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Effect of Ramp Rates on Phase Transitions of a Next Generation 'Binary Liquid Crystal System" (BLCS) 5CB+7CB

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ABSTRACT
This research paper reports the effect of ramp rates on the phase transitions of a Binary Liquid Crystal System (BLCS), the next generation of 5CB and 7CB Liquid Crystals (LCs). For this study, 5CB and 7CB were mixed in a 1:1 by weight percent and ran at three different heating and cooling rates in a Differential Scanning Calorimeter (DSC) to study the effect of ramp rate on the phase transitions of a BLCS. The BLCS shows a shift in the peak of each phase transition appearing in heating and cooling. Heating shows two endothermic melting and nematic transition peaks and cooling shows only one exothermic nematic peak. The transition peaks shift toward a higher temperature in heating and approach a lower temperature in cooling. This shift confirms the presence of thermodynamics and kinetics within the phase transitions of the BLCS. Using kinetic theory and models, we can find the activation energy for each phase transition of the BLCS, which are reported in this paper.

KEYWORDS
Heating rate, Cooling rate, Ramp rates, Binary Liquid Crystal System (BLCS), Mixing, Melting and Nematic phase transitions, Kinetics, Thermal Speed, Thermal Acceleration, Thermal Jerk, Enthalpy, Specific Heat capacity, LoggerPro, Kinetic theory and models.

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I. INTRODUCTION

A fourth state of matter that has properties between crystalline solids and standard liquids are called Liquid Crystals (LCs) and is achieved when substances contain molecules that lose their short-range crystalline positioning but maintain order at longer range. After discovering a double melting phenomenon in 1888, Austrian physiologist Friedrich Reinitzer determined this similar orientation of unaligned molecules allows many liquid crystals to bend and stretch like liquids but interact with light like crystalline solids do. Due to their ability to redirect light polarization, LCs became the focus of research in developing thin panel electronic displays that were to replace old cathode ray tube designs in the early 1960's. [1]

A typical LC may have 4 or less distinct phases including Nematic (N), Smectic A (SmA), Smectic C (SmC), Isotropic (I) which is complete melting to liquid from complete solid crystalline state. The nematic phase has been found to be most beneficial in thin screen technology like Liquid Crystal Displays (LCDs). [1-2] For common LCD use, expansive studies on the thermal behavior of nematic phase transitions for 4-octyl-4-cyanobiphenyl (8CB) and 4-pentyl-4-cyanobiphenyl (5CB) prove those substances have highly thermodynamically favorable nematic phase transitions for LCD utility. Recent studies on nCB LCs like 4-heptyl-4-cyanobiphenyl (7CB) discuss the potential applications of 7CB due to its thermal behavior during nematic transition. [3-6] By mixing 5CB and 7CB in 1:1 by weight percent, a binary liquid crystal system (BLCS) is formed which is being investigated as the next generation of LCs.

Chemical kinetics focuses on the rate that chemical reactions turn reactants into products. Although thermodynamics can inform about the direction of spontaneous change it does not account for how quickly it will occur. More importantly for this work, kinetics should provide insight on the pathway's reactions take to get from reactants to products. In general, the kinetics of a reaction are determined by concentration and surface area of reactants, temperature of reaction, and catalyst presence. [7,8] In this paper, we are using kinetics of phase transitions of LCs.

The ramp rate is the pace that thermal heat flows in the sample and the temperature changes, or a sample is heated and cooled. This study investigates the effects of ramp rates on heating and cooling of a 5CB + 7CB BLCS from -30°C to 101°C and then back to -30°C at three different ramp rates: 5°C/min, 10°C/min and 20°C/min. Research on the effect of ramp rate shows that different LC molecules can have different dynamics. [9,10] Studies found that pentyl-oxy-cyanobiphenyl (5OCB) LC had allofits phase transitions in heating move toward higher temperatures whereas all transitions in cooling shifted to lower temperatures as ramp rate increased. [11,12]

The goal of this work is to compare thermal LC data obtained through other models and theories provided by scientists and authors, to see if they are applicable to the BLCS or not.

II. EXPERIMENTAL SECTION

A Binary Liquid Crystal System (BLCS) is prepared to study the effect of ramp rates in its phase transitions as a next generation Liquid Crystal. To prepare that, the pure and bulk samples of 4-pentyl-4-cyanobiphenyl (5CB) and 4-heptyl-4-cyanobiphenyl (7CB) liquid crystals are taken as parent liquid crystals and then an equal amount of each are added as 1:1 by weight and heated until they melt, mixed, and degassed for an hour and then cooled to the room temperature to be used for study.

This BLCS is then loaded with its reference pan into a Differential Scanning Calorimetry (DSC) from NETZSCH DSC 214 Model from NETZSCH company that is at WPI's chemistry and biochemistry department. This BLCS is then heated and cooled from -30 °C to 101 °C and from 101 °C to -30 °C. Three different ramp rates are used as 5 °C/min, 10 °C/min and 20 °C/min to study the effect of ramp rates of the phase transitions of the next generation of BLCS.

It is found that when BLCS is heated and cooled with three different ramp rates the peaks of each phase transition shift in temperature indicating that there is some kinematics going on. To understand kinematics of each phase transition of BLCS, some models are used as shown in the theory section and then activation energy of each phase transitions are calculated using the following models. The activation energy is then compared for BLCS with its parent LCs. The details of these results can be seen in the results and discussion sections.

III. THEORY

The rate of a reaction is related to its activation energy using the Arrhenius Equation [8],

$$k = Ae^{\frac{-E_a}{RT}} - 1$$

with k as the reaction rate, A as the initial factor, E_a representing the activation energy, R providing the universal gas constant and T representing the temperature of the reaction. The principles of the Arrhenius equation are applied to this study using equation 2,

$$\beta = \beta_o e^{\frac{-E_a}{RT}} - 2$$

with β signifying the ramp rate of the DSC, β_o as a constant, and E_a, R, and T as activation energy, universal gas constant, and temperature of the reaction respectively. Taking the natural log of equation 2 should provide a linear trend for the data to be analyzed, represented by equation 3.

$$ln\beta = ln\beta_o - \left(\frac{Ea}{RT}\right) - 3$$

When equation 3 is rearranged, it results in equation 4,

$$ln\beta = \left(\frac{-Ea}{R}\right) * \frac{1}{T} + ln\beta_o - 4$$

Which has a similar form of a linear function represented by,

$$y = mx + b - 5$$

If the slope is m= $\left(\frac{-E_a}{R}\right)$ and the y-intercept is $ln\beta_o$ in the linear function then the activation energy can be determined using, [3]

$$E_a = m * R \; - 6$$

The activation energy for the molecular rearrangement of 5CB and 7CB molecules in the BLCS that initiates phase transition is obtained using equation 6. [5,10]

$$m = \frac{-Ea}{R} - 7$$

For simplicity, the specific heat capacity (Cp) may also be represented by,

$$C = Cp \qquad\qquad - 8$$

The first derivative of the heat in a system provides the heat flow in a given time, by relating the heat flow (HF) to the mass (m), specific heat capacity (C) and temperature change ($\frac{dT}{dt}$) of a sample seen in equation 9,

$$Heat\ Flow\ (HF) = mC\frac{dT}{dt} = \frac{dQ}{dt} \qquad - 9$$

Taking the first derivative of the heat flow equation provides the thermal speed (v) that gives the change in heat flow over a given time ($\frac{d(HF)}{dt}$). It is the same as taking the second derivative of the heat in the BLCS system and multiplying by sample mass (m) and specific heat capacity (C) as seen in equation 10,

$$v = \frac{d(HF)}{dt} = mC\frac{d^2(Q)}{dt^2} \qquad - 10$$

Thermal acceleration (a) is obtained by taking the second derivative of the heat flow equation, or the third derivative of the heat in the mixture multiplied by its m and C, shown in equation 11,

$$a = mC\frac{d^3(Q)}{dt^3} - 11$$

The thermal jerk (J) of the BLCS is obtained by taking the third derivative of the heat flow equation, or the fourth derivative of the heat in the system multiplied by system m and C, displayed in equation 12,

$$J = mC\frac{d^4(Q)}{dt^4} - 12$$

IV. RESULTS

The details of the effect of ramp rates on each transition occurred in BLCS can be seen below in this section. Each transition for each ramp rate is plotted separately to see clear effects of ramp rates.

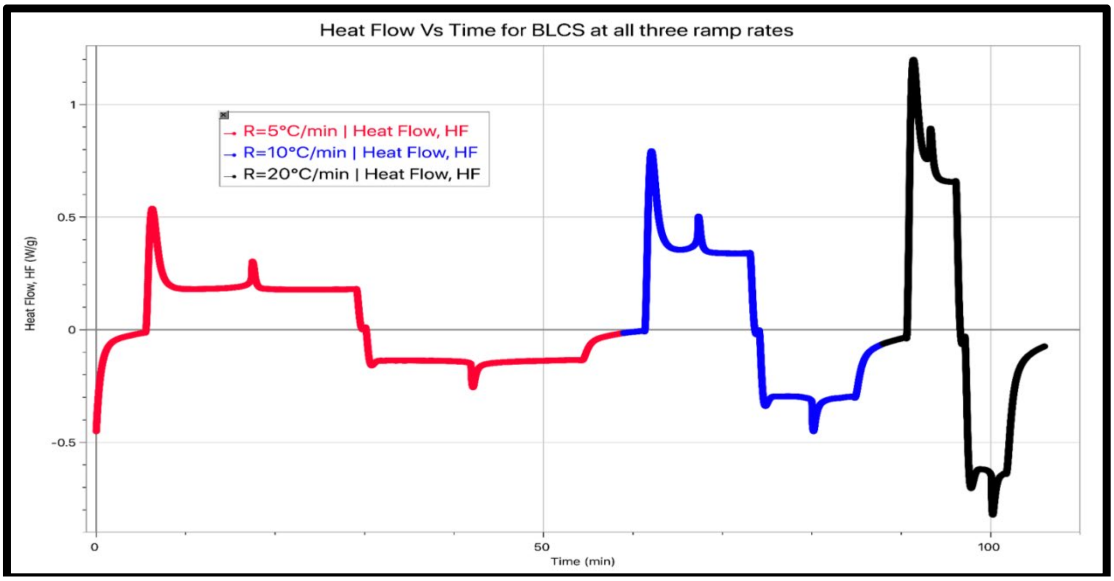

Figure 1. Heat Flow (HF) Vs Time (t) of the 5CB + 7CB BLCS at increasing ramp rates. The red portion of the data represents the heating and cooling scan at R=5°C/min, the blue data is for R=10°C/min and black is for R=20°C/min.

