

# Ultrasonic Behaviour of Cholesteric Liquid Crystal

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**ABSTRACT:** Cholesteric liquid crystals (CLC) change colour at phase transition temperatures and their sensitivity to temperature depends on the particular characteristic composition. The measurement of ultrasonic velocities helps in studying the nature of intermolecular forces. It also provides significant information about the structure and properties of the system. We measured ultrasonic velocity of Cholesteryl Myristate as a function of temperature in the temperature range 70°C to 90°C by changing the concentration of CLC in the solvent. We observed anomalous behaviour in the properties of CLC near phase transition temperatures for all the concentrations. These physicochemical properties also varied with the concentration of CLC in the solvent. This behaviour is due to the physicochemical changes in the LC molecules. The study of the physicochemical properties has applications in basic science, industries and biochemical technologies.

**KEYWORDS:** Cholesteric Liquid Crystal (CLC), phase transition temperature (PTT), ultrasonic velocity, physicochemical properties.

## I INTRODUCTION

Liquid crystal is an intermediate phase between Solids and Liquids. In Cholesteric phase of liquid crystal, the molecular axis shows a preferred orientation labeled as director. The molecules of cholesteric liquid crystals are twisted along the director. [1, 2] The molecular alignment within a layer is parallel, but the alignment in adjacent layers is rotated. The displacement is cumulative through successive layers so that the tip of the director traces out a helical pitch. The pitch exhibits extreme sensitivity to slight changes in temperature.[1,2] The thermotropic liquid crystals are temperature induced and change phase at Phase transition temperature (PTT). Some cholesteric liquid crystals can reflect definite colors at specific temperatures. [3] These color changes are reproducible and reversible as long as the liquid crystal is not physically or chemically damaged. The color-temperature deviation interval depends on the liquid crystal composition.

The Ultrasonic waves are waves of frequencies more than 20 KHz. The measurement of ultrasonic parameters provides significant information about the structure and properties of the system. Gabrielli and Verdini were the first to study ultrasonic velocity, absorption and adiabatic compressibility in liquid crystals [4]. They found an abrupt variation of these parameters at the PTT in case of p-azoxynisole. The subsequent study by different researchers also observed an abrupt change at the phase transition temperatures [5, 6, 7, 8, 9].

In the present work, we have studied the dependence of ultrasonic velocity (V), acoustic impedance (Z) and adiabatic compressibility ( $\beta$ ) of Cholesteric Liquid Crystal on temperature as well as concentration.

## II. MATERIALS AND METHODS

In the present study we have used Cholesteryl Myristate which is Cholesteric liquid crystal (CLC). It is a thermotropic liquid crystal whose properties change with the change in temperature.

Molecular formula: C<sub>41</sub>H<sub>72</sub>O<sub>2</sub>, Melting Point: 84 °C

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**1] Measurement of Ultrasonic velocity:**

Measurement of velocity of an ultrasonic wave is done using multifrequency interferometer by Mittal enterprises. The temperature range of this instrument is from room temperature to 200<sup>0</sup>C. It is provided with digital micrometer to avoid error in the measurement.

The ultrasonic velocity  $U = \frac{2 \times D \times F}{n-1}$

Where: D=Distance of micrometer screw for 'n' rotations  
F=Frequency of the ultrasonic wave

**2] Measurement of Density:**

The conventional methods for measurement of density require very large quantities of sample which is very expensive; we have tried different method for measuring density so as to reduce cost of experimentation without compromising on accuracy of results. For density measurement we have used capillary method. [10]

The formulae used in the present work:

Density  $\rho = \frac{\text{Mass}}{\text{Volume}}$

Where: Volume= $\pi r^2 h$

**3] Measurement of Acoustic Impedance:**

The acoustic impedance varies directly with density as well as ultrasonic velocity.

Acoustic Impedance =  $\rho \times U$

**4] Measurement of Adiabatic Compressibility:**

Adiabatic compressibility of a fluid is a measure of the relative volume change of the fluid as a response to a pressure change.

Adiabatic compressibility =  $(\rho \times U^2)^{-1}$

**III. RESULTS AND DISCUSSION**

The thermotropic liquid crystals change its phase with change in temperature. The temperature at which it changes its phase is called phase transition temperature (PTT). The phase transition temperatures for the Cholesteryl Myristate are measured by Differential Scanning calorimetry. The values of phase transition temperatures are given in table 1.

