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Study of the Bulk Properties of Cholesteric Liquid Crystal Using Ultrasonic Techniques

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Abstract

The present paper reports the study of bulk properties ultrasonic velocity (C), density (ρ), refractive index (n_D), adiabatic compressibility (β_a), specific acoustic impedance (Z) of a cholesteric liquid crystal cholesteric oleyl carbonate. The ultrasonic velocity, density and refractive index are measured for the sample in a temperature range 300 K to 320 K. With the help of measured data adiabatic compressibility and specific acoustic impendence have also been calculated.

Key words: Cholesteric Liquid Crystal, Bulk Properties, Associative Character, Ultrasonic Technique.

The molecules of the system get agitated with temperature rise and they exhibit the dip in the ultrasonic properties of the system because the increased thermal agitation increases the rate of energy loss due to a large number of collisions. On increasing the temperature, the thermal fluctuations will increase and the energy required to bring the molecules to the activated state will also increase. The bulk properties of the system experience the severe change in their variation with temperature. From this study and available literature it is concluded that Cholesteryl Oleyl Carbonate molecules have strong associative character. The bulk properties of cholesteric liquid crystal are temperature dependent.

1. Introduction

A cholesteric liquid crystal is a type of liquid crystal with a helical structure and which is therefore chiral. Cholesteric liquid crystals are also known as chiral nematic liquid crystal.

Cholesteric materials are liquid crystals of mesomorphic phase in which molecules are parallel to each other within the plane of a layer, but the direction is oriented in loose parallel lines to form a helix through the layers. The key property of liquid crystals that differentiates them from liquids is the low degree of order that exists in liquid crystal molecules. Cholesteric materials are temperature sensitive and have color changing ability with temperature. The study of the bulk properties of liquid crystals has been quite important as they are used for biomedical, pharmacological indicator of temperature. The ultrasonic technique is an important tool for investigation of liquid structure. The measured bulk properties are being extensively used to study intermolecular processes in pure liquids.

2. Material and Methods

For present study Cholesteryl Oleyl Carbonate (3-cholestene-3β-ol Oleyl carbonate) has been chosen. Cholesteryl Oleyl carbonate is an organic chemical, a carbonate ester of cholesterol and oleyl alcohol with carbonic acid. It is a transparent liquid, or a soft crystalline material with melting point around 20°C. It can be used with cholesteryl nanoate and cholesteryl benzoate in some thermochromic applications.

2.1 Ultrasonic velocity Measurement

The velocity of ultrasonic wave in the sample has been measured using ultrasonic interferometer make at the frequency of 4 M Hertz with varying temperature.

The measurement of velocity is based on the accurate determination of the wavelength (λ) in the medium. Ultrasonic waves of known frequency (f) are produced by a quartz crystal fixed at the bottom of the cell. These waves are reflected by a movable metallic plate kept parallel to the quartz crystal. If the separation between these two plates is exactly a whole multiple of sound wavelength, standing waves are formed in the medium. This acoustic resonance gives rise to an electrical reaction on the generator driving the quartz crystal and the anode current of the generator becomes maximum. If the distance is now decreased or increased and the variation is exactly one half wavelengths (λ/2) or multiple of it, anode current become maximum. Ultrasonic velocity has been calculated with the help of following formula-

$$C \text{ (velocity)} = \lambda \text{ (wavelength)} \times f \text{ (frequency)}$$

The measuring cell is specially designed doubled walls having two outlets marinating the desired temperature for the sample by the means of water circulation through a thermostat during the experiment.

2.2 Density Measurement

The density measurements were done using a graduated container calibrated with distilled water. The container was placed in a glass jacket in which the water was circulated from the thermostat to maintain the temperature, the experimental liquid crystal was filled in the container and its mass was measured and after maintaining the temperature in the water jacket the volume rise was noted for the taken mass of the material and divided by the volume for getting density at each temperature.

2.3 Refractive Index Measurement

The refractive index of the liquid crystal at different temperatures was measured with a monochromatic light source using the Abbe's refractometer. One-two drops of the sample on prisms p_1 and p_2 and clamp them back in the instrument. Thus, a film of the sample spread uniformly between two prisms. The monochromatic light reaching the surface of p_1 becomes scattered into the film of the sample. Rays with greater angle of refraction than that of the ray corresponding to grazing incidence do not enter prism p_2. Bright and dark portions are seen in the field of view by rotating the prism box slowly and bringing the cross wires on the edge of the bright portion, thus the refractive index of the sample is measured. Average of several observations gives the proper results. The temperature between the prisms was maintained by water circulation from the thermostat.

