the study of nano cluster. The viscosity gives the strength of interaction between the interacting Boehmite nanoparticles and molecules of methanol. Dip at molar concentration 0.7 shows that Boehmite nanoparticles are less settle with less self-life at this concentration and hence decreases the viscosity. The variation of viscosity with molar concentration are given in figure 3.

The variation of adiabatic compressibility versus molar concentration of Boehmite nanoparticles in methanol base nanosuspension shows that adiabatic compressibility (β_a) decreases with increase in molar concentration with a remarkable dip at molar concentration 0.8 indicating strong interaction between Boehmite nanoparticles and molecules of methanol showing agreegation of nanoparticles. The surface area of the material is increased by the reduction in particle size. Due to this higher percentage of the Boehmite Nanoparticles can interact with surrounding fluids. It may due to decrease in interspacing of Boehmite nanoparticles in the medium with increase in molar concentration [14]. The variation of adiabatic compressibility with molar concentration are given in figure 4.

The variation clearly shows that isothermal compressibility (β_i) decreases with increase in molar concentration with a remarkable dip at 0.8 in Boehmite nanoparticle methanol base fluid. Isothermal compressibility (β_i) and adiabatic compressibility (β_a) exhibits similar trend and both decreases with increase in molar concentration of Boehmite nanoparticles in the medium indicating strong interactions between Boehmite nanoparticles and molecules of methanol showing associating tendency of the Boehmite nanoparticles in the medium. The variation of isothermal compressibility with molar concentration are given in figure 5.

From the plot of relaxation time (τ) versus molar concentration, it is observed that relaxation time slightly increases with increase in molar concentration of Boehmite nanoparticles indicating stability of Boehmite nanoparticles in the medium. Dip at 0.7 shows the less settle time of suspended Boehmite nanoparticles in the fluid medium. For the nanoparticles in the medium, the gravitational pull is not stronger than the random thermal motion of the particles hence nanoparticles do not settle which provides long self life at molar concentrations 0.2 to 0.6 and at 0.9 which increases the relaxation time. Stability of Boehmite nanoparticles in nanofluids is totally depends on its surface energy. Less surface energy more stable will be the Boehmite nanoparticles. The relaxation is caused by the energy transfer between translational and vibrational degrees of freedom [15]. The variation of relaxation time with molar concentration are given in figure 6.

Free length is the distance between the surfaces of the neighboring Boehmite nanoparticles. The variation clearly shows that free length slightly decreases with increase in molar concentration with remarkable dip at 0.8. Decrease in free length is a result of increase in surface to volume ratio of Boehmite nanoparticles with methanol molecules, association through interactions between nanoparticles and molecules of the constituents of the nanosuspension. Free length decreases, ultrasonic velocity increases showing an inverse behavior, it is in good agreement with theoretical requirements. The variation of free length with molar concentration are given in figure 7.

The plots of internal pressure (π_i) and free volume (V_f) versus molar concentration of Boehmite nanoparticles in nanofluids represented that the internal pressure as well as free volume in this nanosuspension medium is a measure of attraction between the components of the constituents. It is observed that internal pressure decreases with dip at molar concentration 0.7. But exactly reverse is the case for free volume (V_f). It is observed that free volume increases with increase in molar concentration and found to be remarkable peak at molar concentration 0.7 indicating association in the components of the medium. Such behavior of internal pressure and free volume generally indicates the association through interactions between Boehmite nanoparticles and molecules of methanol. This suggests close packing of the molecules [16] inside the shield, it should be kept in mind that the main contribution to internal pressure comes from those interactions varying most rapidly near the equilibrium separation in the medium. The variation of internal pressure and free volume with molar concentration are given in figure 8 and figure 9.

As the size of the material decreases, the percentage of surface atoms increases, hence large amount of substance comes in contact with surrounding materials. This results in increase in acoustic impedance. The increase in acoustic impedance (Z) with molar concentration can be explained on the basis of the interactions between components of the nanosuspension, which decreases the distance of components of the medium, making relative fewer gaps between them [17-20]. The acoustic impedance is found have similar type of trend as that of ultrasonic velocity. The variation of acoustic impedance with molar concentration are given in figure 10.

