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Thermal and Acoustical Studies of CuO Nanofluids

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ABSTRACT

Copper oxide nanoparticles are used in the synthesis of CuO nanofluids for increasing the thermal conductivity of nanofluids. The method of preparation of nanofluids in stable form is of much significant in the field of nanofluid and its application. In this present work, CuO nanoparticles (particle size: 40 nm) are dispersed in double distilled water and nanofluids are prepared at ten different concentration (0.2% - 2.0%) in steps of 0.2 at room temperature. Viscosity studies are carried out at different temperatures (303K, 308K, 313K & 318K) for the prepared nanofluids. From the experimental values, the activation energy is calculated and ultrasonic velocity, density, refractive index and thermal conductivity studies are performed at room temperature. Various molecular interaction parameters are determined to analyze the nature of molecular interaction in the sample taken for study.

Key Words: Activation Energy, Molecular Interaction Parameters, Cuo Nanofluids, Ultrasonic Velocity, Thermal Conductivity

INTRODUCTION

Nanofluids are the colloidal suspension of the dispersed nanoparticles in the base fluid. These colloidal suspension in nanoscale range are first coined by Choi in the year 1995 [1]. By dispersing nanoparticle in the base fluid can offer tremendous change in the thermal properties. Generally, the nanoparticles dispersed in nanofluids may be of metals (e.g. Al, Au, Fe, Ag) non-metals (e.g. Sio2, Al2O3, ZnO, CuO), carbides and carbon nanotubes. Commonly used base fluids are water, oil (coconut oil, castor oil, rapeseed oil), organic liquids like ethanol, butanol, ethylene glycol and polymeric solutions [2]. Due to its improved thermal conductivity nanofluids have greater desirability. Nanofluids provide auspicious heat transfer applications in the industrial sectors for heating, transportation, power generation, bearings, ventilation, cooling, thermal therapy, micro-manufacturing, therapy, ventilation, optoelectronic devices etc [2].

Nanofluids have extremely large surface to volume ratio and thus have great potential in heat transfer applications. They have enhanced thermal properties, due to the presence of small sized nanoparticles and find wide range of applications like electronics, transportations, medical field. The important goal in nanofluid research is to develop nanofluid with stability for industrial applications. Nanofluids are prepared by sonication process which is a usual and simple method. Ultrasonication is an accepted technique for dispersing aggregated nanoparticles for the preparation of aqueous nano-suspensions [3]. The nanofluids synthesized using metal or metal oxide nanoparticles have relatively high thermal conductivity than the base fluid [4]. Copper oxide nanoparticles, used to prepare CuO nanofluid are the most fascinating type of material. They are showing multifunctional properties with hopeful applications in many areas like catalysts, superconductors, solar energy, batteries, magnetic storage media [5].

This paper explains the method of preparation of CuO nanofluids at ten different concentration and clarifies the interaction present between the solute and solvent molecules using ultrasonic procedure. CuO nanofluids are prepared using two-step method with water as the base fluid. The acoustical parameters are considered to investigate the interactions taking place in the prepared nanofluid and the results are discussed. A significant enhancement in the thermal conductivities of the CuO nanofluids was noticed with the increase in concentration and these performances formed an attention in heat transfer researches using nanofluids [6].

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MATERIALS AND METHODS

CuO Nanofluids were prepared by two step method by dispersing the CuO nanoparticles uniformly in distilled water with the aid of sonication. CuO nanoparticles was purchased from US nano Laboratories. The nanopowders of CuO were dispersed in distilled water to obtain CuO nanofluids of ten different concentration (0.2% - 2.0%) in steps of 0.2 at room temperature. The quick settlement of nanoparticles is the extremely unwanted problem for various hands-on heat transfer/cooling applications. The nanoparticles can remain suspended for long time because of its smaller size. At the same time, it is a great challenge in lab-scale research for producing stable nanofluids. However, the enduring constancy of the nanofluids is a real issue. Using Mittal make single frequency Ultrasonic interferometer (2 MHz, F-81 model), the Ultrasonic velocity measurements are made for different concentrations of the synthesized nanofluids at 303K. The viscosity of the suspensions was carried out for all concentrations at four different temperatures 303K, 308K, 313K, 318K using Digital Viscometer (BROOKFIELD make). With the specific gravity bottle (5 cc), the density of the nanofluids are determined.

