Cholesteryl Ester Liquid Crystal Thermometer

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Purpose:

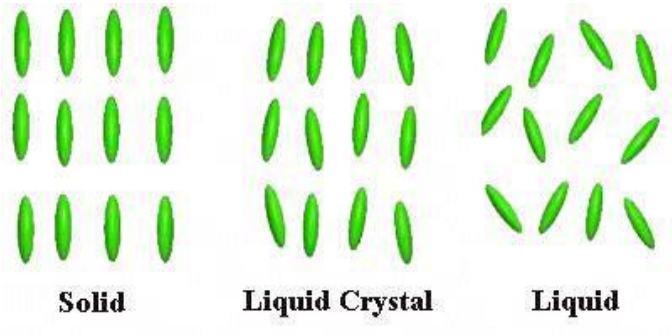
To relate crystal structure, wavelength and pitch together.

Learning Objectives:

1) Recall the description of pitch.
2) Synthesize and define liquid crystals.
3) Distinguish between different wavelengths of reflected light and compare them to the pitch.
4) Evaluate a ratio of Cholesterol components and come up with a temperature scale

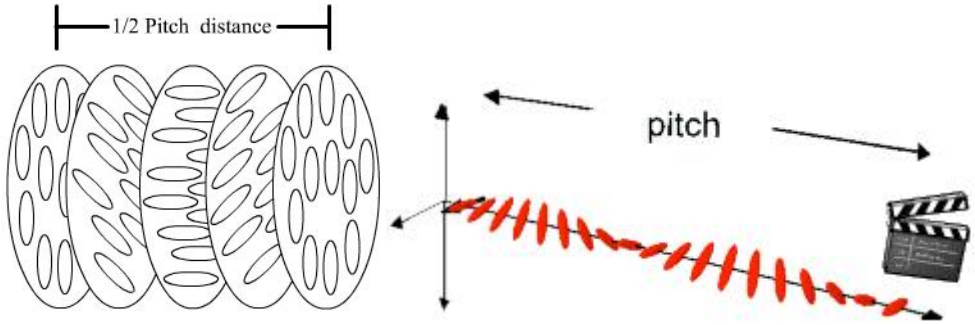
Introduction:

A liquid crystal is a solution which is in-between a liquid and a solid. It has a similar order to a solid, because adjacent layers are formed, but each layer is going a slightly different direction, similar to a liquid.



http://www.iq.usp.br/wwwdocentes/mralcant/AboutLC.html

Liquid crystals form a structure similar to that of a spiral staircase. Each rod of the liquid crystal represents a stair on a spiral staircase. There is a distance called a pitch, which represents the distance that rises up the length of the spiral staircase molecule before the rung of the staircase becomes parallel to another rung in the original position. