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Thermodynamically and Acoustically Free Length Study of Alpha- Alumina (A-Al2O3) Nano Suspension in Ethanol Base Fluid

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ABSTRACT

The present paper reports the comparison of free length thermodynamically and acoustically of alpha alumina (α-Al2O3) nano suspension in ethanol base fluid. α-Al2O3 nanoparticles were synthesized through alkoxide route using sol-gel method. Intermolecular free length has been calculated by thermo acoustical method at different temperatures over the entire range of concentrations and compared with the valued obtained from well established thermodynamic method. The ultrasonic velocity measurement at 4 MHz with an interferometric technique has been made on alpha alumina (α-Al2O3) nano suspension in ethanol base fluid. Measurement was taken for the density. The intermolecular free length was calculated from the velocity and density measurements. Free length is related with the surface of nanoparticles and nanoparticle surfactant interactions and help for the study of thermo acoustic and thermodynamic properties of nanosuspension.

Keywords: α-Al2O3; ethanol; free length; nanosuspension

I. INTRODUCTION

During recent years, studies of free length of nanoparticles have gained much importance. Extensive use of free length has been made to study the attraction and repulsion forces between the nanoparticles in nanosuspension. Thermo acoustically free length of nanoparticles in nanosuspension is given by, $L_f = K (\beta a)^{1/2} = K/U\rho^{1/2}$

Where βa, U and ρ respectively the adiabatic compressibility, ultrasonic velocity and density of nanoparticles in suspended medium. The constant K is called Jacobson's constant, which depends on temperature. Jacobson determined the value of K empirically between 0 and 50^{0}C.

Thermodynamically, free length of nanoparticles in nanosuspension is given by,

$$L_f = 2V_a/A$$

Where V_a and A represents the available volume and the surface area of nanoparticles in nanosuspension. Also,

$$V_a = V - V_O$$

$$A = (36\pi N V_O^2)^{1/3}$$

Where N is the Avogadro number V_O, and V is the molar volume at zero temperature and at temperature T, respectively.

Thermodynamically, the value of V_a can be calculated using critical temperature from the following relation,

$$V_a = V[1-(1-T/Tc)^{0.3}]$$

Where Tc is the critical temperature.

The free length has been widely used to interpret the interactions between nano suspensions in the base fluid. There has been an increasing interest in the study of interactions between the nanoparticles in the suspended medium [1-2]. Ultrasonic study of nanosuspension has been extensively carried out in different branches of science to measure the thermodynamic properties to predict the nature of interactions of nanosuspension in base fluid [3-5]. Ultrasonic velocity and thermo acoustic parameters as a function of the concentration in nanoparticle suspension are useful in gaining insight into the structure and bonding of associated nano complexes and other processes in nanosuspension. The materials of interest in this study are α-Al_2O_3 and ethyl alcohol (C_2H_5OH). Thus ethyl alcohol has an OH group that might be expected to lead to the formation of a hydrogen-bonded nano complex with α-Al_2O_3 at the oxygen site and perhaps electrostatic bonding at the other sites. These types of nanosuspension are of interest to organic chemists who want to know about the type of bond and the number of each kind of nanoparticles in the α-Al_2O_3 nano complex.

In this work, measurements of free length acoustically and thermodynamically are functions of concentration and temperatures are reported. The data presented may stimulate other researchers to consider the interactions of nanoparticles in nanosuspension. Such data are valuable in building a core of basic information about nanosuspension. The method used in the measurement of ultrasonic velocity at 4 MHz was the interferometric method over the temperature range 25-40^{0}C.

The main objective of present work is to contribute the free length of α-Al_2O_3 nanosuspension properties database in current literature in order to better understand the effects of various parameters such as particle size and temperatures. Free length is highly dependent on specific surface area of nanoparticle in nanosuspension.

II. EXPERIMENTAL AND METHODS

The test liquid samples used were spectroquality. All these samples are of BDH analar grade and were assume to be sufficiently pure so that no further purification was necessary. In this study the ultrasonic measurements have been made by interferometric method at fixed frequency 4 MHz over the entire range of concentrations and in the temperature range 25 – 40^{0}C. The velocity of ultrasound thus measured was accurate to within 0.01%. The densities were measured with an Anton Paar DMA 35 N vibrating tube densimeter with a ±0.5 × 10^{-3}g/cm^3 resolution. The temperature of nanosuspension medium was controlled to within 0.2^{0}C. Nanoparticles of alpha alumina (α-Al_2O_3) was prepared by sol-gel method [6-11] from Aluminum isopropoxide [Al $(OC_3H_7)_3$] and aluminum nitrate. The average particle size α-Al_2O_3 has been estimated by using Debye-Scherrer formula. The average estimate size of α-Al_2O_3 nano particles is found to be 20-30 nm Pawar et.al. The prepared α-Al_2O_3 nano particles were suspended in ethanol.

