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RESEARCH ARTICLE

THERMODYNAMIC PARAMETERS OF SOME BENZYLIDENE AMINO PHENYL BENZOATE LIQUID CRYSTALS

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ABSTRACT

Liquid crystalline materials find potential applications in diversified fields. Physical properties of liquid crystalline materials govern their use in different devices. A particular application demands the physical property in a particular range. In view of this the temperature variation of density and hence thermal expansion coefficient is measured on the three liquid crystalline compounds namely,
1. *(E)*-4-((hexyloxy)benzylidene)amino)phenyl 4-butoxy benzoate (S-1)
2. *(E)*-4-((hexyloxy)benzylidene)amino)phenyl 4-(decycloxy benzoate) (S-2) and
3. *(E)*-4-((hexyloxy)benzylidene)amino)phenyl 4-(tridecycloxy benzoate) (S-3)
Using the thermal expansion coefficient, the number of thermo dynamical parameters was evaluated. The results revealed that all the thermo dynamic parameters show the characteristic changes at the phase transformation.

INTRODUCTION

The liquid crystalline research is a part of material work which consists of design, synthesis and characterization of new materials and further to test their suitability in applications by measuring different physical parameters like viscosity, electrical and magnetic susceptibilities, optical properties and thermo dynamical properties. The thermodynamic parameters provide the necessary input to understand different kinds of interactions involved in the molecular formation. In the present study the temperature variation of density is measured as described in the literature (Ajeetha *et al.,* 2006; Ranga Reddy *et al.,* 1999; Rao *et al.,* 1991; Gogoi *et al.,* 2002; Gogoi *et al.,* 2005; Datta Prasad *et al.,* 2009; Sivaram *et al.,* 1999). Using the density data, thermal expansion coefficient and various thermo dynamical parameters viz., Moelwyn-Hughes parameter (C_1), the reduced molar volume ($\tilde{V}$), the isochoric temperature coefficient of internal pressure (X), the Sharma's parameter(S_0), fractional free volume (f), Thermal parameter (A^*), Gruneisen parameter (Γ_p), the reduced bulk modulus (β^-), isothermal, isochoric and isobaric Gruneisen parameter (Γ_{ith}, Γ_{ich}, Γ_{iba}), Beyer's nonlinearity parameter (B/A), isochoric temperature coefficient of volume expansivity (X^I), Pressure coefficient of bulk modulus (C_1^*) have been evaluated for the benzylidene amino phenyl benzoate liquid crystalline compounds with side chain n=6 and end chains m=4,10 and 13. The molecular structure of the compounds is shown in Figure 1. The results are discussed with the light of the literature data available on number of liquid crystalline compounds.

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Experimental

The density of the LC compounds is measured by using dilatometer, which consists of specially constructed Pyknometer. The Pyknometer consists of capillaries with a diameter of about 250 microns and 0.07-0.12 m length is mounted on a U-shaped glass tube. The Pyknometer was calibrated by measuring the molar volume of water at different temperatures. The sample is filled in pyknometer and its mass was measured by using chemical balance with an accuracy of 0.0001×10^{-3} Kg. The pyknometer was kept in heating chamber at a temperature 10^{o}C above the clearing temperature. Then the sample was slowly cooled until the sample level reaches the mark in capillaries. The excess sample in the cups of the capillaries was removed by syringe.

Conventional cathetometer was used to measure the liquid crystal levels in the capillaries. The main scale and verneir scale is replaced with a digital scale instead of viewing the liquid levels through the telescope eyepiece, a charge-coupled device camera is attached to the telescope and the levels of capillary were observed on a monitor with a very high magnification. The detailed experimental setup is shown in Figure 2.

Theory and Expressions

The theory for the estimation of different thermodynamic parameters using the coefficient of thermal expansion (α) are reported by several authors (Ranga Reddy *et al.,* 1999; Reddy *et al.,* 2007; Fakruddin *et al.,* 2010) and the relevant expressions are given below. The Moelwyn-Hughes parameter (Moelwyn-Hughes, 1951) and the reduced molar volume ($\tilde{V}$) are evaluated from the following expressions.

$$C = \frac{13}{3} + (\alpha T)^{-1} + \frac{4}{3}(\alpha T) \quad (1)$$

$$\tilde{V} = \left[1 + \frac{\alpha T}{3(1+\alpha T)}\right]^3 \quad (2)$$

Using the coefficient of thermal expansion Haward and Parker (Haward and Parker, 1968) obtained an expression for the isochoric temperature coefficient of internal pressure (X) as

$$X = \frac{-2(1+2\Gamma)}{V^{C_1}} \quad (3)$$

The isochoric temperature coefficient of volume expansivity (X^1) can be given as

$$X^1 = -(1 + 2\alpha T) \quad (4)$$

The Sharma parameter (Sharma, 1983; Reddy *et al.,* 2007) (S_o) is given by the expression

$$S_o = \frac{-X}{2}(3 + 4\alpha T) \quad (5)$$

The fractional free volume (f) is a measure of disorder due to increasing mobility of molecules in a polymer and can be expressed in terms of the isothermal microscopic Gruneisen parameter (Γ) as

$$f = \left(\frac{V_a}{V}\right) = \left(\frac{1}{\Gamma+1}\right) \quad (6)$$

Where V_a is the available volume of a liquid crystal.