The molar volume (Vm) of Boehmite nanoparticles depends on the structural arrangement and interactions between the components of the medium. The structural arrangement may be decided by the interaction forces in the nanosuspension [21-30]. The variation of molar volume with molar concentration are given in figure 11. The molar volume is found to have similar type of trend as that of molar compressibiliry.

It is observed that Vander Waal's constant increases with increase in molar concentration with remarkable peak at 0.7. This is because of the association of the interacting molecules inside the medium. The change in Vander Waal's constant (b) would be due to a change in geometry of the Boehmite nanoparticles. The variation of Vander Waal's constant with molar concentration is given in figure 12.

The variation of molar sound velocity (R) versus molar concentration of Boehmite nanoparticles shows that, it is increases with increase in molar concentration up to 0.7 then decreases indicating aggregation of Boehmite nanoparticles in the medium. It may due to increase in surface to volume ratio. It shows similar treands as that of ultrasonic velocity as it depends on it. The variation of molar sound velocity with molar concentration are given in figure 13.

It is observed that molar compressibility (W) increases with increase in molar concentration of Boehmite nanoparticles in the medium due to aggration of Boehmite nanoparticles in the medium. Indicating strong interactions between the components of the constituents. Its variation with molar concentration is given in figure 14.

The variation of isothermal Bulk modulus with molar concentration of Boehmite nanoparticles in methanol base nanosuspension are given in figure 15. The variation clearly shows that isothermal Bulk modulus (B_i) increases with increase in molar concentration with a remarkable peak at 0.8. It exhibits similar trends as that of ultrasonic velocity and inverse trend as that of isothermal compressibility.

It is observed that volume expansivity decreases with increase in molar concentration of Boehmite nanoparticles in methanol base nanosuspension due to aggration of nanoparticles in the suspension medium. As it is depends on internal pressure and isothermal compressibility it shows their resultant effects. Its variation with molar concentration is given in figure 16.