RESULTS AND DISCUSSION

Activation Energy Studies

Viscosity studies are performed for CuO nanofluids in the concentration range of 0.2% – 2.0% at different temperatures 303K, 308K, 313K and 318K and the results are shown in Fig. 1. It is because of the presence of frictional force among the layers of the nanofluid, the relative viscosity increases as the concentration increases and decreases as the temperature increases [7]. Fig.2. shows the variation of log viscosity (ln η) against inverse of temperature (1/T) for CuO nanofluid. The ln η against 1/ T graph shows that the curve fit is a straight line. Log η is very nearly a linear function of the inverse of the absolute temperature *T*.

The apparent activation energy of viscous flow, *Q*, is associated to concentration *c* and molecular weight. In all the cases, the ln η value increases with concentration and decreases with decrease in temperature. From the Arrhenius expression given by Moore et al [8] as, $\eta = A\, e^{Q/RT}$

A is the pre-exponential term with an activation entropy significance and Q is the apparent activation energy of flow. In Fig. 3, the activation energy decreases from 0.2% to 0.6% and increases from 0.6% to 1.0% and then decreases further at higher concentration indicating a non-linear variation in the interaction of nanoparticle with the fluid. The density and ultrasonic velocity show uniform increase with the increase in nanoparticle concentration [Fig.4 & Fig.5]. This linear increase of velocity indicates the interaction energy between water molecules and nanoparticle clusters are terminated by hydrogen atom. Hence, there is a significant interaction between particles and water molecules which favors increase in velocity [9].

Molecular Interaction Studies

The experimental values of ultrasonic velocity, viscosity and density of CuO nanofluids, are used to determine numerous molecular interaction parameters like adiabatic compressibility (β), intermolecular free length (Lf), free volume (Vf), internal pressure (π) and specific acoustic impedance (Z), Classical absorption co-efficient (α/f2), viscous relaxation time (τ), Relative association, Rao's constant and Wada's constant. From Table 1, it is observed that Adiabatic compressibility and free length decreases as the concentration increases [9]. Fig.6 shows that free volume varies non-linearly. From the graph of free volume against concentration, it is clear that the values first decrease and then increases at 0.6% and then it goes on decreasing due to non-linear variation in the solute and solvent interaction [9]. The internal pressure shows a reverse trend of free volume.

It is observed that the relaxation time of the CuO nanofluid decreases first and then found increased as the concentration of the solution increases. Owing to structural relaxation process, the relaxation time is approximately 10-12 sec. The non-linear variation of relaxation time is due to the rearrangement of molecules by cooperative process [10]. It is seen that Classical absorption co-efficient decreases as the molar concentration increases. This decrease in classical absorption co-efficient values is caused by hydrogen bond formation at higher level of concentration of the CuO nanofluids [11]. Acoustic impedance showed an increase with increase in concentration due to increasing particle-fluid interactions [10]. It is indicated that the Specific acoustical impedance (Z-values) are analogous with that of the ultrasonic velocity values.

The resistance extended to the sound wave by the components of the mixture is termed as Specific acoustic impedance. It is nearly communal with the adiabatic compressibility. Rao's constant and Wada's constant both found to increase linearly with the increase in the concentration of the CuO nanofluid [10].

From Table. 2, it is observed that thermal conductivity of CuO nanofluid at different concentrations. It is clear that thermal conductivity increases with increase in concentrations of nanofluids. Brownian motion of suspended nanoparticles is attributed as one of the key factors of the greatly enhanced thermal conductivity [12-14].

CONCLUSION

The ultrasonic velocity, density and viscosity of CuO nanofluid has been studied for different concentration of CuO nanoparticles in the distilled water. The particle-fluid interaction is examined from the increase in ultrasonic velocity as the concentration increases. It is clear that ultrasonic velocity is elevated for CuO nanofluids when related with the base liquid and provide enrichment of nanosuspension that can be used for many industrial applications. The acoustical parameters and thermal conductivity was studied for the CuO nanofluid at room temperature. The acoustical study shows the strong molecular interaction among CuO nanoparticles and fluid. The enhancement in the thermal conductivity of nanofluid with higher level of particle concentration is caused by the presence of nanoparticle suspension in the base fluid due to Brownian motion.