Thermal parameter (A^*), is a dimensionless parameter which shows that at low temperatures, a liquid crystal tends to be ordered exhibiting a small thermal expansion and small fractional free volume, thereby making A^* equal to unity.

$$A^* = \left(\frac{1+f^*}{1-f}\right) = 1 + \left(\frac{f}{\Gamma}\right) \quad (7)$$

The Gruneisen parameter (Γ_p) for liquid crystals can be found from

$$\Gamma_p = \left(\frac{2}{3}\right)\alpha T + \left(\frac{1}{2\alpha T}\right) + 2 \quad (8)$$

The isothermal, isobaric and isochoric Gruneisen parameters are identical to the corresponding acoustical parameters so one can write

$$\Gamma_{ich} = \Gamma_{ith} + \Gamma_{iba} \quad (9)$$

The isochoric Gruneisen parameter Γ_{ich} could be evaluated using the following equation

$$\Gamma_{ich} = -\frac{E-F}{F} \quad (10)$$

Where $E = -[2 + (\alpha T)^{-1}]\left[2\alpha\left(\tilde{V}\right)^{C1-1}\right]$ and F=-2α

The isothermal Anderson-Gruneisen parameter (δ) is known to be an important parameter in the theory of temperature dependence of bulk modulus in solids. It is defined as

$$\delta = 2\Gamma_{iba} \quad (11)$$

The Anderson-Gruneisen parameter is distinguished from the Moelwyn-Hughes parameter by introducing a new parameter θ as

$$\theta = 2(\Gamma_{ith} - \Gamma_{iba}) + 1 \quad (12)$$

The pressure coefficient of bulk modulus C_1^* as derived from α and V is given as

$$C_1^* = \left(1 + \frac{\delta}{3}\right)\left[1 + (1 + \frac{1}{\alpha T})/(1 + \frac{\delta}{3})\right] \quad (13)$$

RESULTS AND DISCUSSION

The temperature variation of density for the liquid crystalline compounds is measured and illustrated in Figures 3, 4 and 5. The density is found to decrease with increase of temperature and density jumps observed at phase transformations. The thermal expansion coefficient (α) and various thermo dynamic parameters were estimated and represented in Tables 1, 2 and 3. The temperature variation of Moelwyn-Hughes parameter (C_1), Reduced bulk modulus (β^-), Reduced molar volume ($\tilde{V}$) of the liquid crystalline compounds are shown in Figures 6-9. The Sharma parameter (S_o) is found to be constant in all the three compounds and it is around 1.118 ±0.001. The parameters C_1, Γ_p, β^-, δ, B/A slightly decreases with increase of temperature and in the vicinity of the phase transformation there is abrupt decrease in the above values. Reduced molar volume ($\tilde{V}$), isochoric temperature coefficient of internal pressure (X), fractional free volume (f) is found to be increase with the increase of temperature and during phase transformation there is a sudden increase in the above values. The thermal parameter (A^*) is found to be unity. According to literature (Reddy *et al.,* 2007) also the value is unity for all the liquid crystalline compounds. The Beyer's nonlinearity parameter (B/A) lies in the range 11-12.

Table 1. Thermodynamic parameters of (*E*)-4-((4-(hexyloxy)benzylidene)amino)phenyl 4-butoxy benzoate

T(K)	C_1	$\bar{V}$	X	S_o	f	A^*	Γ_p	$\bar{\beta}$
498	12.5277	1.1148	-0.6398	1.1190	0.0755	1.0036	6.0990	0.2561
499	12.5119	1.1150	-0.6396	1.1190	0.0757	1.0036	6.0911	0.2559
500	12.4962	1.1152	-0.6394	1.1191	0.0758	1.0036	6.0833	0.2557
501	12.4806	1.1154	-0.6393	1.1191	0.0759	1.0037	6.0755	0.2556
502	12.4650	1.1157	-0.6391	1.1191	0.0760	1.0037	6.0677	0.2554
503	12.4495	1.1159	-0.6389	1.1191	0.0761	1.0037	6.0599	0.2552
504	12.4340	1.1161	-0.6388	1.1191	0.0762	1.0037	6.0522	0.2551
505	12.4187	1.1163	-0.6386	1.1191	0.0763	1.0037	6.0445	0.2549
506	12.4033	1.1165	-0.6384	1.1192	0.0764	1.0037	6.0369	0.2547
507	12.3881	1.1167	-0.6382	1.1192	0.0765	1.0037	6.0292	0.2545
508	12.3729	1.1169	-0.6381	1.1192	0.0766	1.0037	6.0216	0.2544
509	12.3577	1.1171	-0.6379	1.1192	0.0767	1.0038	6.0141	0.2542
510	12.3427	1.1173	-0.6377	1.1192	0.0768	1.0038	6.0065	0.2540
511	12.3277	1.1176	-0.6375	1.1192	0.0769	1.0038	5.9990	0.2539
512	12.3127	1.1178	-0.6374	1.1193	0.0770	1.0038	5.9915	0.2537
513	12.2978	1.1180	-0.6372	1.1193	0.0771	1.0038	5.9841	0.2535
514	12.2830	1.1182	-0.6370	1.1193	0.0772	1.0038	5.9767	0.2534
515	12.2682	1.1184	-0.6369	1.1193	0.0773	1.0038	5.9693	0.2532
516	12.2535	1.1186	-0.6367	1.1193	0.0774	1.0039	5.9619	0.2530
517	12.2388	1.1188	-0.6365	1.1193	0.0775	1.0039	5.9546	0.2529
518	12.2242	1.1190	-0.6363	1.1193	0.0776	1.0039	5.9473	0.2527
519	6.9470	1.3820	-0.4305	1.0926	0.1541	1.0335	3.3093	0.1056
520	6.9446	1.3826	-0.4301	1.0924	0.1542	1.0336	3.3082	0.1054
521	6.9423	1.3831	-0.4296	1.0922	0.1543	1.0336	3.3070	0.1052
522	6.9399	1.3836	-0.4292	1.0920	0.1543	1.0337	3.3058	0.1050
523	12.1520	1.1201	-0.6355	1.1194	0.0781	1.0039	5.9112	0.2518
524	12.1378	1.1203	-0.6353	1.1194	0.0782	1.0040	5.9041	0.2517
525	12.1236	1.1205	-0.6351	1.1195	0.0783	1.0040	5.8970	0.2515
526	12.1094	1.1207	-0.6350	1.1195	0.0784	1.0040	5.8899	0.2513