Figure 1 shows that as the ramp rate of the DSC was increased from 5 to 20°C/min the cycle took less time to complete. The two sharp upward peaks in the positive portion of each heating run represent the endothermic melting and heating nematic phase transitions with no change in temperature. The singular, downward facing peak in the negative (cooling) portion of each heating represents the exothermic cooling nematic phase transition of the 5CB + 7CB BLCS.

In Figure 2, a slight shift to the right in melting and heating nematic peaks is observed as ramp rate increases along with a shift to cooler temperatures in the cooling nematic transition. It is also seen that the entire HF Vs T graph gets taller as ramp rate increases.

Figure 3 compares the peak shift and shape of melting and heating nematic phase transition peaks based on the ramp rate used for the 5CB + 7CB BLCS. At R=5°C/min the melting and nematic transition in heating are tall and narrow, whereas the transition peaks at R=20°C/min are short and broad. The melting and nematic transition peaks in heating at R=10°C/min are not too short, tall, broad or narrow and fall in between the peak shapes of the other two rates. Both melting and nematic peaks in heating are observed to shift right with an increase in ramp rate and are shown in Table 1.

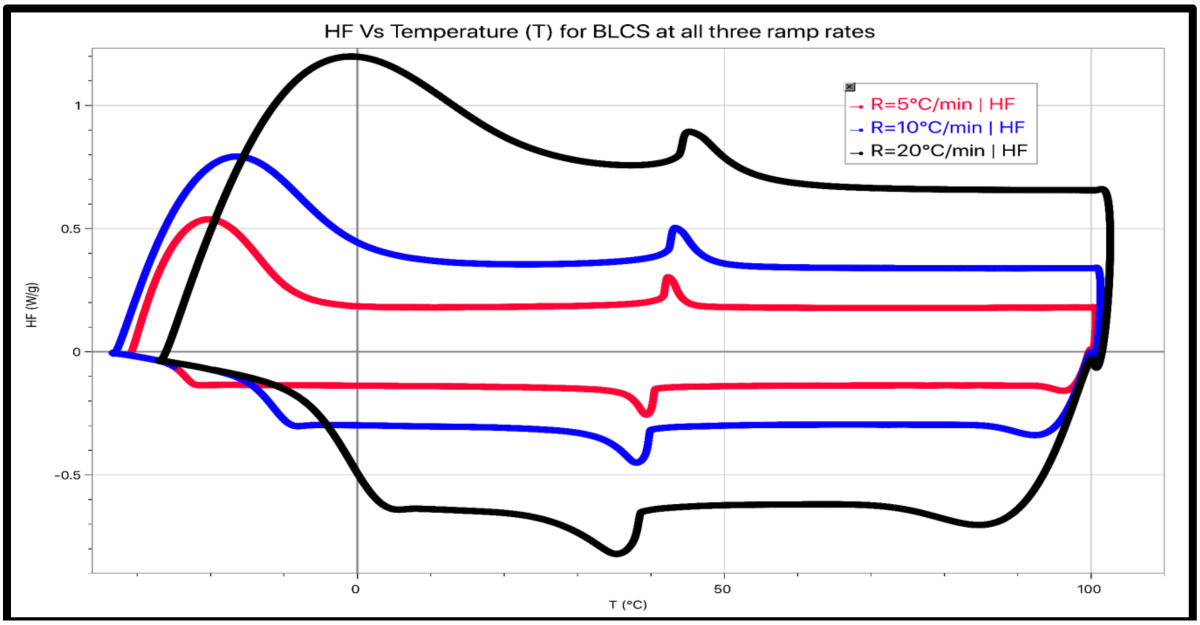

Figure 2. HF Vs Temperature (T) of the 5CB and 7CB BLCS for three DSC scans at increasing ramp rate. The red plot signifies the heat flow vs temperature of the mixture at R=5°C/min, the blue data at R=10°C/min and the black data at R=20°C/min.

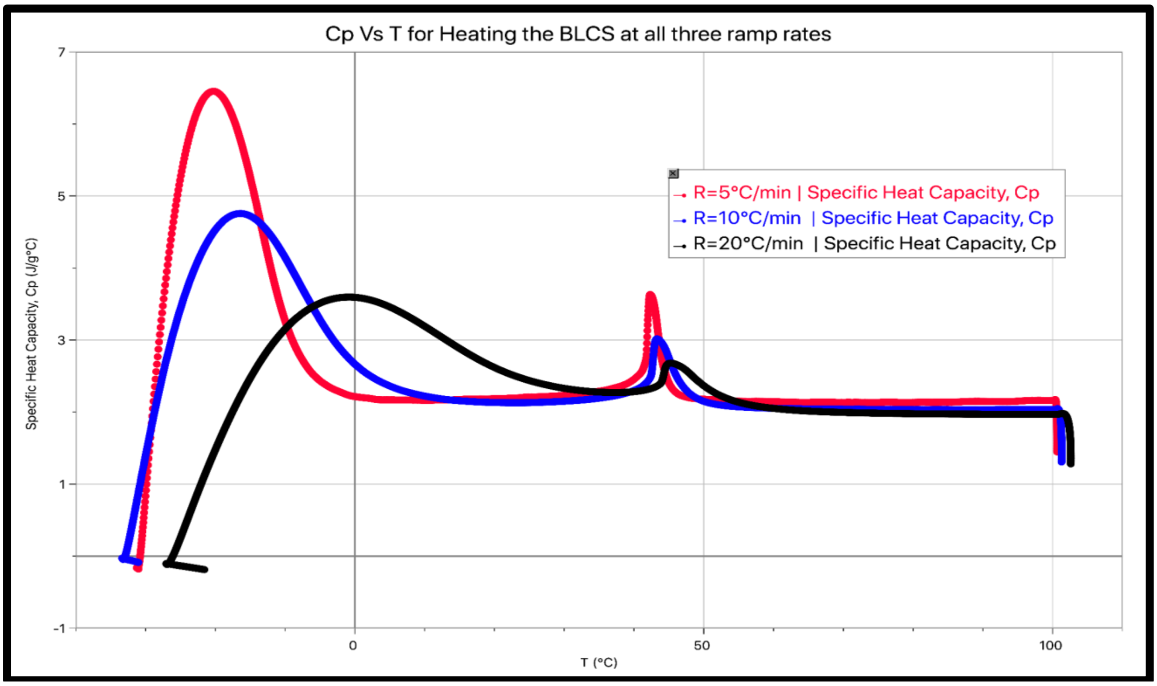

Figure 3. Specific Heat Capacity (Cp) Vs Temperature (T) for the Heating scan of the 5CB and 7CB BLCS at three different rates. The red data represents the Cp Vs T at R=5°C/min, the blue at R=10°C/min and the black at R=20°C/min.

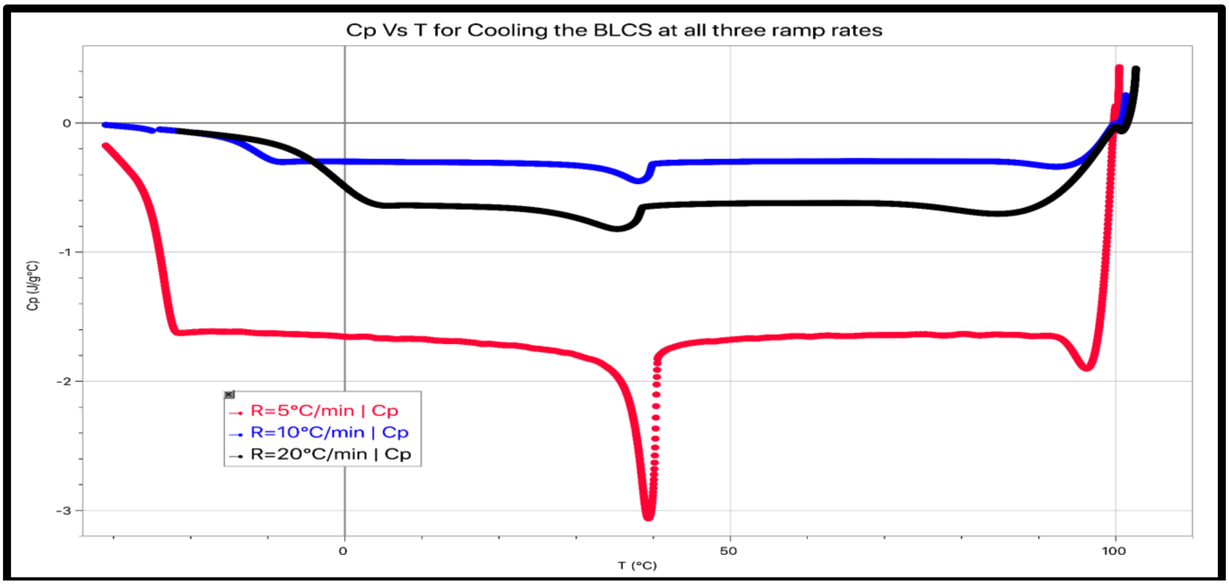

Figure 4. Cp Vs T for the Cooling scan of the 5CB and 7CB BLCS at three different rates. The red plot portrays the Cp Vs T at R=5°C/min, the blue plot at R=10°C/min and the black plot at R=20°C/min.