Methanol + Boehmite nanoparticles

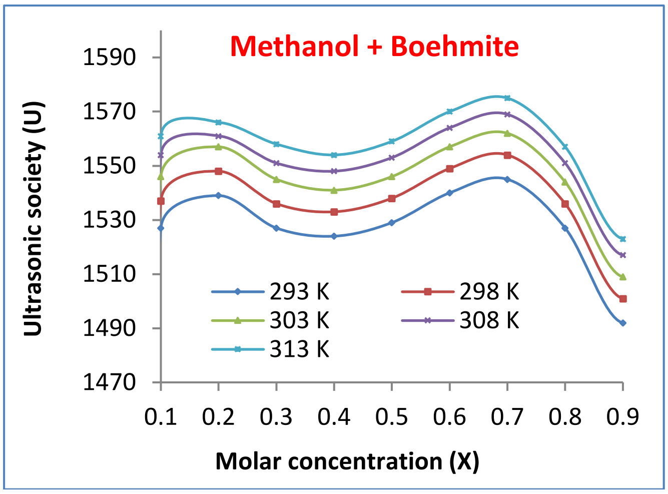


Fig. 1 Variation of u versus x

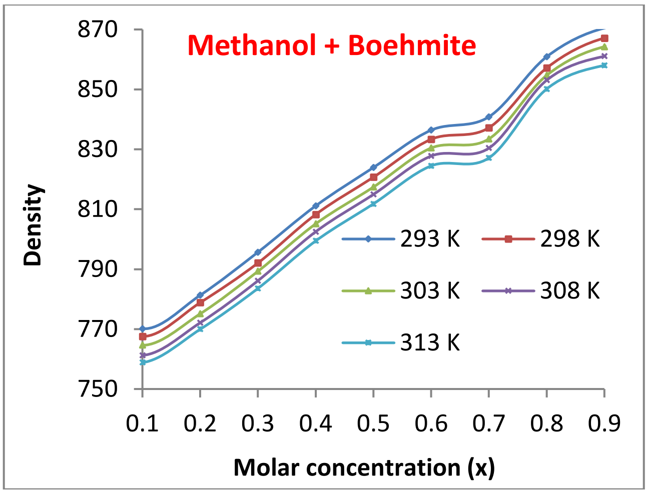


Fig. 2 Variation of ρ versus x

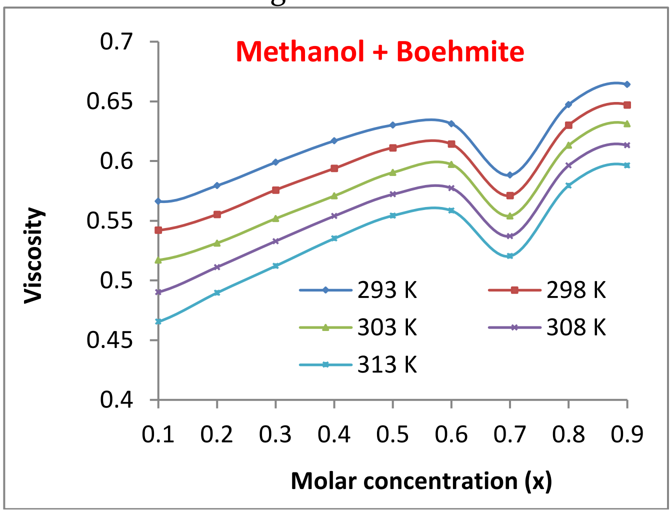


Fig. 3 Variation of η versus x

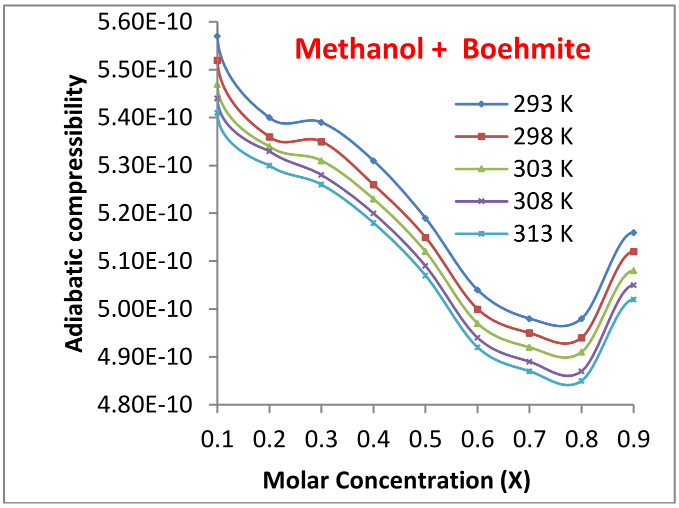


Fig. 4 Variation of β_a versus x

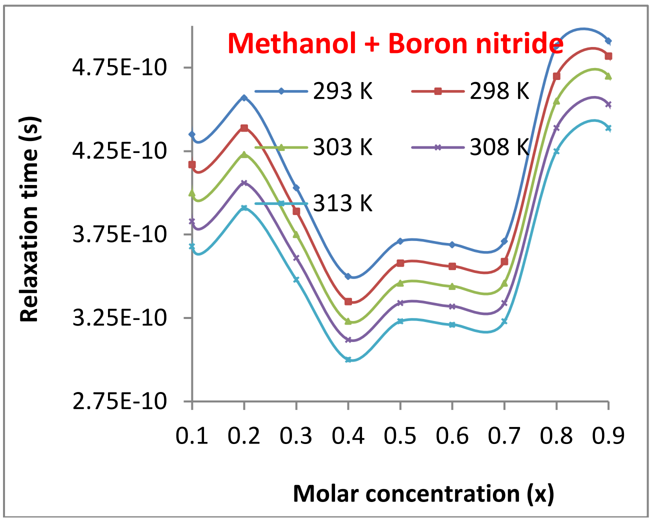


Fig. 5 Variation of β_i versus x

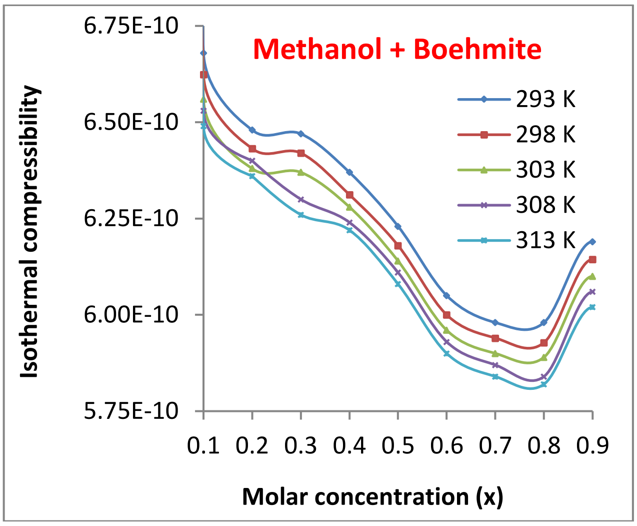


Fig. 6 Variation of τ versus x

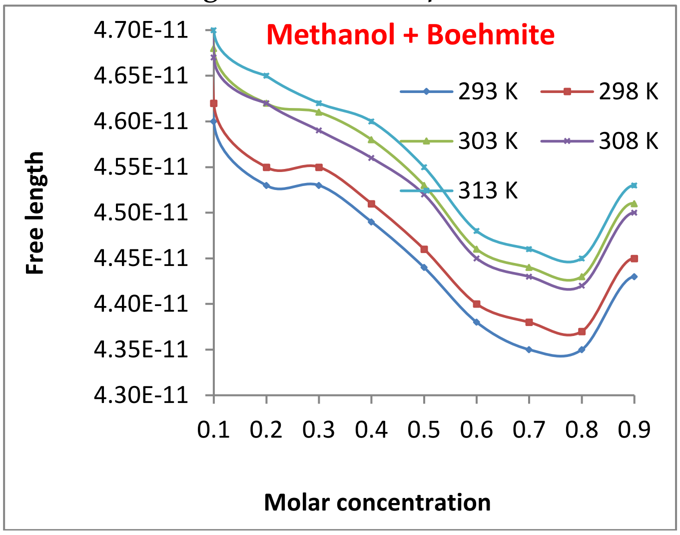


Fig. 7 Variation of L_f versus x

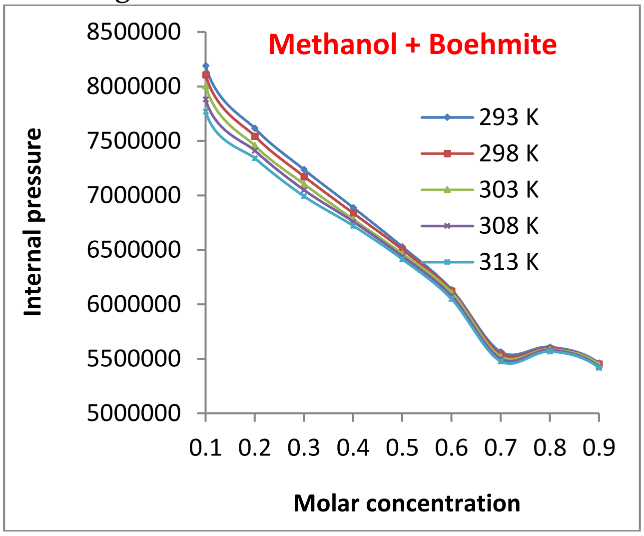


Fig. 8 Variation of πi versus x