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Conflict of interest

There is no conflict of interest in publishing the article

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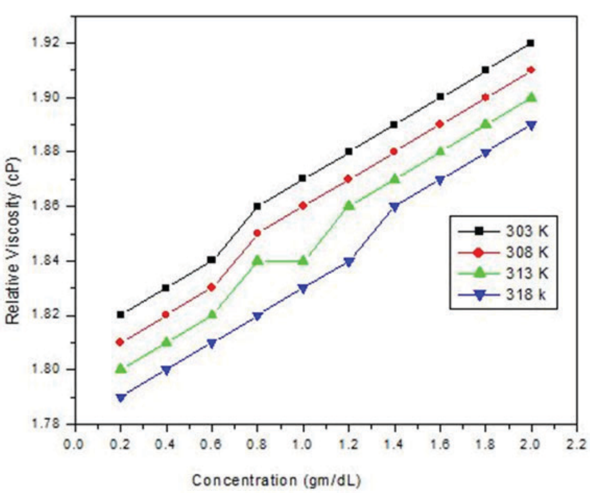

Figure 1: Variation of Relative Viscosity against concentration.

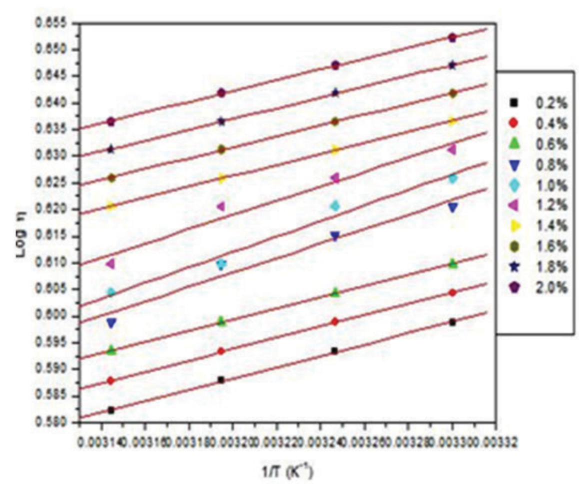

Figure 2: Variation of log η against 1/T.

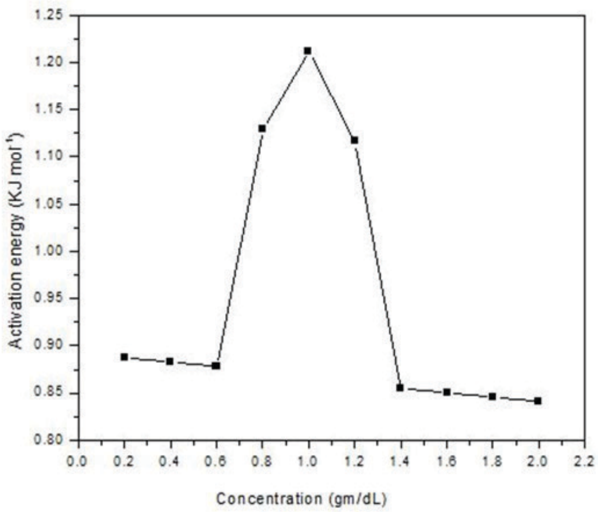

Figure 3: Variation of Activation energy against concentration.

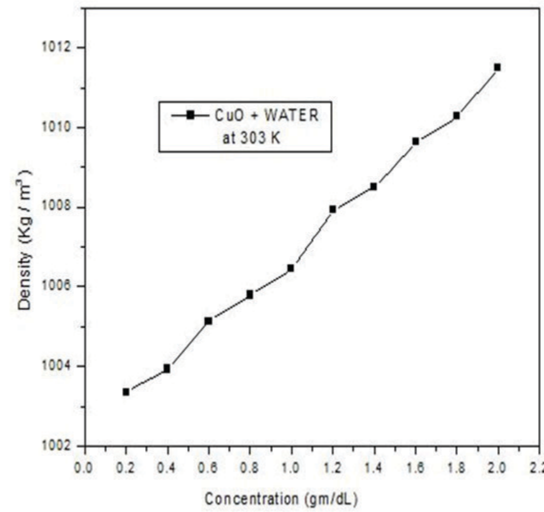

Figure 5: Variation of Density against concentration.