III. PREPARATION OF SAMPLES

Nanoparticles of alpha alumina (α-Al_2O_3) was prepared by sol-gel method from Aluminum isopropoxide [Al $(OC_3H_7)_3$] and aluminum nitrate. Starting solution was prepared by adding aluminum isopropoxide [Al $(OC_3H_7)_3$] gradually in 0.2 M aluminum nitrate and solution continuously stirred for 48 hours. Later, Sodium dodecylbenzen sulfonate (SDBS) was added and stirred for one hour. Now this solution were heated up to 60°C and stirred constantly for evaporation process. Now the paste so obtained was heated at 90°C for 8 hours, we get nanoparticles of alpha alumina (α-Al_2O_3) in powder form.

The prepared sample were characterized for their phase purity and crystallinity by X-ray powder diffraction (XRD) using PAN-analytical diffractometer (Cu-Ka radiation) at a scanning step of 0.01^o, continue time 20 s, in the 2h range from 10^o to 120^o. Formation of the compound confirmed by XRD pattern matched with the standard data available in JCPDS file. From this study, average particle size α-Al_2O_3 has been estimated by using Debye-Scherrer formula

$$D = \frac{0.9\lambda}{WCos\theta} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where 'λ' is the wavelength of X-ray (0.154060nm), 'W' is FWHM (full width at half maximum), 'θ' is the diffraction angle and 'D' is particle diameter (size). The average estimate size of α-Al_2O_3 nano particles is found to be 20-30 nm. The prepared α-Al_2O_3 nano particles were suspended in ethanol. Fig.1 represents XRD pattern of α-Al_2O_3 nanoparticles and Fig. 2 (A) and 2 (B) represents SEM images of α-Al_2O_3 nanoparticles.