In Figure 4, the characteristics of nematic transition peaks of a 5CB + 7CB BLCS in cooling at different ramp rates is displayed. The absence of the crystallization peak is shown. It is shown that at R=5°C/min the nematic transition peak in cooling is the tallest and most narrow peak. The transition peaks for R=10°C/min and R=20°C/min have similarly short and broad shapes but R=10°C/min nematic peak is a little less wide and tall. The cooling scan in R=5°C/min however is much further separated from the other two data sets unlike in Figure 3 where the data sets are nearly overlapping.

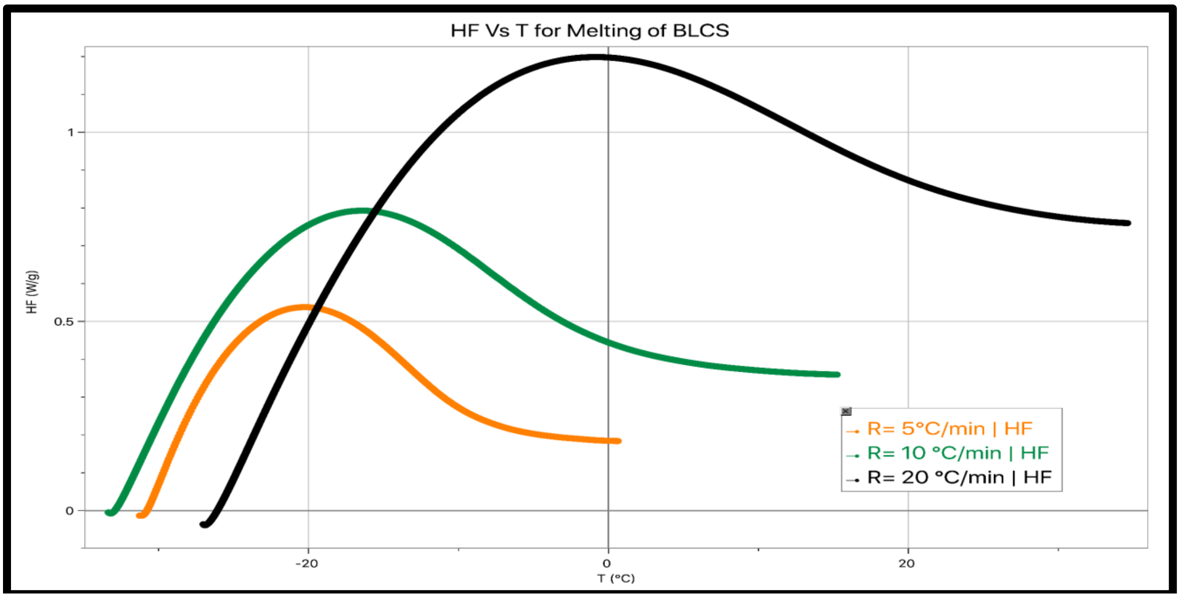

Figure 5. Comparing HF Vs T for the Melting transition Peaks of the LC mixture from R=5°C/min to R=20°C/min.

Figure 5 compares the HF Vs T for the melting transitions for each ramp rate. As the rate increases so does the width and height of the melting transition peak for the LC mixture. Being able to inspect and compare the transition peaks in such detail makes it easy to learn and study the behavior of LC phase transitions.

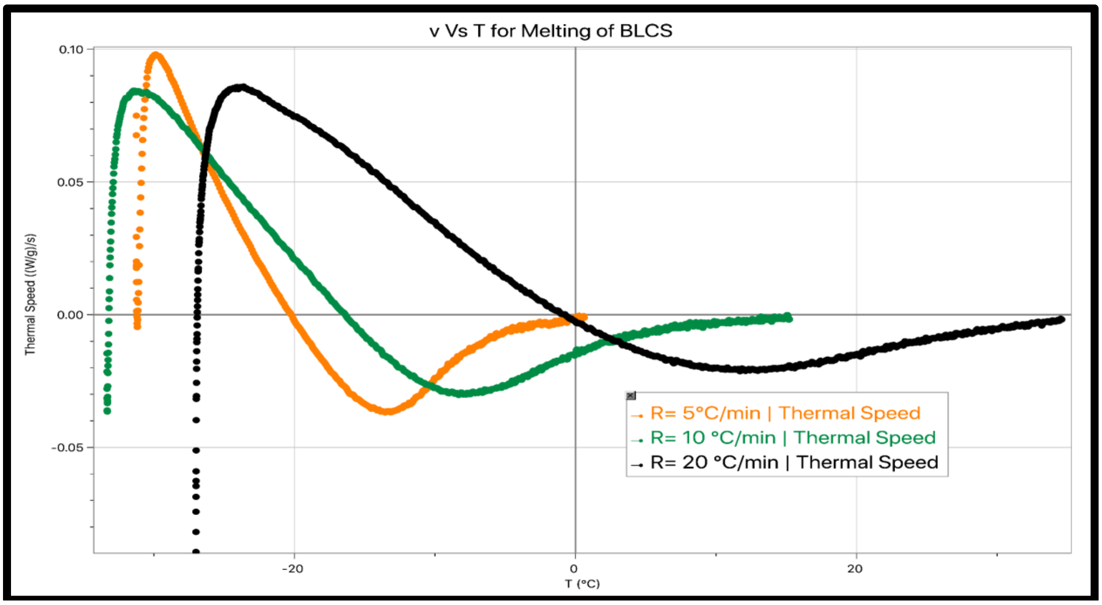

Figure 6. Thermal Speed (v) of Melting Transition peaks for each ramp rate of heating the LC mixture. First derivative of HF Vs T of melting transition.

Figure 6 shows the first derivative of the melting transition peaks for each ramp rate in Figure 5. The thermal speed was plotted on the y-axis with the temperature on the x-axis. The first derivative for each rate's melting peak shows the dynamics of the melting transition peak during heating and were all calculated in LoggerPro. Maximum values of thermal speed for all phase transitions of BLCS at each ramp rate are found in Table 3.

Figure 7 shows the second derivative of the melting transition peaks for each ramp rate in Figure 5. The second derivative represents thermal acceleration during the melting transition during heating and was plotted on the y-axis with the temperature on the x-axis. The thermal acceleration determines how long it takes the LC mixture to complete the melting transition. Maximum thermal acceleration values for all transitions at each ramp rate are found in Table 4.

Figure 8 shows the third derivative of the melting transition peaks for each ramp rate in Figure 5. The third derivative represents the thermal jerk of each melting phase transition and was plotted as a calculated column on the y-axis and temperature on the x-axis using LoggerPro. Maximum thermal jerk values for all phase transitions at each ramp rate are found in Table 5.

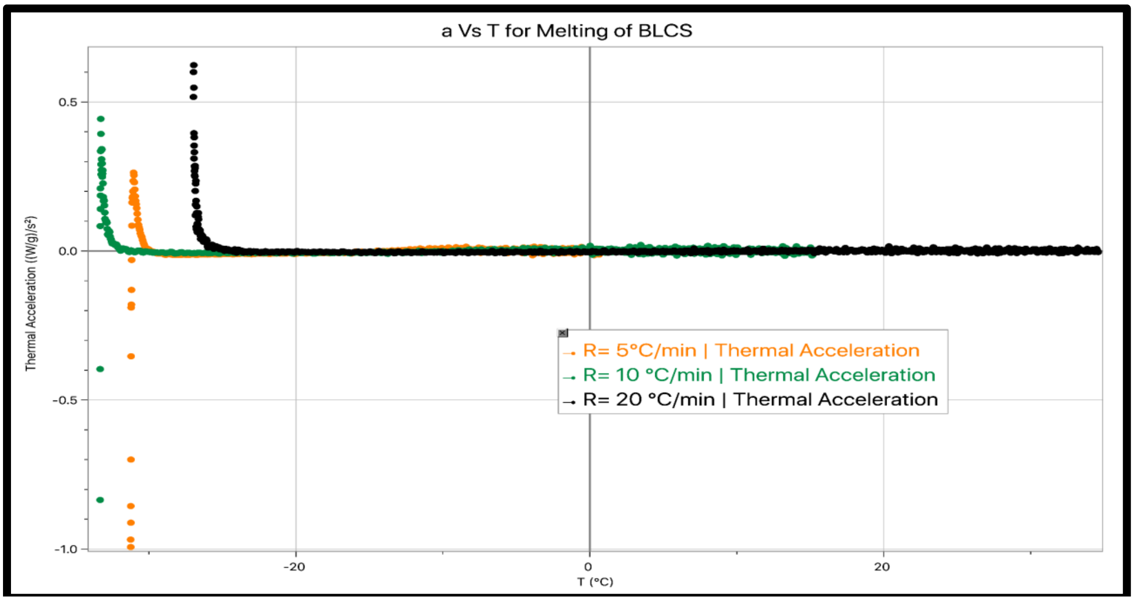

Figure 7. Thermal Acceleration (a) of the Melting transition peaks for each ramp rate of the heated LC mixture. Second Derivative of HF Vs T for melting transition.