**Table 1: Phase Transition Temperatures of CLC**

Sample	Heating		Cooling	
	PTT <sup>0</sup> C	ΔH J/g	PTT <sup>0</sup> C	ΔH J/g
CLC	45.19	-8.44		
	71.49	-13.91	34.09	0.08
	79.12	-0.45	76.05	0.64
	84.59	-0.35	84.59	-0.28

From table 1, the melting point is 71.49<sup>0</sup>C, Smectic-Cholesteric transition temperature Ts is 79.12<sup>0</sup>C and Cholesteric-Isotropic Transition temperature is 84.59<sup>0</sup>C. [11]

Ultrasonic velocity, height and mass of Cholesteryl Myristate were measured for four different concentrations. Their dependence on temperature as well as concentration was studied throughout the mesomorphic region. The measurements were taken with special attention near phase transition temperature. The parameters were studied upto 90<sup>0</sup>C ie 6<sup>0</sup>C beyond mesomorphic isotropic transition. All the solutions for different concentration of CLC showed remarkable change at different temperatures. The readings given in the present study are of the solutions.

The results for Ultrasonic Velocity and Density are given in table 2 and the results for Acoustic Impedance and Adiabatic Compressibility are given in table 3.

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**Table 2: Ultrasonic Velocity and Density for different concentrations of CLC**

Temp	Ultrasonic Velocity (m/sec)				Density (gm/cm <sup>3</sup> )			
	0.1gm	0.2gm	0.3gm	0.4gm	0.1gm	0.2gm	0.3gm	0.4gm
70	1392	1393	1395	1398	356.64	359.15	366.02	373.64
72	1388	1390	1393	1396	357.19	359.44	365.58	371.75
74	1380	1385	1387	1390	358.53	359.74	365.98	373.35
76	1375	1380	1381	1384	359.45	359.05	363.17	367.30
77	1361	1366	1371	1377	361.62	361.29	363.73	365.63
78	1359	1362	1366	1371	361.54	361.81	363.74	364.12
79	1317	1324	1332	1339	362.66	369.3	369.01	369.34
80	1348	1350	1356	1362	356.31	365.05	365.93	366.45
81	1356	1359	1363	1371	359.57	367.57	368.65	369.16
82	1351	1355	1359	1364	361.71	369.60	370.80	372.97
83	1342	1346	1353	1357	375.58	380.75	378.78	381.14
84	1303	1305	1308	1311	382.55	383.91	389	390.89
85	1339	1342	1346	1349	378.39	378.96	382.48	382.95
86	1332	1339	1341	1344	375.24	374.43	377.99	379.78
88	1329	1332	1335	1339	366.93	368.05	381.09	379.95
90	1316	1318	1323	1327	365.16	368.68	375.01	378.40

**Table 3: Acoustic Impedance and Adiabatic Compressibility for different concentrations of CLC**

Temp	Acoustic Impedance gm cm <sup>-2</sup> s <sup>-1</sup>				Adiabatic Compressibility x 10 <sup>-5</sup> Dyne <sup>-1</sup> cm <sup>2</sup>			
	0.1gm	0.2gm	0.3gm	0.4gm	0.1gm	0.2gm	0.3gm	0.4gm
70	4964.43	5002.98	5106.02	5223.49	1.4532	1.4346	1.4032	1.3716
72	4957.88	4996.32	5092.54	5189.64	1.4559	1.4384	1.4088	1.3784
74	4947.74	4982.41	5076.25	5166.33	1.4616	1.4424	1.4125	1.3846
76	4942.54	4955.01	5015.41	5083.54	1.4715	1.4495	1.4182	1.3948
77	4921.67	4935.23	4986.75	5034.85	1.4991	1.4612	1.4225	1.3998
78	4913.43	4927.87	4968.78	4992.15	1.4976	1.4596	1.4184	1.3841
79	4776.34	4889.54	4915.25	4945.22	1.5897	1.4952	1.4762	1.4366
80	4803.13	4928.22	4962.13	4991.08	1.5445	1.4836	1.4695	1.4289
81	4875.79	4995.33	5024.82	5061.21	1.5325	1.4794	1.4632	1.4215
82	4886.72	5008.12	5039.21	5087.43	1.5178	1.4766	1.4587	1.4165
83	5040.36	5087.19	5124.95	5172.13	1.4784	1.4615	1.4412	1.4023
84	4984.69	5010.14	5088.21	5124.58	1.5396	1.5084	1.4654	1.4286
85	5066.76	5085.66	5148.21	5166.08	1.4748	1.4639	1.4401	1.4121
86	4998.2	5013.65	5068.95	5104.26	1.4852	1.4765	1.4488	1.4183
88	4876.62	4902.36	5021.11	5087.56	1.4969	1.4812	1.4595	1.4293
90	4805.52	4859.21	4961.47	5021.45	1.5002	1.4888	1.4642	1.4363

The graphs of ultrasonic velocity vs temperature, acoustic impedance vs. temperature and adiabatic compressibility vs. temperature are as given in Fig.1, Fig.2 and Fig.3 respectively.