Table 1.Continued

T(K)	Γ_{ith}	Γ_{ich}	Γ_{iba}	θ	δ	B/A	X^1	C_1^*
498	5.7638	3.0238	2.7399	7.0477	5.4799	11.5277	-1.249	9.032
499	5.7559	3.0198	2.7361	7.0396	5.4723	11.5119	-1.249	9.016
500	5.7481	3.0157	2.7323	7.0315	5.4647	11.4962	-1.250	9.000
501	5.7403	3.0117	2.7285	7.0234	5.4571	11.4806	-1.250	8.984
502	5.7325	3.0076	2.7248	7.0153	5.4496	11.4650	-1.251	8.968
503	5.7247	3.0036	2.7210	7.0073	5.4421	11.4495	-1.251	8.952
504	5.7170	2.9996	2.7173	6.9993	5.4347	11.4340	-1.252	8.936
505	5.7093	2.9956	2.7136	6.9913	5.4273	11.4187	-1.252	8.920
506	5.7016	2.9917	2.7099	6.9834	5.4199	11.4033	-1.253	8.905
507	5.6940	2.9877	2.7062	6.9755	5.4125	11.3881	-1.253	8.889
508	5.6864	2.9838	2.7026	6.9677	5.4052	11.3729	-1.254	8.874
509	5.6788	2.9799	2.6989	6.9598	5.3979	11.3577	-1.254	8.858
510	5.6713	2.9760	2.6953	6.9520	5.3906	11.3427	-1.255	8.843
511	5.6638	2.9721	2.6917	6.9442	5.3834	11.3277	-1.255	8.827
512	5.6563	2.9682	2.6880	6.9365	5.3761	11.3127	-1.256	8.812
513	5.6489	2.9644	2.6845	6.9288	5.3690	11.2978	-1.256	8.797
514	5.6415	2.9605	2.6809	6.9211	5.3618	11.2830	-1.257	8.782
515	5.6341	2.9567	2.6773	6.9135	5.3547	11.2682	-1.257	8.766
516	5.6267	2.9529	2.6738	6.9058	5.3476	11.2535	-1.258	8.751
517	5.6194	2.9491	2.6702	6.8982	5.3405	11.2388	-1.258	8.736
518	5.6121	2.9453	2.6667	6.8907	5.3335	11.2242	-1.259	8.722
519	2.9735	1.4906	1.4828	3.9812	2.9657	5.9470	-2.038	2.926
520	2.9723	1.4897	1.4826	3.9794	2.9652	5.9446	-2.040	2.923
521	2.9711	1.4887	1.4823	3.9775	2.9647	5.9423	-2.042	2.919
522	2.9699	1.4878	1.4821	3.9756	2.9643	5.9399	-2.044	2.915
523	5.5760	2.9266	2.6493	6.8533	5.2987	11.1520	-1.261	8.648
524	5.5689	2.9229	2.6459	6.8459	5.2918	11.1378	-1.262	8.633
525	5.5618	2.9192	2.6425	6.8385	5.2850	11.1236	-1.262	8.619
526	5.5547	2.9156	2.6391	6.8312	5.2782	11.1094	-1.263	8.604

Table 2. Thermodynamic parameters of (*E*)-4-((4-(hexyloxy)benzylidene)amino)phenyl 4-(decycloxy) benzoate