The ultrasonic velocity, refractive index and density have been taken as a primary data while specific acoustic impedance and adiabatic compressibility has been computed with the help of following formulae.

$$\text{Adiabatic Compressibility } (\beta_a) \quad = \quad (\rho C^2)^{-1} \quad\quad\quad (1)$$
$$\text{Specific Acoustic Impedance } (Z) \quad = \quad \rho.C \quad\quad\quad (2)$$

3. Results and Discussion

The ultrasonic parameters such as ultrasonic velocity, density, refractive index which are measured for cholesteric liquid crystal for a temperature range from 300K to 320K. Using the measured data adiabatic compressibility and specific acoustic impendence are calculated using the relation given in the above section. The measured parameters, ultrasonic velocity and refractive index and density are plotted in Figures 1, 2, 3.
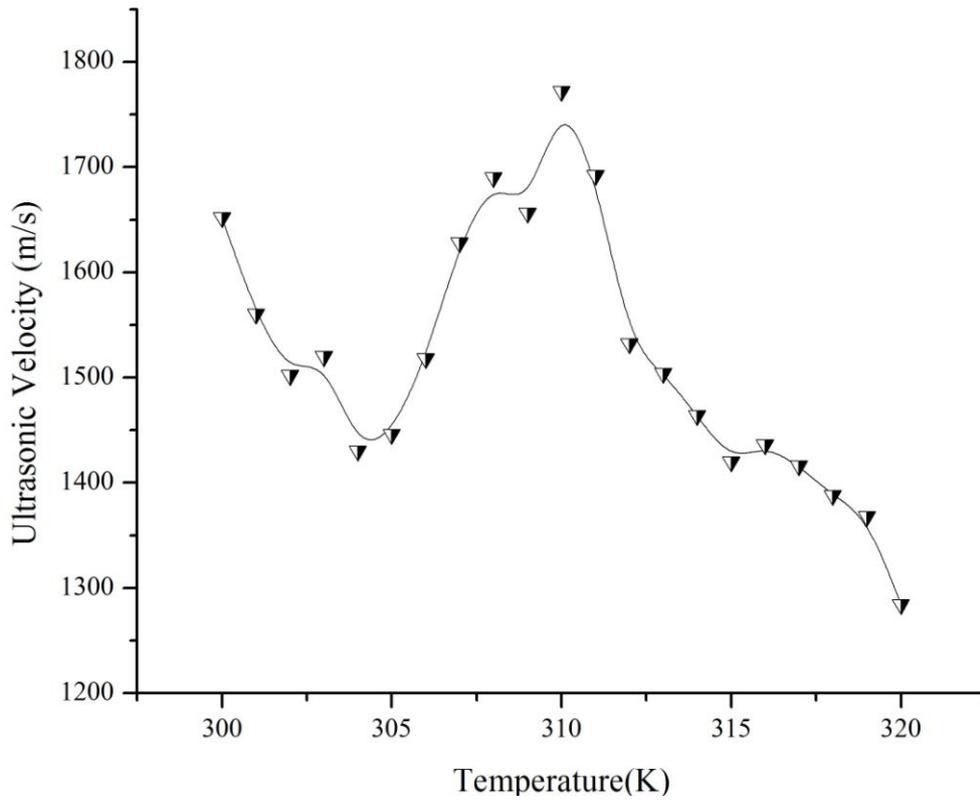
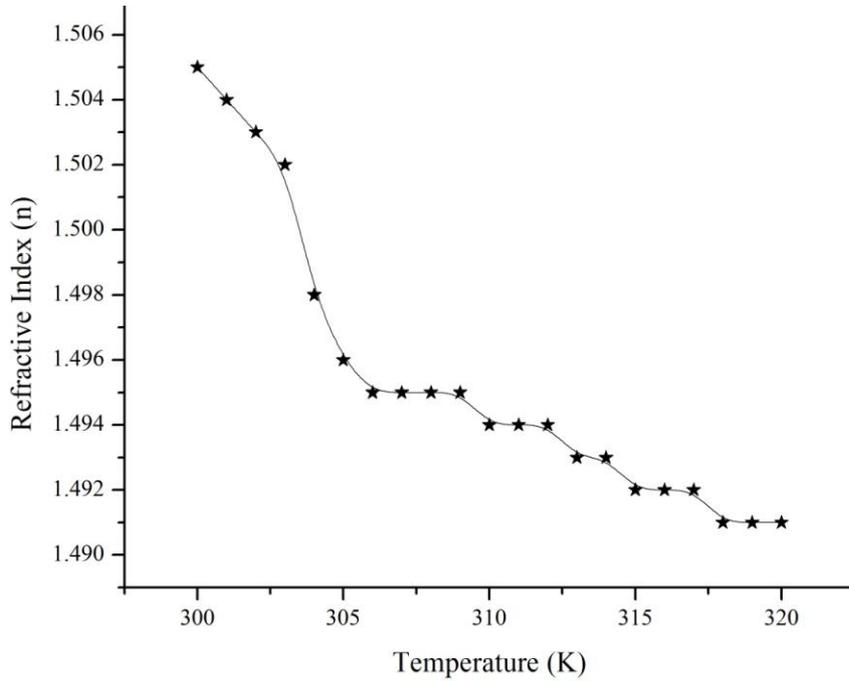Figure -1 -Ultrasonic Velocity Vs Temperature
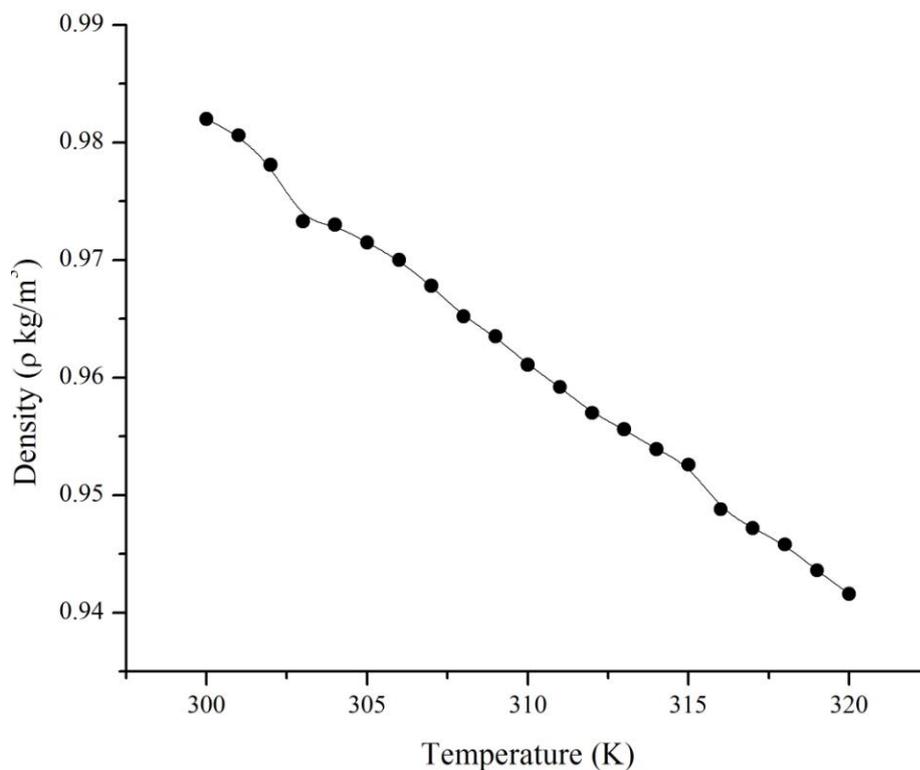