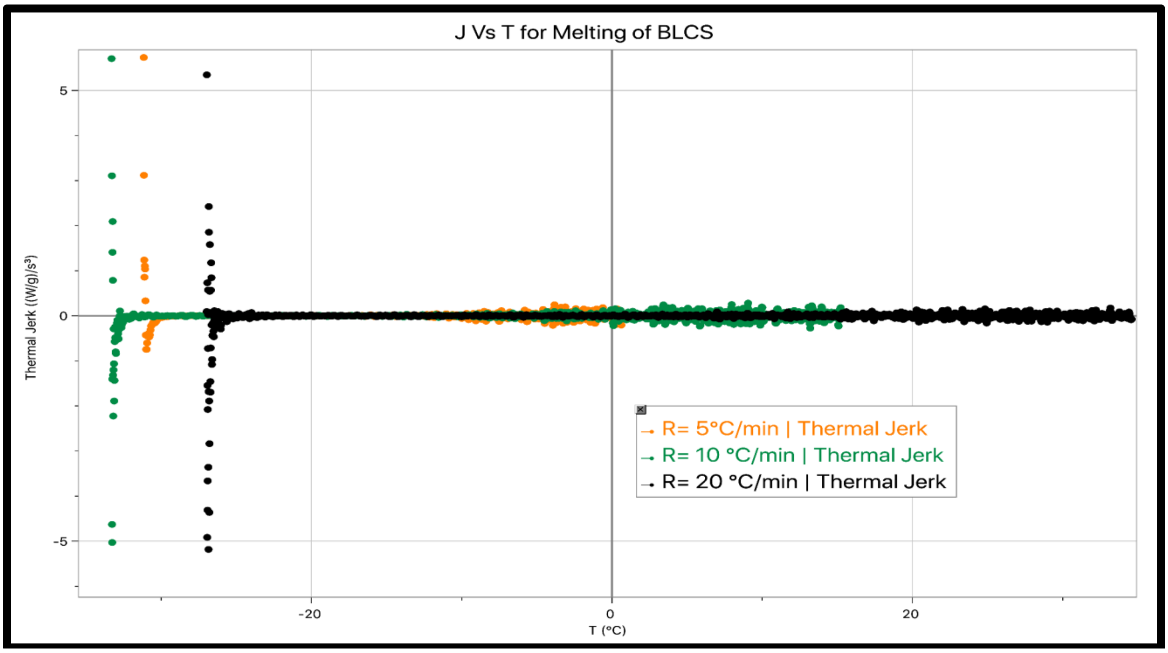

Figure 8. Thermal Jerk (J) of the Melting transition peaks for each ramp rate of heating the LC mixture. Third derivative of HF Vs T of melting transition.

Figure 9 details a HF Vs T plot of nematic transition peaks at different ramp rates to compare their shape and size to each other. An increase in ramp rate is seen to increase the height and width of nematic peak transitions. An increase in wing jump is also observed with an increase in ramp rate.

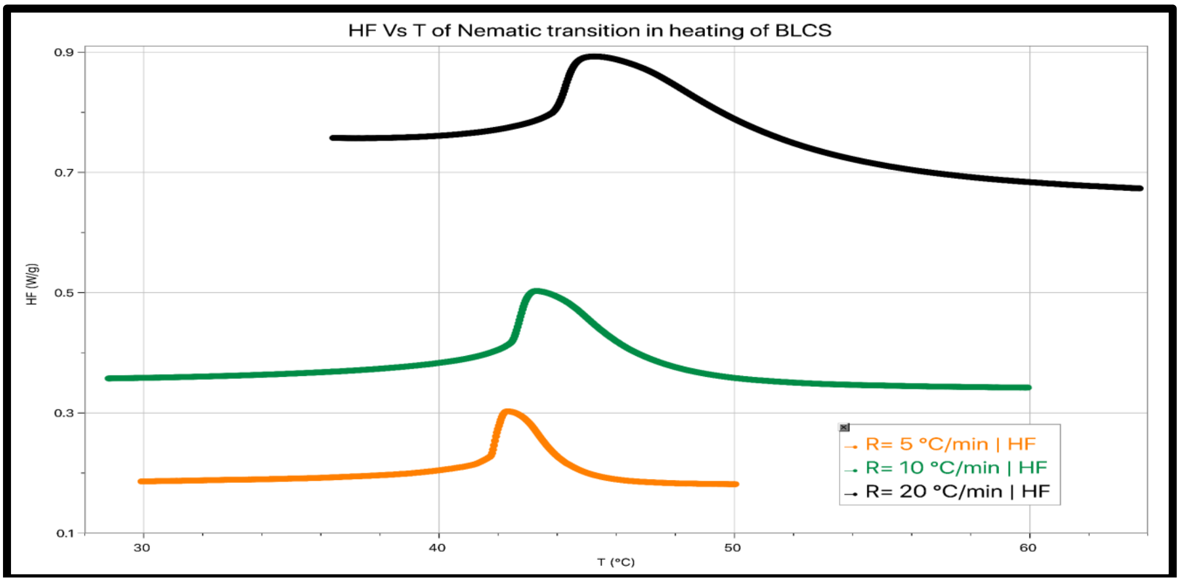

Figure 9. Comparison of HF Vs T for the Heating Nematic transition Peaks of the LC mixture from R=5°C/min to R=20°C/min.

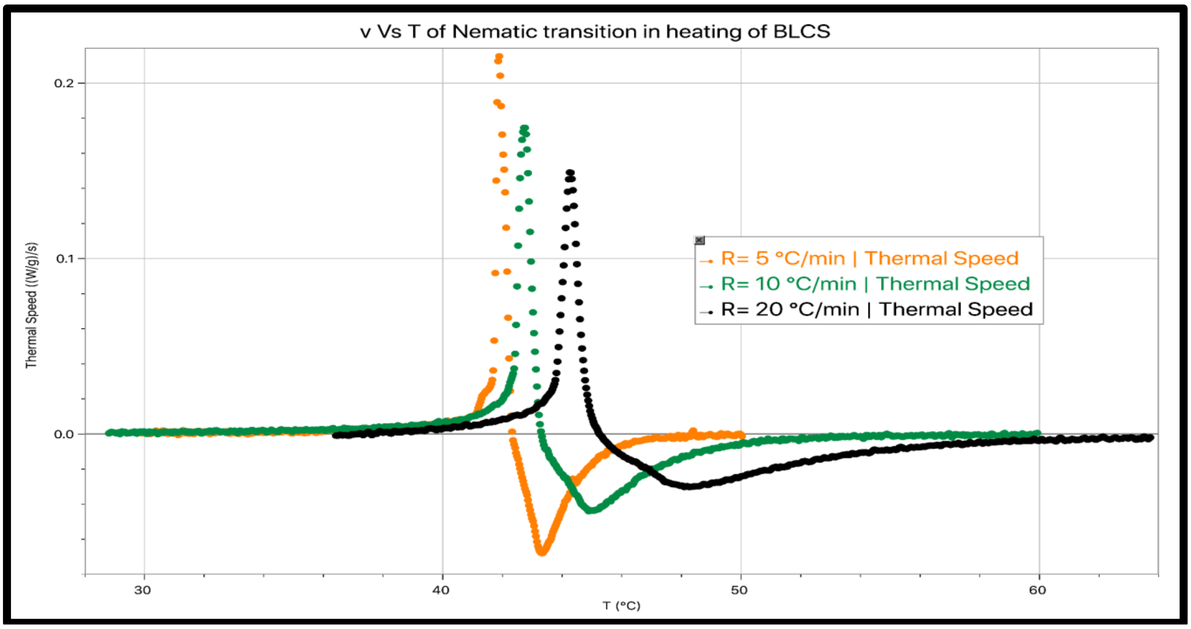

Figure 10. Thermal Speed of Heating Nematic Transition peaks for each ramp rate of the LC mixture heating run. First derivative of HF Vs T of heating nematic transition.

Figure 10 shows the first derivative of the HF VS T of heating nematic transition peaks seen in Figure 9. The thermal speed was plotted on the y-axis and the temperature on the x-axis using a calculated column in LoggerPro. This d^2Q/dt^2 Vs T plot highlights the dynamics of the nematic transition in heating by showing the one positive and one negative peak for each ramp rate, suggesting the nematic transition requires BLCS particles to slow down and then speed up.

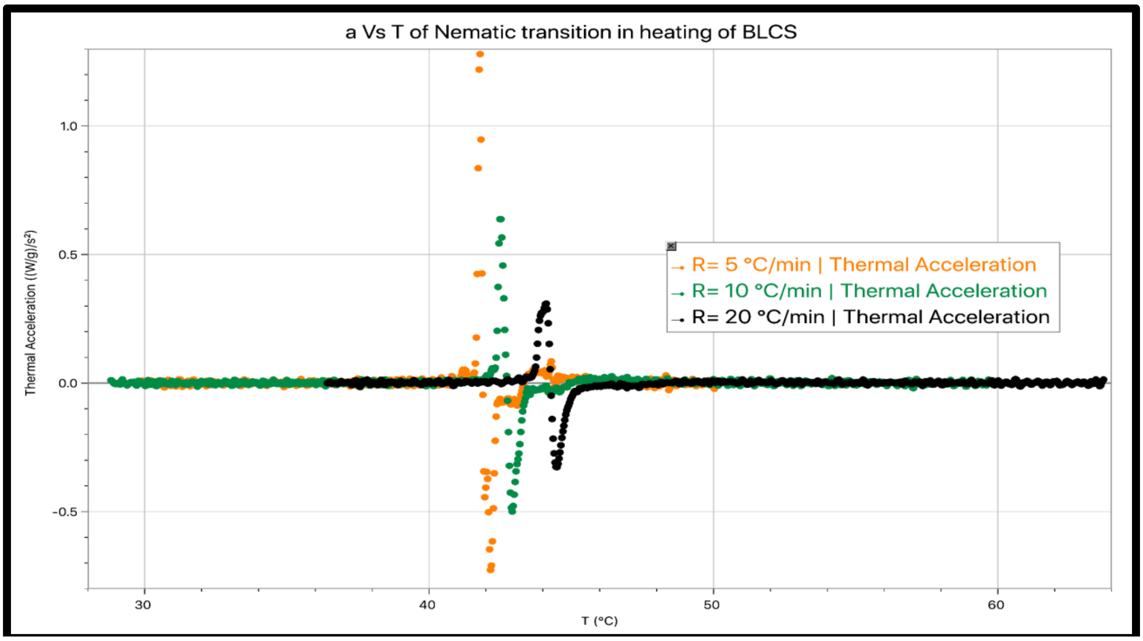

Figure 11. Thermal Acceleration of Heating Nematic transition peaks for each ramp rate of heating the LC mixture. Second derivative of HF Vs T for heating nematic transition.