T(K)	C_1	$\vec{V}$	X	S_O	f	A^*	Γ_p	$\vec{\beta}$
457	13.2346	1.1060	-0.6470	1.1183	0.0712	1.0031	6.4525	0.2633
458	13.2159	1.1062	-0.6468	1.1183	0.0713	1.0031	6.4431	0.2631
459	13.1972	1.1065	-0.6466	1.1183	0.0714	1.0031	6.4337	0.2629
460	13.1786	1.1067	-0.6464	1.1183	0.0715	1.0031	6.4244	0.2627
461	13.1600	1.1069	-0.6463	1.1184	0.0716	1.0031	6.4152	0.2626
462	13.1416	1.1071	-0.6461	1.1184	0.0717	1.0031	6.4060	0.2624
463	13.1232	1.1073	-0.6459	1.1184	0.0718	1.0032	6.3968	0.2622
464	13.1049	1.1075	-0.6457	1.1184	0.0719	1.0032	6.3876	0.2620
465	13.0867	1.1078	-0.6455	1.1184	0.0720	1.0032	6.3785	0.2619
466	13.0686	1.1080	-0.6454	1.1185	0.0722	1.0032	6.3695	0.2617
467	13.0505	1.1082	-0.6452	1.1185	0.0723	1.0032	6.3604	0.2615
468	13.0326	1.1084	-0.6450	1.1185	0.0724	1.0032	6.3515	0.2613
469	13.0147	1.1086	-0.6448	1.1185	0.0725	1.0032	6.3425	0.2611
470	12.9969	1.1088	-0.6447	1.1185	0.0726	1.0032	6.3336	0.2610
471	12.9791	1.1090	-0.6445	1.1186	0.0727	1.0033	6.3247	0.2608
472	12.9615	1.1093	-0.6443	1.1186	0.0728	1.0033	6.3159	0.2606
473	12.9439	1.1095	-0.6441	1.1186	0.0729	1.0033	6.3071	0.2604
474	12.9264	1.1097	-0.6440	1.1186	0.0730	1.0033	6.2984	0.2603
475	12.9089	1.1099	-0.6438	1.1186	0.0731	1.0033	6.2896	0.2601
476	12.8916	1.1101	-0.6436	1.1186	0.0732	1.0033	6.2810	0.2599
477	12.8743	1.1103	-0.6434	1.1187	0.0733	1.0033	6.2723	0.2597
478	12.8571	1.1105	-0.6433	1.1187	0.0734	1.0034	6.2637	0.2596
479	12.8400	1.1108	-0.6431	1.1187	0.0735	1.0034	6.2551	0.2594
480	12.8229	1.1110	-0.6429	1.1187	0.0737	1.0034	6.2466	0.2592
481	12.8059	1.1112	-0.6427	1.1187	0.0738	1.0034	6.2381	0.2590
482	12.7890	1.1114	-0.6426	1.1187	0.0739	1.0034	6.2297	0.2589
483	12.7721	1.1116	-0.6424	1.1188	0.0740	1.0034	6.2212	0.2587
484	7.0398	1.3628	-0.4451	1.0985	0.1508	1.0308	3.3557	0.1130
485	7.0369	1.3634	-0.4447	1.0983	0.1509	1.0309	3.3542	0.1128
486	8.7684	1.2085	-0.5647	1.1215	0.1131	1.0115	4.2196	0.1900
487	12.7054	1.1125	-0.6417	1.1188	0.0744	1.0035	6.1879	0.2580
488	12.6889	1.1127	-0.6415	1.1189	0.0745	1.0035	6.1796	0.2578
489	12.6725	1.1129	-0.6414	1.1189	0.0746	1.0035	6.1714	0.2576
490	12.6561	1.1131	-0.6412	1.1189	0.0747	1.0035	6.1632	0.2575
491	12.6399	1.1133	-0.6410	1.1189	0.0748	1.0035	6.1551	0.2573
492	12.6236	1.1135	-0.6408	1.1189	0.0749	1.0035	6.1470	0.2571
493	12.6075	1.1137	-0.6407	1.1189	0.0750	1.0035	6.1389	0.2570
494	12.5914	1.1140	-0.6405	1.1190	0.0751	1.0036	6.1309	0.2568
495	12.5754	1.1142	-0.6403	1.1190	0.0752	1.0036	6.1229	0.2566