Figure -2 -Refractive Index Vs Temperature

Figure -3 -Density Vs Temperature

The adiabatic compressibility and specific acoustic impendence, are plotted in Figures 4 and 5.

The Ultrasonic velocity for sample starts as decreasing as temperature increase at about 300 K, after a dip at 304 K the Ultrasonic velocity starts increasing and at about 310 K it becomes maximum and further increase in the temperature makes it to decrease in a steady way. The transition at 310 K is significant due to the decreasing values of the ultrasonic velocity after this point. In a similar way the refractive index is also showing a dip in the variation about 304 K. But overall variation of refractive index is decreasing with temperature, which may be due to the change in density with variation in temperature. We found that Specific acoustic impendence is minimum at 303 K and maximum at 310 K. On the other hand adiabatic compressibility is highest at 303 K whiles it minimum at 310 K although the Specific acoustic impendence is minimum at 303 K and maximum at 310 K.

The ultrasonic velocity varies non-linearly showing peaks at transition temperatures. The specific acoustic impedance also has the similar behaviour under the transition temperatures. The graph of the adiabatic compressibility reflexes the opposite behaviour as those of ultrasonic velocity and specific acoustic impedance which results in a strong support in the declaration that the liquid crystal under investigation have strong associative characteristics.
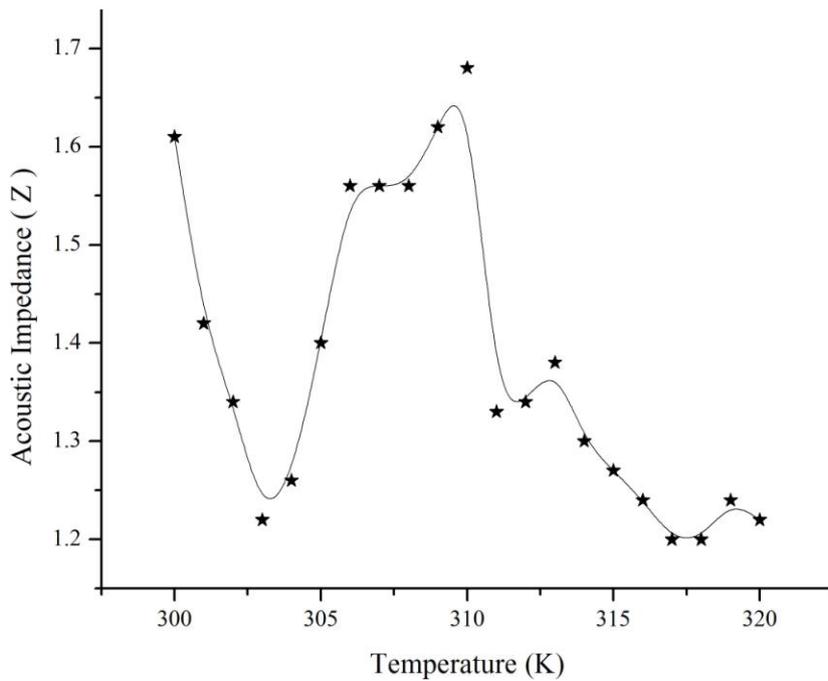
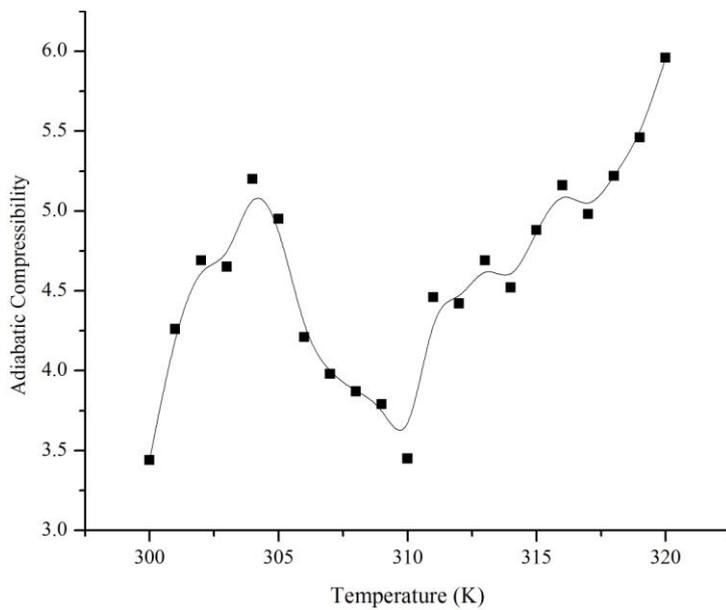Figure -4 -Specific Acoustic Impedance Vs Temperature

Figure -5 -Adiabatic Compressibility Vs Temperature

4. Conclusions

In the present study and available literature values it is observed that ultrasonic technique is one of the best techniques to study discontinuities, transition and bulk properties of the liquid crystalline materials. On increasing the temperature, the thermal fluctuations increases and the energy required to bring the molecules to the activated state also increases. The bulk

properties of the system experience the severe changes with variation in temperature. It is found that the molecules of the liquid crystal under study are more associative in nature. The bulk properties of cholesteric liquid crystal are temperature dependent.

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