In Figure 11 the second derivative of the HF Vs T for heating nematic transition peaks is displayed. Given the required change in thermal speed shown in Figure 10 to go from negative to positive speed requires acceleration. The acceleration of the BLCS particles during the heating nematic transition is plotted here and shows two peaks for every ramp rate. The peaks for R=5°C/min are much taller and thinner than R=10°C/min acceleration peaks and much more so than R=20°C/min peaks. The two peak values means the thermal speed changed due to acceleration, twice.

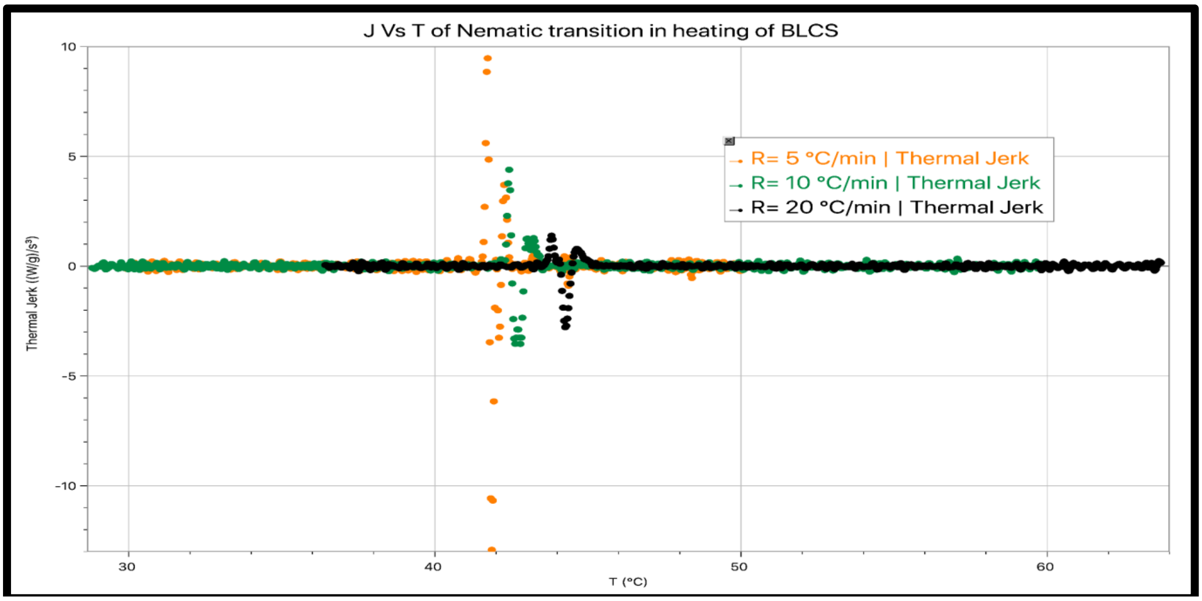

Figure 12. Thermal Jerk of the Heating Nematic transition peaks for each ramp rate of the LC mixture during heating. Third derivative of HF Vs T for heating nematic transition.

Figure 12 shows the third derivative of the HF Vs T of nematic transition peaks in heating called thermal Jerk. The plot of thermal jerk for each rate of the 5CB + 7CB BLCS shows three peaks that get shorter and wider as ramp rate increases.

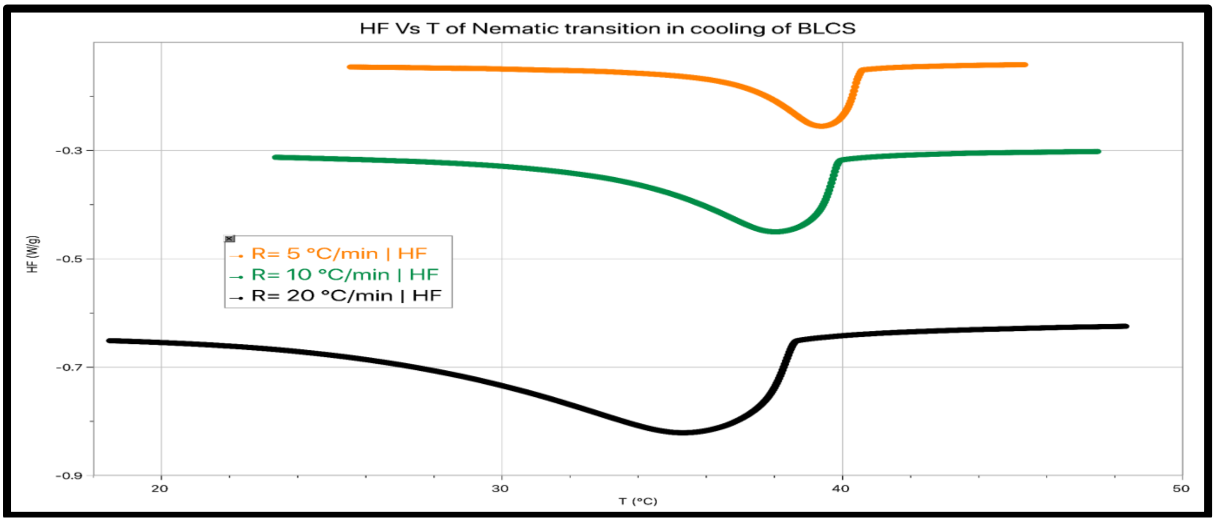

Figure 13. Comparing HF Vs T for the Cooling Nematic transition Peaks of the LC mixture from R=5°C/min to R=20°C/min.

Figure 13 compares the shape and size of nematic transition peaks in cooling of a 5CB + 7CB BLCS at different ramp rates. An increase in ramp rate seems to result in an increase in nematic peak width and height. A slight increase in wing jump is also seen with an increase in ramp rate. There is also a shift left, to cooler temperatures for the nematic transition as the ramp rate goes up.

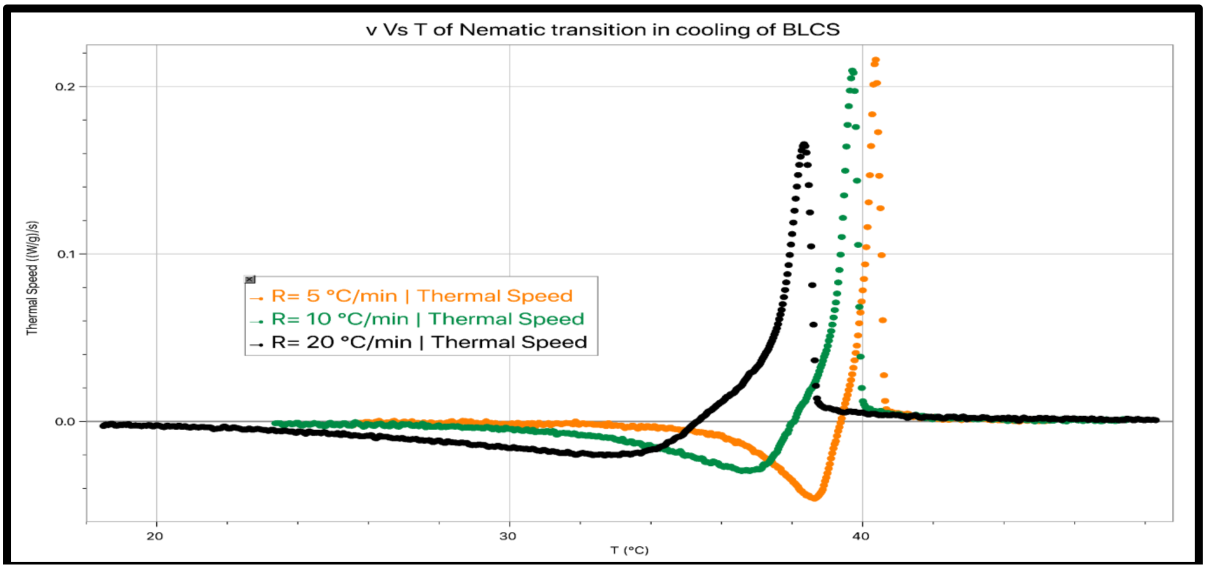

Figure 14. Thermal Speed of Cooling Nematic Transition peaks for each ramp rate of heating the LC mixture. This plot is the first derivative of HF Vs T for cooling nematic transition.

Figure 14 displays the first derivative of the HF Vs T plot of cooling nematic transitions seen in Figure 13. The thermal speed was plotted on the y-axis with the temperature on the x-axis using calculated columns in LoggerPro. The plot of d^2Q/dt^2 for cooling nematic transitions shows a negative and positive peak, portraying that the particles in the BLCS need to slow down and then speed up to complete the transition.