Table 2. Continued

T(K)	Γ_{ith}	Γ_{ich}	Γ_{iba}	θ	δ	B/A	X^1	C_1^*
457	6.1173	3.2065	2.9108	7.4130	5.8216	12.2346	-1.2285	9.7527
458	6.1079	3.2016	2.9062	7.4033	5.8125	12.2159	-1.2290	9.7336
459	6.0986	3.1968	2.9017	7.3936	5.8035	12.1972	-1.2295	9.7145
460	6.0893	3.1920	2.8972	7.3840	5.7945	12.1786	-1.2300	9.6956
461	6.0800	3.1872	2.8927	7.3745	5.7855	12.1600	-1.2305	9.6767
462	6.0708	3.1825	2.8883	7.3650	5.7766	12.1416	-1.2310	9.6580
463	6.0616	3.1777	2.8838	7.3555	5.7677	12.1232	-1.2315	9.6393
464	6.0524	3.1730	2.8794	7.3460	5.7588	12.1049	-1.2320	9.6206
465	6.0433	3.1683	2.8750	7.3366	5.7500	12.0867	-1.2325	9.6021
466	6.0343	3.1636	2.8706	7.3273	5.7413	12.0686	-1.2330	9.5836
467	6.0252	3.1590	2.8660	7.3180	5.7325	12.0505	-1.2335	9.5653
468	6.0163	3.1543	2.8619	7.3087	5.7238	12.0326	-1.2340	9.5470
469	6.0073	3.1497	2.8576	7.2994	5.7152	12.0147	-1.2345	9.5287
470	5.9984	3.1451	2.8533	7.2902	5.7066	11.9969	-1.2350	9.5106
471	5.9895	3.1405	2.8490	7.2811	5.6980	11.9791	-1.2355	9.4925
472	5.9807	3.1360	2.8447	7.2720	5.6895	11.9615	-1.2360	9.4745
473	5.9719	3.1314	2.8405	7.2629	5.6810	11.9439	-1.2365	9.4566
474	5.9632	3.1269	2.8362	7.2538	5.6725	11.9264	-1.2370	9.4388
475	5.9544	3.1224	2.8320	7.2448	5.6641	11.9089	-1.2375	9.4210
476	5.9458	3.1179	2.8278	7.2359	5.6557	11.8916	-1.2380	9.4033
477	5.9371	3.1134	2.8236	7.2269	5.6473	11.8743	-1.2385	9.3857
478	5.9285	3.1090	2.8195	7.2180	5.6390	11.8571	-1.2390	9.3682
479	5.9199	3.1046	2.8153	7.2092	5.6307	11.8400	-1.2395	9.3507
480	5.9114	3.1002	2.8112	7.2004	5.6225	11.8229	-1.2400	9.3333
481	5.9029	3.0958	2.8071	7.1916	5.6143	11.8059	-1.2405	9.3160
482	5.8945	3.0914	2.8030	7.1828	5.6061	11.7890	-1.2410	9.2987
483	5.8860	3.0870	2.7989	7.1741	5.5979	11.7721	-1.2415	9.2815
484	3.0199	1.5261	1.4937	4.0522	2.9875	6.0398	-1.9680	3.0661
485	3.0184	1.5250	1.4933	4.0501	2.9867	6.0369	-1.9700	3.0618
486	3.8842	2.0400	1.8441	5.0801	3.6882	7.7684	-1.4860	5.1152
487	5.8527	3.0698	2.7828	7.1397	5.5657	11.7054	-1.2435	9.2135
488	5.8444	3.0655	2.7788	7.1311	5.5577	11.6889	-1.2440	9.1967
489	5.8362	3.0613	2.7749	7.1226	5.5498	11.6725	-1.2445	9.1799
490	5.8280	3.0571	2.7709	7.1142	5.5419	11.6561	-1.2450	9.1632
491	5.8199	3.0529	2.7670	7.1058	5.5340	11.6399	-1.2455	9.1466
492	5.8118	3.0487	2.7631	7.0974	5.5262	11.6236	-1.2460	9.1300
493	5.8037	3.0445	2.7592	7.0890	5.5184	11.6075	-1.2465	9.1135
494	5.7957	3.0403	2.7553	7.0807	5.5106	11.5914	-1.2470	9.0971
495	5.7876	3.0362	2.7514	7.0724	5.5029	11.5754	-1.2475	9.0808

Table 3. Thermodynamic parameters of (*E*)-4-((4-(hexyloxy)benzylidene)amino)phenyl 4-(tridecycloxy benzoate)

T(K)	C_1	$\bar{V}$	X	S_O	f	A^*	Γ_p	$\bar{\beta}$
447	13.4271	1.1039	-0.6487	1.1181	0.0701	1.0030	6.5487	0.2651
448	13.4075	1.1041	-0.6485	1.1181	0.0702	1.0030	6.5389	0.2649
449	13.3879	1.1043	-0.6484	1.1181	0.0703	1.0030	6.5291	0.2647
450	13.3685	1.1045	-0.6482	1.1182	0.0704	1.0030	6.5194	0.2645
451	13.3491	1.1047	-0.6480	1.1182	0.0705	1.0030	6.5097	0.2644
452	13.3298	1.1050	-0.6478	1.1182	0.0706	1.0030	6.5001	0.2642
453	13.3106	1.1052	-0.6477	1.1182	0.0707	1.0030	6.4905	0.2640
454	13.2915	1.1054	-0.6475	1.1182	0.0708	1.0030	6.4809	0.2638
455	13.2725	1.1056	-0.6473	1.1183	0.0710	1.0031	6.4714	0.2636
456	13.2535	1.1058	-0.6471	1.1183	0.0711	1.0031	6.4619	0.2635
457	13.2346	1.1060	-0.6470	1.1183	0.0712	1.0031	6.4525	0.2633
458	13.2159	1.1062	-0.6468	1.1183	0.0713	1.0031	6.4431	0.2631
459	13.1972	1.1065	-0.6466	1.1183	0.0714	1.0031	6.4337	0.2629
460	13.1786	1.1067	-0.6464	1.1183	0.0715	1.0031	6.4244	0.2627
461	13.1600	1.1069	-0.6463	1.1184	0.0716	1.0031	6.4152	0.2626
462	13.1416	1.1071	-0.6461	1.1184	0.0717	1.0031	6.4060	0.2624
463	13.1232	1.1073	-0.6459	1.1184	0.0718	1.0032	6.3968	0.2622
464	13.1049	1.1075	-0.6457	1.1184	0.0719	1.0032	6.3876	0.2620
465	13.0867	1.1078	-0.6455	1.1184	0.0720	1.0032	6.3785	0.2619
466	13.0686	1.1080	-0.6454	1.1185	0.0722	1.0032	6.3695	0.2617
467	13.0505	1.1082	-0.6452	1.1185	0.0723	1.0032	6.3604	0.2615
468	13.0326	1.1084	-0.6450	1.1185	0.0724	1.0032	6.3515	0.2613
469	13.0147	1.1086	-0.6448	1.1185	0.0725	1.0032	6.3425	0.2611
470	12.9969	1.1088	-0.6447	1.1185	0.0726	1.0032	6.3336	0.2610
471	12.9791	1.1090	-0.6445	1.1186	0.0727	1.0033	6.3247	0.2608
472	12.9615	1.1093	-0.6443	1.1186	0.0728	1.0033	6.3159	0.2606
473	7.0732	1.3567	-0.4498	1.1003	0.1497	1.0299	3.3724	0.1155
474	7.0701	1.3572	-0.4494	1.1001	0.1498	1.0300	3.3708	0.1153
475	7.0670	1.3578	-0.4489	1.0999	0.1499	1.0301	3.3692	0.1151
476	12.8916	1.1101	-0.6436	1.1186	0.0732	1.0033	6.2810	0.2599
477	12.8743	1.1103	-0.6434	1.1187	0.0733	1.0033	6.2723	0.2597
478	12.8571	1.1105	-0.6433	1.1187	0.0734	1.0034	6.2637	0.2596
479	12.8400	1.1108	-0.6431	1.1187	0.0735	1.0034	6.2551	0.2594
480	12.8229	1.1110	-0.6429	1.1187	0.0737	1.0034	6.2466	0.2592
481	12.8059	1.1112	-0.6427	1.1187	0.0738	1.0034	6.2381	0.2590
482	12.7890	1.1114	-0.6426	1.1187	0.0739	1.0034	6.2297	0.2589
483	12.7721	1.1116	-0.6424	1.1188	0.0740	1.0034	6.2212	0.2587