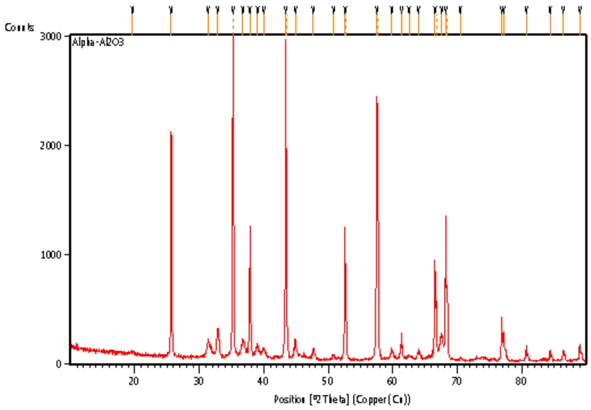

Figure 1. XRD pattern of α-Al_2O_3 nanoparticles

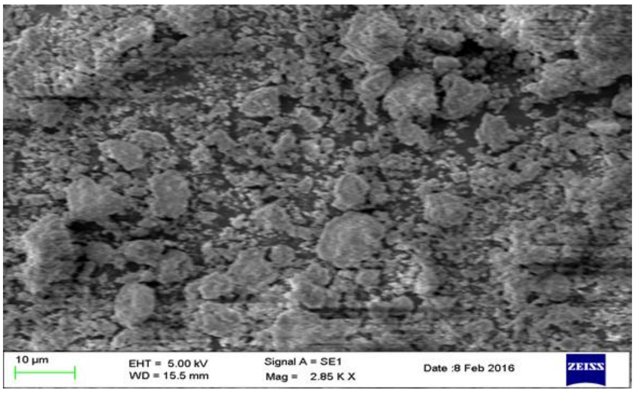

Figure 2(A). SEM image of α-Al_2O_3 nanoparticles

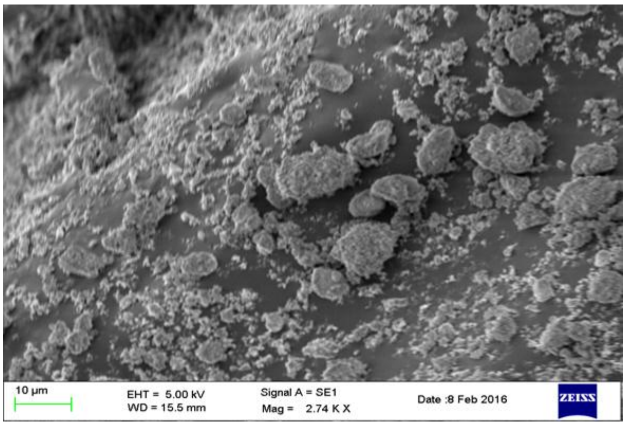

Figure 2(B). SEM image of α-Al_2O_3 nanoparticles

IV. RESULTS AND DISCUSSION

The intermolecular forces, which in one way or another determine the said properties of nanosuspension, consist of attractive forces and repulsive forces. These forces have opposite directions but are numerically equal under given external conditions. The attractive forces are dependent on the distance between what are called the centres of attraction of the nanoparticles, whereas the repulsive forces are dependent on the distance between the surfaces of the nanoparticles. Centres of attraction do not coincide with the geometrical centre of the nanoparticles. The distances between the surfaces have a clear physical significance, and thus lend themselves more easily. Surface tension, viscosity, thermal expansion and molecular association will be related to the intermolecular free length. The acoustic wave which was excited in the nano suspended medium is momentarily to the intermolecular length. Free length is long, ultrasonic velocity has a low value. Its value corresponded to the molecular shape Figure 3 contains the plot of free length computed acoustically versus molar concentration. Figure 4 represents the thermodynamical free length versus molar concentration of α- Al_2O_3 nanosuspension in ethanol. It is observed that free lengths computed acoustically are slightly more than computed by thermodynamically.

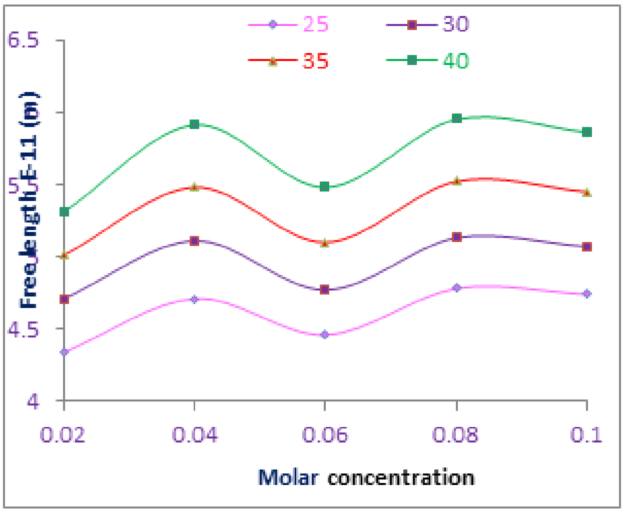

Figure 3. Acoustical free length versus molar concentration of α- Al_2O_3 nanosuspension in ethanol

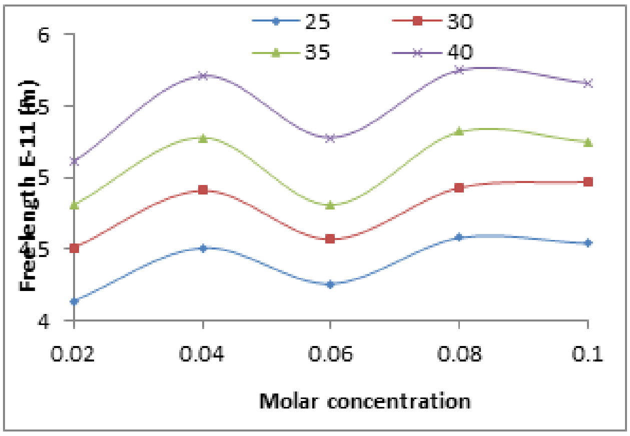

Figure 4. Thermodynamical free length versus molar concentration of α- Al_2O_3 nanosuspension in ethanol

V. CONCLUSIONS

1. The free length computed acoustically and thermodynamically shows considerable deviation from any linear variation with respect to molar concentrations.
2. The free length computed acoustically have slightly greater value than the value computed by thermodynamically.
3. Non linear variation of free length versus molar concentration is due to Brownian motion of nanoparticles in nanosuspension.
4. Behavior of nanoparticles in ethanol base fluid nano suspension dependent on its specific surface area.
5. Free length study of nanoparticles in nanosuspension highly useful in understanding nature of interactions, internal structure and the aggregation behavior.

VI. REFERENCES

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