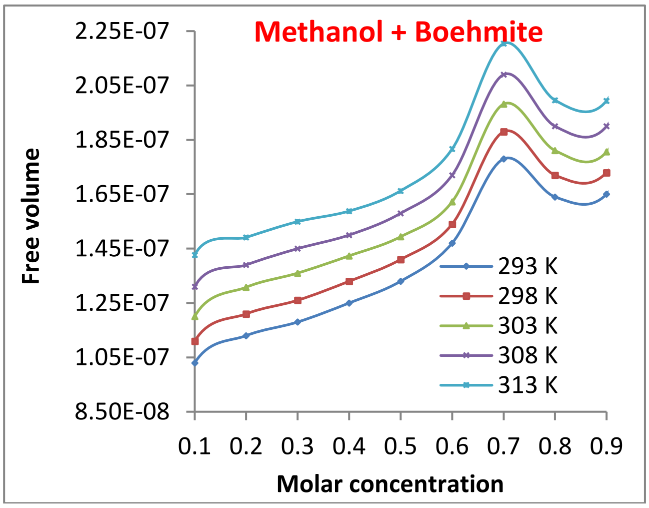


Fig. 9 Variation of V_f versus x

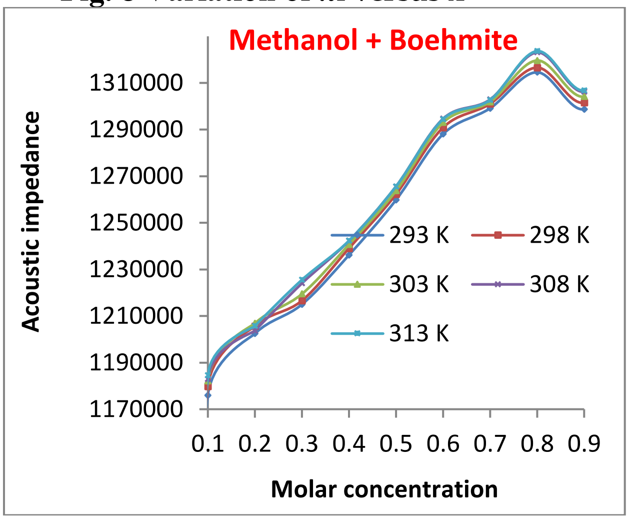


Fig. 10 Variation of Z versus x

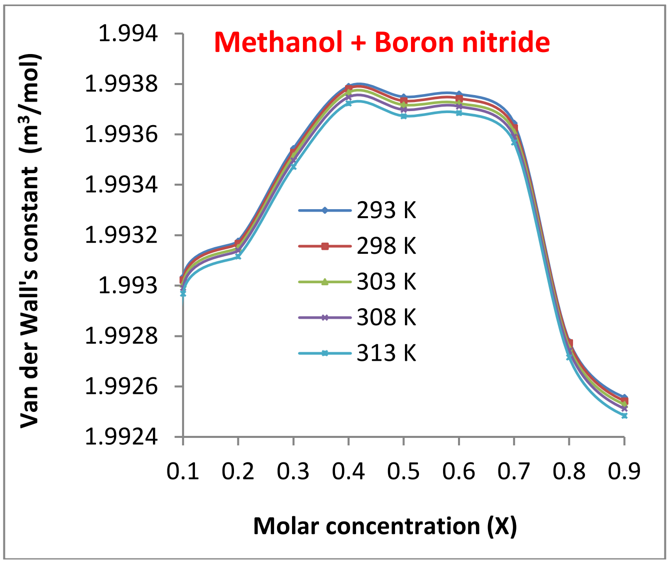


Fig. 11 Variation of Vm versus x

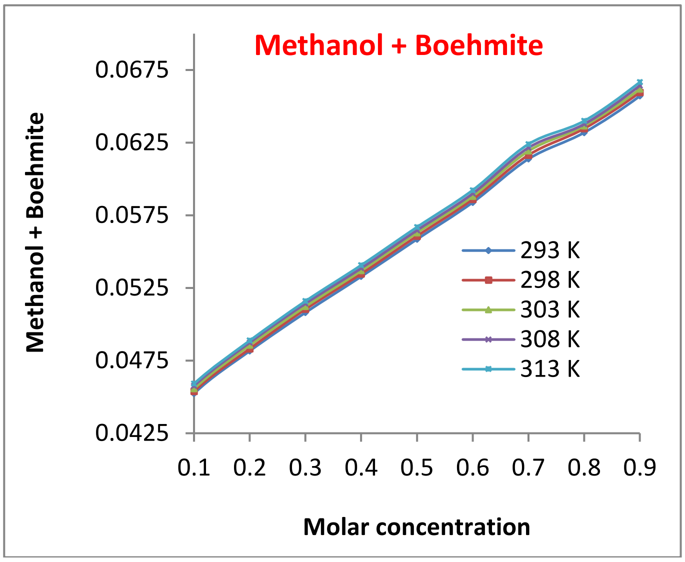


Fig. 12 Variation of b versus x

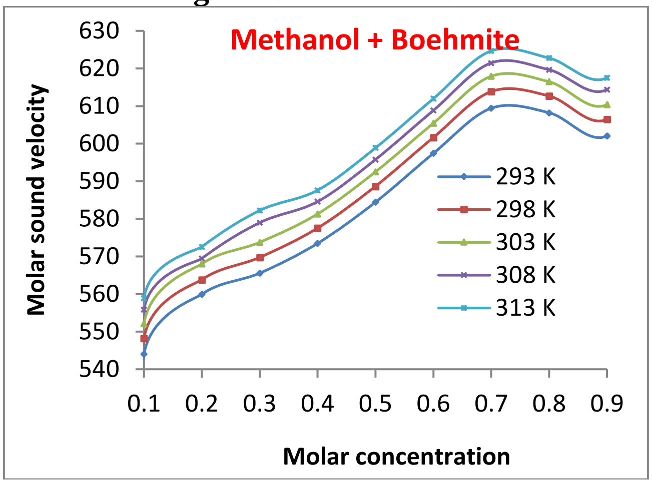