In Figure 15, the second derivative of the HF Vs T plot for the nematic cooling transition peaks at varying rates. The thermal acceleration was plotted on the y-axis using a calculated column in LoggerPro. The three positive and negative acceleration peaks, two for each ramp rate, represents that the BLCS particles need to accelerate twice to complete the cooling nematic transition.

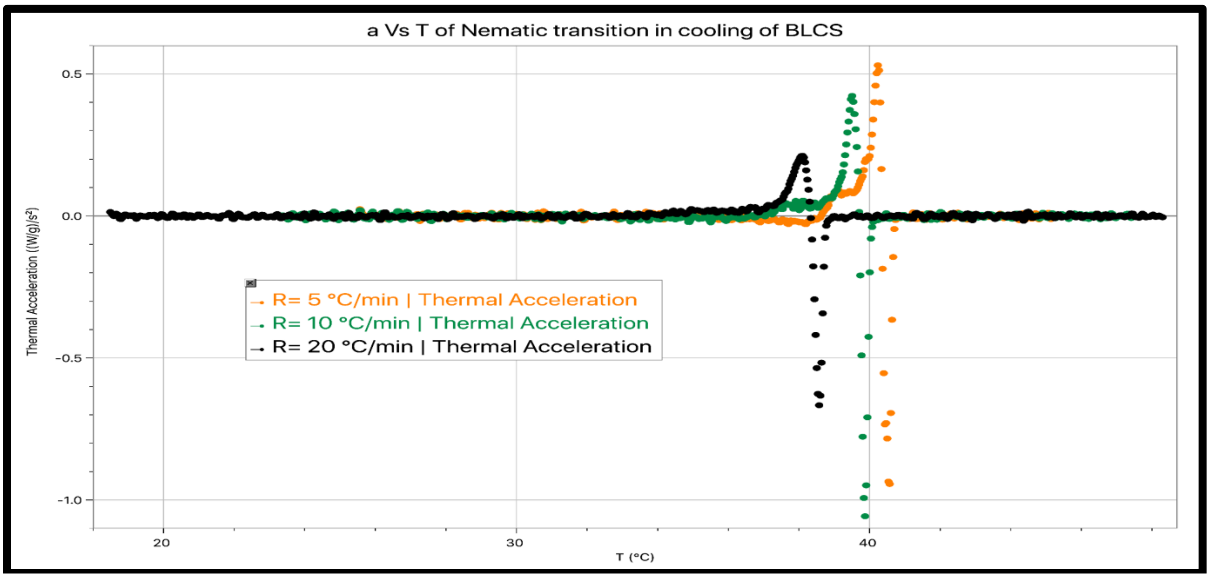

Figure 15. Thermal Acceleration of the Cooling Nematic transition peaks at each ramp rate while the LC mixture was heated. This is the second derivative of HF Vs T for cooling nematic transition.

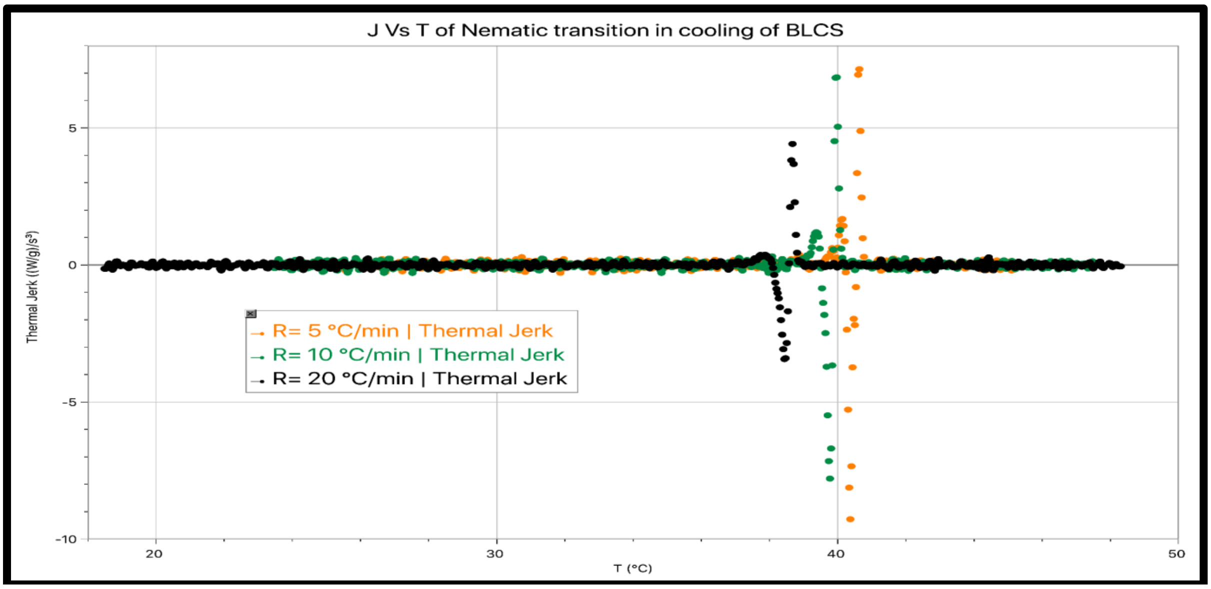

Figure 16. Comparing the thermal jerk of the Cooling Nematic transition peaks for each ramp rate of the heated LC mixture. This plot is the third derivative of HF Vs T for the cooling nematic transition.

Figure 16 shows the third derivative of the HF Vs T of nematic transition peaks in cooling called thermal Jerk. The plot of thermal jerk for each rate of the 5CB + 7CB BLCS shows two peaks that get shorter and wider as ramp rate increases. A shift to the left is seen in the peaks as ramp rate increases as well.

V. DISCUSSION

An upward shift in melting and nematic transition temperature of the 5CB + 7CB BLCS is observed in heating as the ramp rate is increased from 5 to 20°C/min displayed in Figure 17. Melting temperatures, at increasing ramp rate were -20.23°C, -16.49°C and -0.79°C and heating nematic temperatures were 42.33°C, 43.27°C and 45.15°C as ramp rate increased as seen in Table 1. An opposite less dramatic downward shift in nematic transition temperature is seen in cooling as ramp rate increases shown in Table 1. As ramp rate increased, the cooling nematic transition temperatures were 39.41°C, 38.07°C and 35.32°C as shown in Figure 17.

Table 2 outlines the data for the activation energy of melting, heating nematic and cooling nematic phase transitions following theories mentioned in the theory section. These data were calculated using Logger Pro's linear fit function displayed in Figures 18, 19, 20. Logger Pro software also provided a linear fit equation with uncertainty. The activation energy for the melting transition of the 5CB + 7CB BLCS was -7.170±0.489 J, for the heating nematic transition -7577.4±160.2 J, and for the cooling nematic transition was +3731.3±101.6 J. Perhaps the melting transition requires much less energy because the different sized parent LCs 5CB and 7CB are able to initially melt from solid state with little energy input but require much more energy to untangle and reach a completely liquid state. Similarly with the cooling nematic transition, that will take much more energy to reorganize the 5CB and 7CB molecules from a completely liquid state because they will get tangled, preventing easy reorganization to crystal lattice structure.

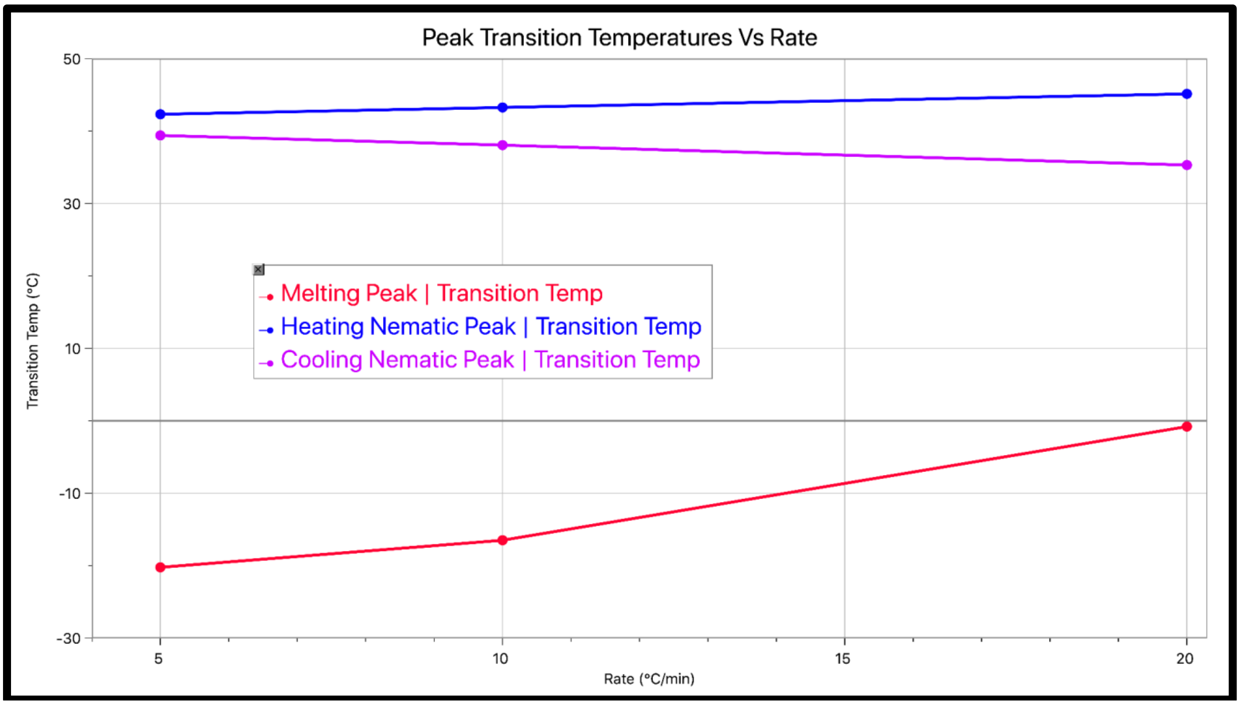

Figure 17. Comparing Melting, Heating Nematic and Cooling Nematic transition temperatures of the 5CB + 7CB BLCS at R= 5,10 and 20°C/min.