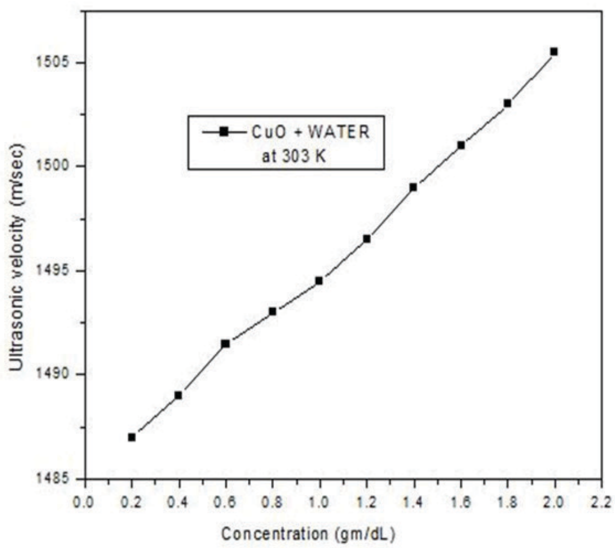

Figure 4: Variation of Ultrasonic velocity against concentration.

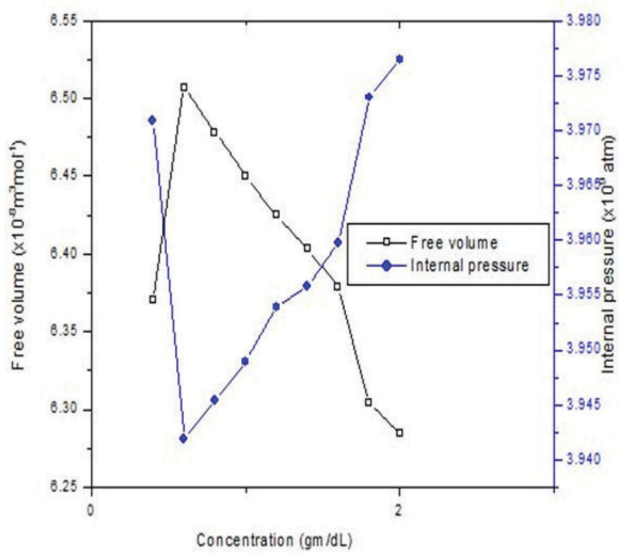

Figure 6: Variation of free volume and internal pressure against concentration.

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

Concentration in %	Adiabatic compressibility ($x10^{-10}$ m^2N^{-1})	Intermolecular free length ($x10^{-11}$ m)	Free Volume ($x10^{-8}$ m^3mol^{-1})	Absorption co-efficient ($x10^{-14}$ m^{-1} s^{-2})	Relaxation time ($x10^{-12}$ s)
0.2	4.5073	4.4053	6.3948	1.4504	1.0937
0.4	4.4927	4.3981	6.3700	1.4517	1.0962
0.6	4.4722	4.3881	6.5072	1.4269	1.0793
0.8	4.4603	4.3823	6.4782	1.4295	1.0823
1.0	4.4485	4.3764	6.4497	1.4321	1.0854
1.2	4.4300	4.3674	6.4247	1.4321	1.0868
1.4	4.4128	4.3589	6.4033	1.4319	1.0885
1.6	4.3961	4.3506	6.3789	1.4323	1.0902
1.8	4.3816	4.3434	6.3043	1.4410	1.0983
2.0	4.3619	4.3336	6.2842	1.4397	1.0992

Table 2: Various Molecular interaction Parameters of CuO Nanofluid at 303K

Concentration in %	Specific Acoustical Impedance (x 10^6 kg m^{-2} s^{-1})	Internal pressure (x10^9 atm)	Relative association	Rao's constant (x 10^{-4} m^3 mol^{-1} $[ms^{-1}]^{1/3}$)	Wada's constant (x$10^{-3}$$m^3$$mol^{-1}$ $[Nm^{-2}]^{1/7}$)	Thermal conductivity (W/m/K)
0.2	1.4919	3.9683	1.0045	2.0037	0.3895	39.4392
0.4	1.4948	3.9709	1.0046	2.0065	0.3901	39.4669
0.6	1.4991	3.9419	1.0052	2.0083	0.3905	39.5245
0.8	1.5016	3.9454	1.0055	2.0108	0.3909	39.5411
1.0	1.5041	3.9489	1.0058	2.0132	0.3914	39.5579
1.2	1.5083	3.9539	1.0069	2.0142	0.3917	39.6097
1.4	1.5117	3.9558	1.0070	2.0172	0.3923	39.6506
1.6	1.5154	3.9598	1.0076	2.0189	0.3927	39.6929
1.8	1.5184	3.9730	1.0078	2.0216	0.3932	39.7230
2.0	1.5228	3.9764	1.0085	2.0233	0.3936	39.7808