Fig. 13 Variation of R versus x

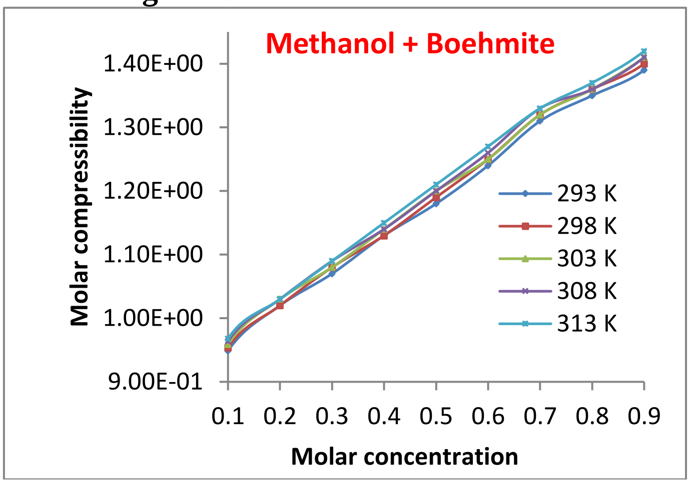


Fig. 14 Variation of W versus x

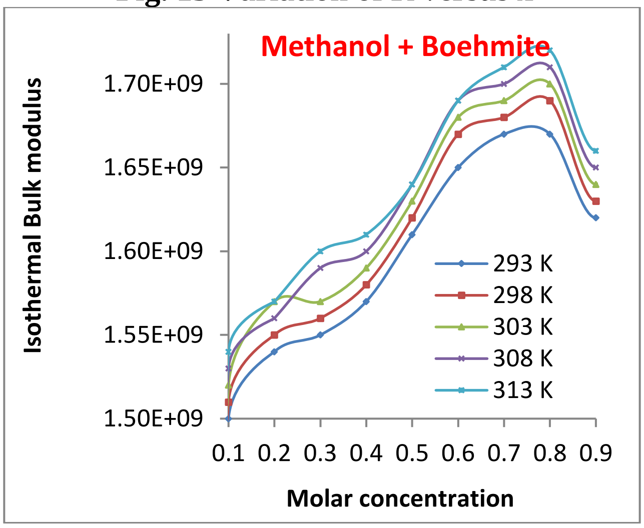


Fig. 15 Variation of B_i versus x

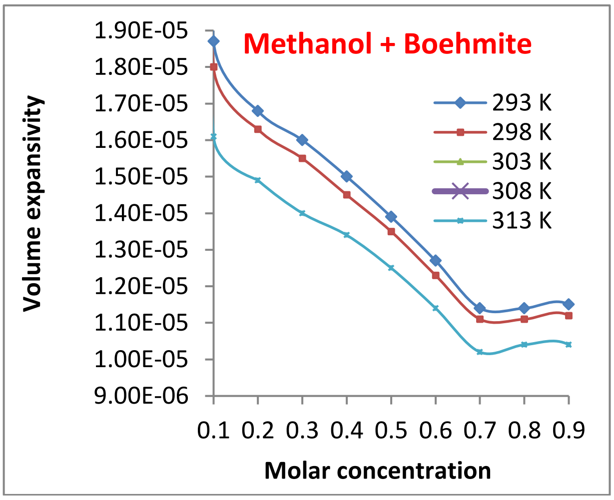


Fig. 16 Variation of α versus x

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