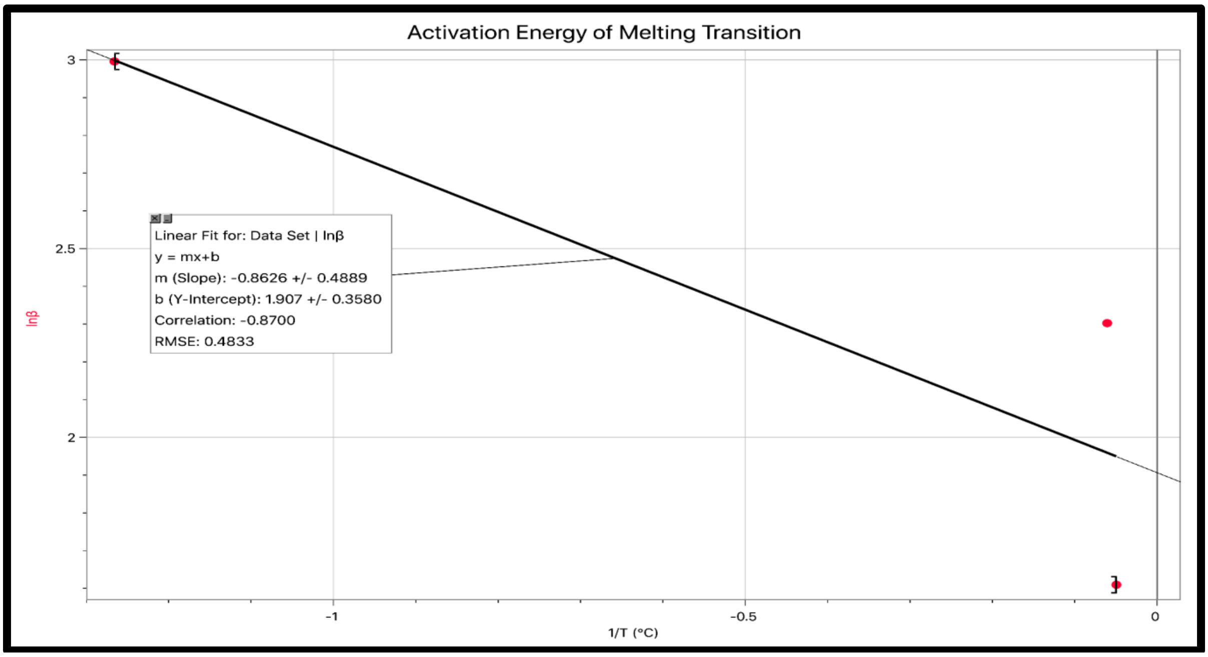

Figure 18. Linear fit of lnβ Vs 1/T for melting transition temperatures at R=5, 10 and 20°C/min, the slope of which is used to calculate the activation energy for the melting transition of the 5CB + 7CB BLCS.

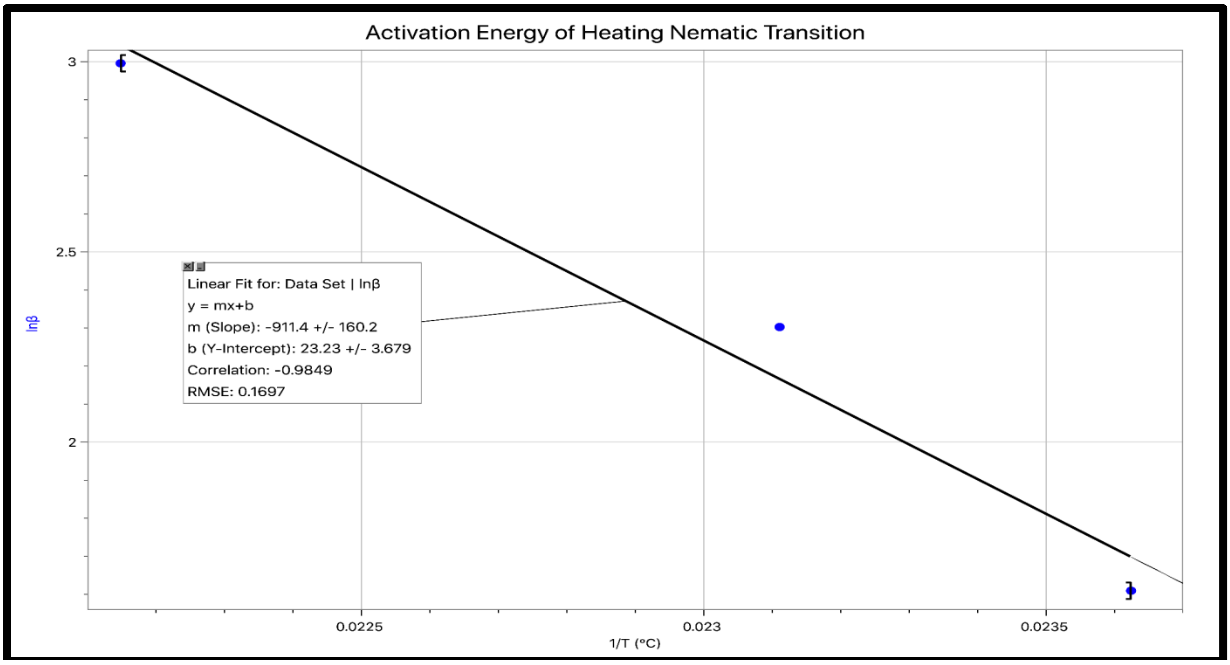

Figure 19. Plot showing the linear fit of lnβ Vs 1/T graph for the heating nematic transition temperatures at R=5, 10 and 20°C/min, the slope of which is used to calculate the activation energy for the heating nematic transition of the 5CB + 7CB BLCS.

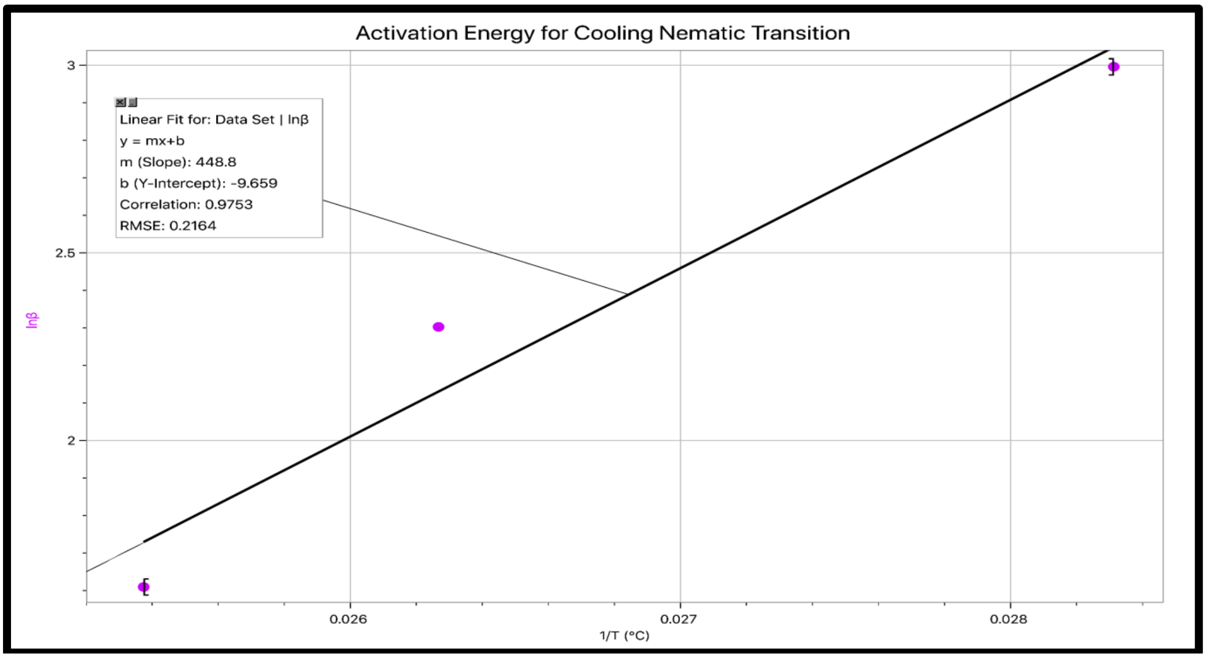

Figure 20. Linear fit of lnβ Vs 1/T for the cooling nematic transition temperatures at R=5, 10 and 20°C/min, the slope of which is used to calculate the activation energy for the cooling nematic transition of the 5CB + 7CB BLCS.