Table 3. Continued

T(K)	Γ_{ith}	Γ_{ich}	Γ_{iba}	θ	δ	B/A	X^1	C_1^*
447	6.2135	3.2561	2.9574	7.5123	5.9148	12.4271	-1.223	9.9485
448	6.2037	3.2511	2.9526	7.5022	5.9053	12.4075	-1.224	9.9285
449	6.1939	3.2460	2.9479	7.4921	5.8958	12.3879	-1.224	9.9086
450	6.1842	3.2410	2.9432	7.4820	5.8864	12.3685	-1.225	9.8888
451	6.1745	3.2360	2.9385	7.4720	5.8770	12.3491	-1.225	9.8691
452	6.1649	3.2310	2.9338	7.4621	5.8677	12.3298	-1.226	9.8495
453	6.1553	3.2261	2.9292	7.4522	5.8584	12.3106	-1.226	9.8300
454	6.1457	3.2211	2.9245	7.4423	5.8491	12.2915	-1.227	9.8105
455	6.1362	3.2162	2.9199	7.4325	5.8399	12.2725	-1.227	9.7912
456	6.1267	3.2113	2.9153	7.4227	5.8307	12.2535	-1.228	9.7719
457	6.1173	3.2065	2.9108	7.4130	5.8216	12.2346	-1.228	9.7527
458	6.1079	3.2016	2.9062	7.4033	5.8125	12.2159	-1.229	9.7336
459	6.0986	3.1968	2.9017	7.3936	5.8035	12.1972	-1.229	9.7145
460	6.0893	3.1920	2.8972	7.3840	5.7945	12.1786	-1.230	9.6956
461	6.0800	3.1872	2.8927	7.3745	5.7855	12.1600	-1.230	9.6767
462	6.0708	3.1825	2.8883	7.3650	5.7766	12.1416	-1.231	9.6580
463	6.0616	3.1777	2.8838	7.3555	5.7677	12.1232	-1.231	9.6393
464	6.0524	3.1730	2.8794	7.3460	5.7588	12.1049	-1.232	9.6206
465	6.0433	3.1683	2.8750	7.3366	5.7500	12.0867	-1.232	9.6021
466	6.0343	3.1636	2.8706	7.3273	5.7413	12.0686	-1.233	9.5836
467	6.0252	3.1590	2.8662	7.3180	5.7325	12.0505	-1.233	9.5653
468	6.0163	3.1543	2.8619	7.3087	5.7238	12.0326	-1.234	9.5470
469	6.0073	3.1497	2.8576	7.2994	5.7152	12.0147	-1.234	9.5287
470	5.9984	3.1451	2.8533	7.2902	5.7066	11.9969	-1.235	9.5106
471	5.9895	3.1405	2.8490	7.2811	5.6980	11.9791	-1.235	9.4925
472	5.9807	3.1360	2.8447	7.2720	5.6895	11.9615	-1.236	9.4745
473	3.0366	1.5383	1.4982	4.0767	2.9964	6.0732	-1.946	3.1141
474	3.0350	1.5372	1.4978	4.0745	2.9956	6.0701	-1.948	3.1097
475	3.0335	1.5361	1.4973	4.0722	2.9947	6.0670	-1.950	3.1052
476	5.9458	3.1179	2.8278	7.2359	5.6557	11.8916	-1.238	9.4033
477	5.9371	3.1134	2.8236	7.2269	5.6473	11.8743	-1.238	9.3857
478	5.9285	3.1090	2.8195	7.2180	5.6390	11.8571	-1.239	9.3682
479	5.9199	3.1046	2.8153	7.2092	5.6307	11.8400	-1.239	9.3507
480	5.9114	3.1002	2.8112	7.2004	5.6225	11.8229	-1.240	9.3333
481	5.9029	3.0958	2.8071	7.1916	5.6143	11.8059	-1.240	9.3160
482	5.8945	3.0914	2.8030	7.1828	5.6061	11.7890	-1.241	9.2987
483	5.8860	3.0870	2.7989	7.1741	5.5979	11.7721	-1.241	9.2815