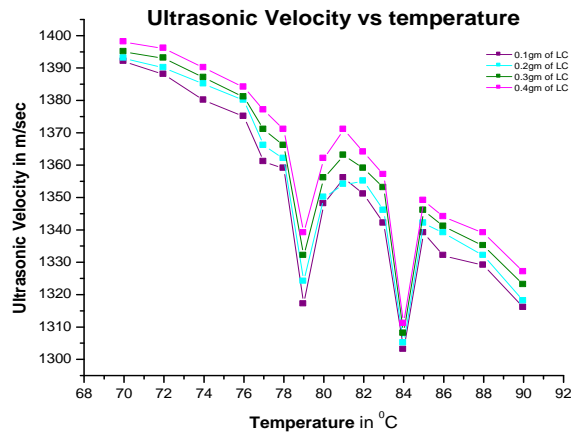


Fig.1: Ultrasonic Velocity vs temperature

The graph of ultrasonic velocity vs temperature in figure 1 shows that ultrasonic velocity decreases with temperature but it increases with concentration of CLC. The velocity shows an abrupt variation near PTTs. The linear decrease in ultrasonic velocity shows abrupt dips at the Smectic-Cholesteric and Cholesteric-Isotropic transitions. It shows linear trend in isotropic and anisotropic region.

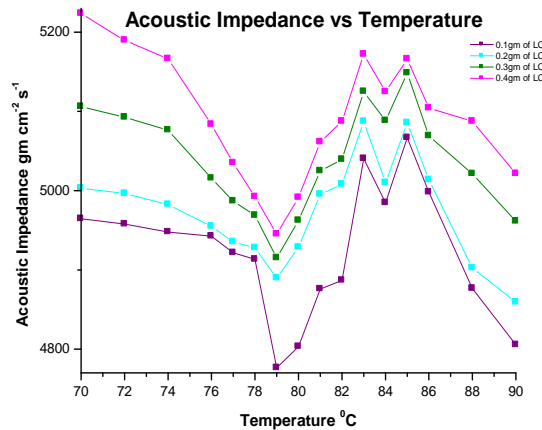


Fig.2: Acoustic Impedance vs Temperature

The graph of acoustic impedance vs temperature in figure 2 shows that acoustic impedance decreases with temperature but it increases with concentration of CLC. At PTTs it shows an abrupt change in the pattern. Similar to ultrasonic velocity acoustic impedance shows abrupt dip at the Smectic-Cholesteric transition. The values again decrease at Cholesteric-Isotropic transitions. It shows linear trend in isotropic and anisotropic region.

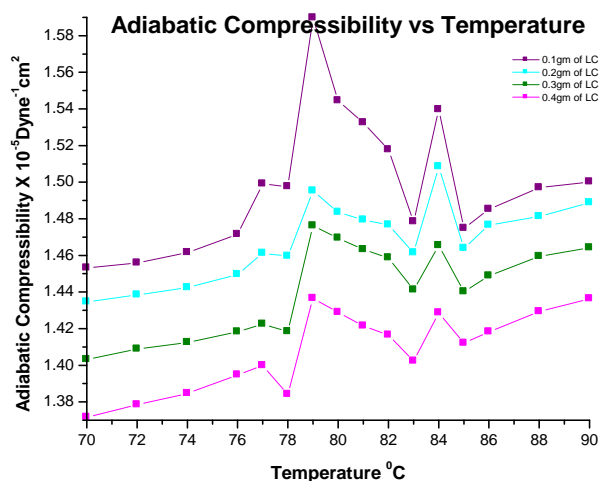


Fig.3: Adiabatic Compressibility vs Temperature

From Fig.3 it is clearly evident that adiabatic compressibility changes with temperature as well as with concentration. Adiabatic compressibility decreases with the concentration of CLC but increases with the temperature. It shows an abrupt variation in behaviour near PTT. Adiabatic compressibility increases linearly in isotropic and anisotropic region but exhibits abrupt jumps at both the transitions.

### III. CONCLUSION

The ultrasonic velocity (V), acoustic impedance (Z) and adiabatic compressibility ( $\beta$ ) of Cholesteric Liquid Crystal show dependence on temperature as well as concentration. These thermoacoustic properties show change in behaviour near phase transition temperature. This realignment of liquid crystal molecules has applications in medical diagnosis, displays and thermal imaging.

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