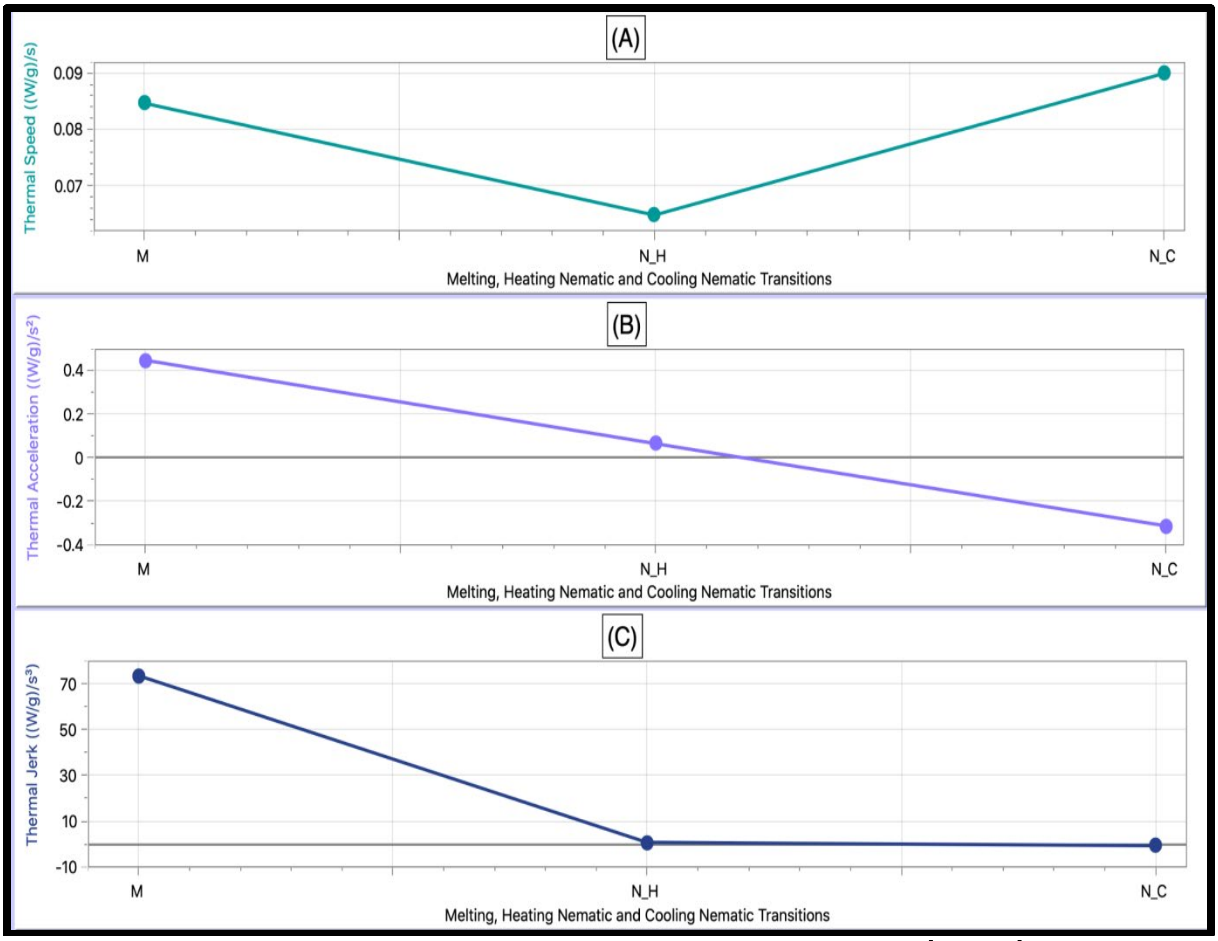

Figure 21. Comparison of (a) Thermal Speed (d(HF)/dt), (b) thermal acceleration (d^2(HF)/dt^2, and (c) thermal Jerk (d^3(HF)/dt^3 between M, N_H and N_C transitions of the 5CB + 7CB BLCS at 10°C/min.

Figure 21 shows a comparison between Melting, Heat Nematic and Cool Nematic for thermal speed, thermal acceleration, and thermal jerk as effect of ramp rates for 10°C/min. All speed, acceleration and jerk values are found in Tables 3-5 but average values for each transition are used for comparison in Figure 21. Thermal speed is maximum for cool Nematic, thermal acceleration is minimum for cool Nematic and jerk is constant for cool Nematic as can be seen in Figure 21. It is clear from it that BLCS molecules are trying to cool down by reducing their thermal acceleration and showing almost no change in thermal jerk but maximum values in thermal speed as they just moved from the higher temperature Isotropic state.

Maximum values came for the thermal speed of the 5CB + 7CB BLCS during heating at R=5°C/min as seen in Table 3. During the melting phase transition at 5°C/min the thermal speed was v=0.0981 (W/g)/s. The heating nematic phase had two peaks for thermal speed v_1= 0.216 and v_2= -0.0692 (W/g)/s, and so did the cooling nematic peak v_1= -0.0467 and v_2= 0.217 (W/g)/s. This suggests that the heating nematic and cooling nematic transitions are when the BLCS molecules are moving the quickest. For thermal acceleration, the maximum value for the melting transition came during the R=20°C/min cycle at a=0.626 (W/g)/s^2. The heating nematic peak gave two values for maximum acceleration a_1=1.279 and a_2= -0.730 (W/g)/s^2 at R=5°C/min, as well as the cooling nematic transition values a_1=0.531 and a_2= -0.945 (W/g)/s^2, shown in Table 4.

Lastly, the thermal jerk of the 5CB + 7CB BLCS showed a maximum value during the R=10°C/min cycle for the melting transition of J=73.4 (W/g)/s^3. Both the heating and cooling nematic transitions had maximum thermal jerk values at R=5°C/min, where the heating showed three peaks and the cooling only showed two. For heating at R=5°C/min the maximum values for jerk were J_1=9.48, J_2=-12.91, and J_3=3.77 (W/g)/s^3. In cooling the maximum values for thermal jerks were J_1=-9.27 and J_2=7.16 (W/g)/s^3 shown in Table 5.

VI. DATA TABLES

In this research, several data analyses were performed to obtain detailed thermal data of BLCS as effect of ramp rates and shown in a separate section of Data Tables here.

Table 1. Comparison of Melting, Heating Nematic and Cooling Nematic phase transition temperatures at rates R= 5,10 and 20°C/min.

Rate (°C/min)	T_M (°C)	Heating T_N (°C)	Cooling T_N (°C)
5	-20.23	42.33	39.41
10	-16.49	43.27	38.07
20	-0.79	45.15	35.32

Table 2. Calculated Activation Energy of Melting, Heating Nematic and Cooling Nematic phase transitions.

Transition	E_a (J)	Uncertainty (J)	Intercept (J)	Uncertainty (J)
Melting	-7.170	± 0.4889	1.91	± 0.3580
Heating N	-7577.4	± 160.2	23.23	± 3.679
Cooling N	+3731.3	± 101.6	-9.659	± 2.710

Table 3. Details of Thermal Speed for Melting, and Heating and Cooling Nematic phase transitions at each ramp rate.

Thermal Speed (dQ/dt)	R= 5°C/min	R= 10°C/min	R= 20°C/min
Melting Peak	v: 0.098142	v: 0.084745	v: 0.086176
Heating Nematic Peak	v_1: 0.2162	v_1: 0.1748	v_1: 0.1492
	v_2: -0.0692	v_2: -0.0451	v_2: -0.0312
Cooling Nematic Peak	v_1: -0.0467	v_1: -0.0301	v_1: -0.0209
	v_2: 0.2167	v_2: 0.2102	v_2: 0.1660

Table 4. Details of Thermal Acceleration for Melting, Heating Nematic and Cooling Nematic phase transitions at each ramp rate.

Thermal Acceleration (d^2Q/dt^2)	R= 5°C/min	R= 10°C/min	R= 20°C/min
Melting Peak	a: 0.265	a: 0.445	a: 0.626
Heating Nematic Peak	a_1: 1.279	a_1: 0.637	a_1: 0.308
	a_2: -0.730	a_2: -0.505	a_2: -0.330
Cooling Nematic Peak	a_1: 0.531	a_1: 0.428	a_1: 0.215
	a_2: -0.945	a_2: -1.058	a_2: -0.668

Table 5. Details of Thermal Jerk for Melting, Heating Nematic and Cooling Nematic phase transitions at each ramp rate.

Thermal Jerk (d^3Q/dt^3)	R= 5°C/min	R= 10°C/min	R= 20°C/min
Melting Peak	J: 61.9	J: 73.4	J: -150.7
Heating Nematic Peak	J_1: 9.48	J_1: 4.39	J_1: 1.398

	J_2: -12.91	J_2: -3.58	J_2: -2.791
	J_3: 3.77	J_3: 1.31	J_3: 0.795
Cooling Nematic Peak	J_1: -9.27	J_1: -7.81	J_1: -3.43
	J_2: 7.16	J_2: 6.84	J_2: 4.42

VII. CONCLUSION

This paper reports detailed results of the effect of ramp rates on the phase transitions of a next generation Binary Liquid Crystal System (BLCS) made by mixing 5CB + 7CB in 1:1 percent by weight. This BLCS was run in a DSC instrument to get its thermal data for three different rates. The sample was heated from -30°C to 101°C then cooled back to -30°C in DSC at ramp rates: 5°C/min, 10°C/min and 20°C/min. The 5CB + 7CB BLCS had no observed crystallization in cooling but all other phase transitions, including melting, heating nematic and cooling nematic were affected by ramp rates and show activated dynamics. The melting and nematic phase transitions in heating shifted to higher temperatures as ramp rate increased while the nematic phase transition in cooling shifted to lower temperature when ramp rate was increased. The activation energy was determined for each phase transition of BLCS following Arrhenius theory and kinetic models as shown in the theory section. The activation energy for melting (M), heat Nematic (N_H),and cool Nematic (N_C) are found as -7.170, -7,577, and +3731 J/mol respectively. The lowest activation energy was found for M whereas the highest was found for N_H. Suggesting that it is easy to complete the crystallization transition, and harder for the BLCS to go from melting to nematic phases when the ramp rates are increased. The higher activation energy of the nematic phase transition suggests the BLCS is more stable and wants to stay in the nematic state.

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