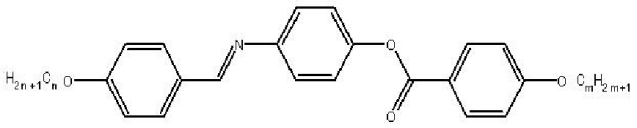

Figure 1. Molecular Structure of the Liquid crystalline compounds

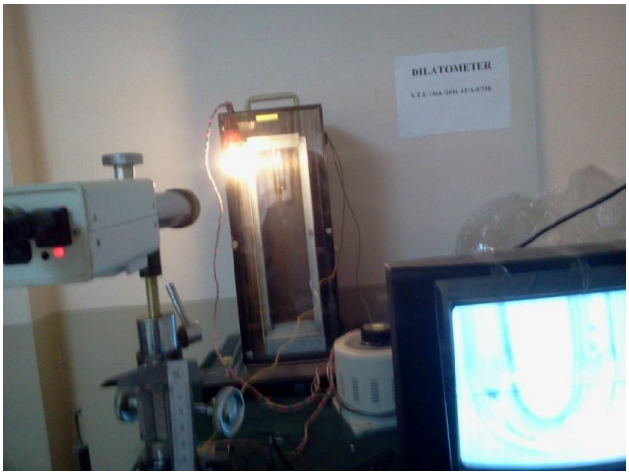

Figure 2. Experimental setup

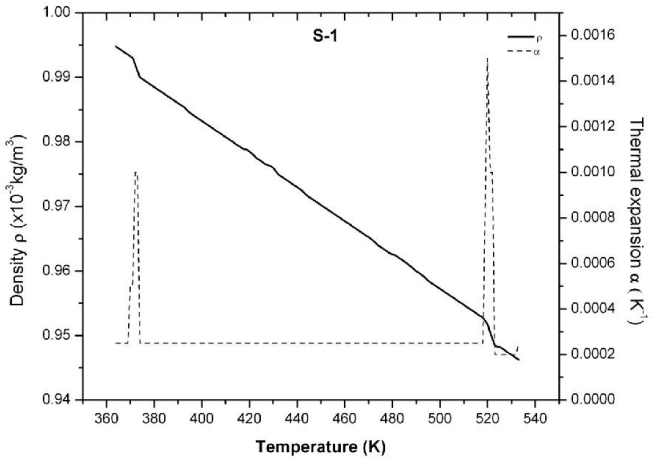

Figure 3. Variation of density and thermal expansion coefficient with temperature in S-1

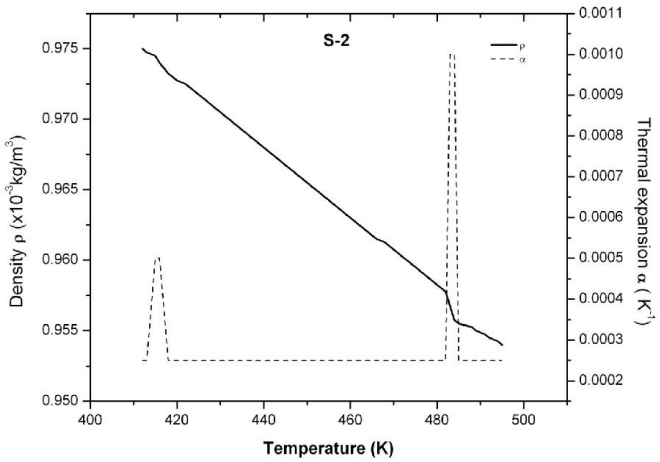

Figure 4. Variation of density and thermal expansion coefficient with temperature in S-2

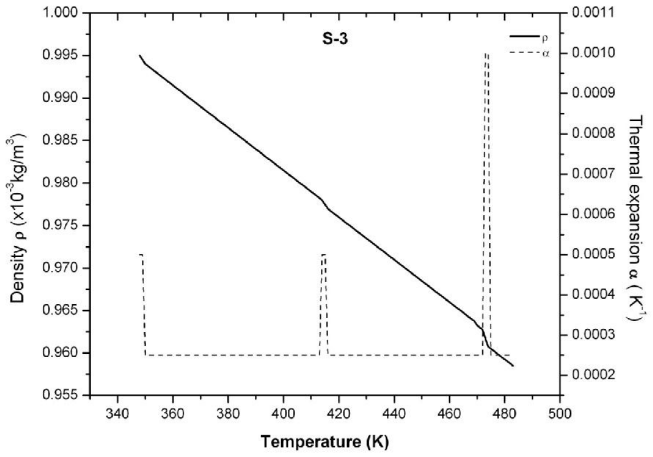

Figure 5. Variation of density and thermal expansion coefficient with temperature in S-3

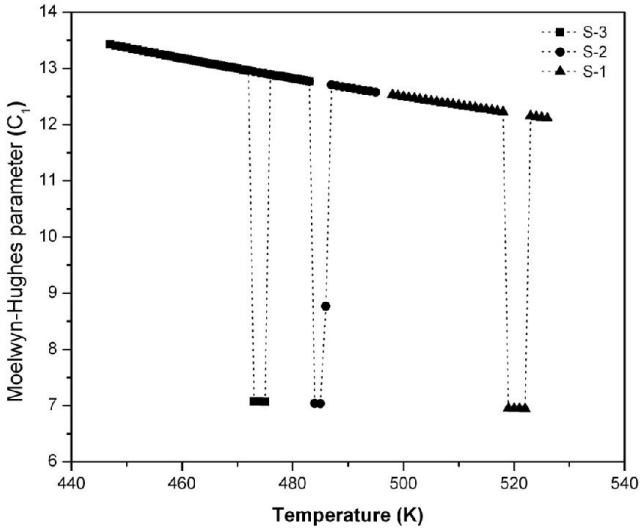

Figure 6. Variation of Moelwyn-Hughes parameter with temperature in S-1, S-2 and S-3

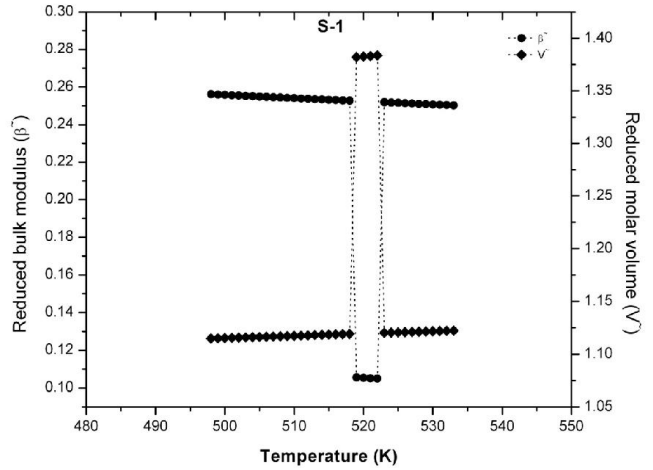

Figure 7. Variation of Reduced bulk modulus (β^-) and Reduced molar volume ($\bar{V}$) with temperature in S-1

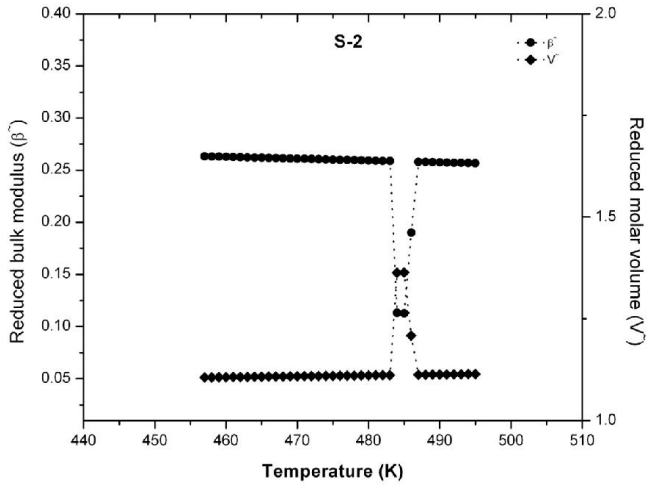

Figure 8. Variation of Reduced bulk modulus (β^-) and Reduced molar volume ($\bar{V}$) with temperature in S-2

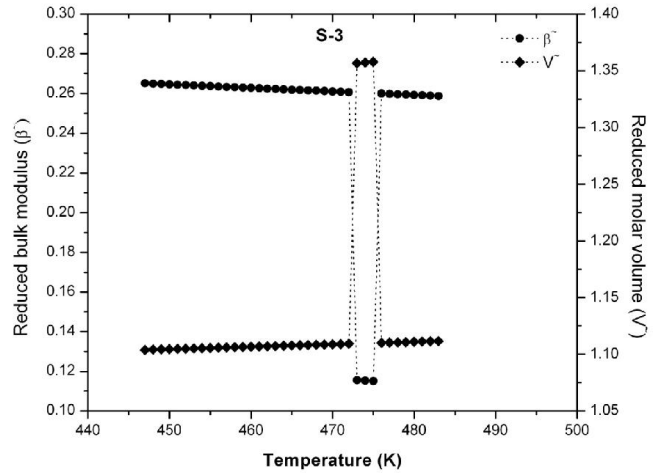

Figure 9. Variation of Reduced bulk modulus (β^-) and Reduced molar volume ($\bar{V}$) with temperature in S-3

In the vicinity of phase transformation there is a sudden change in this value and which is found to be 6-7. The isothermal, isochoric and isobaric Gruneisen parameters (Γ_{ith}, Γ_{ich}, Γ_{iba}) have consistent values in liquid crystalline phase but there is steep decrease in these values at phase transformations.

Conclusions: All the thermo dynamical parameters evaluated have almost constant values in a particular phase and in the vicinity of phase transformation there are abrupt changes. At phase transformation, the value of Moelwyn-Hughes parameter and Beyer's nonlinearity parameter reduces suddenly by 5.2-5.8 in three liquid crystalline compounds. The reduced molar volume increases by 0.24-0.26, whereas the Sharma parameter and the thermal parameter are found to be constant irrespective of phase transitions.

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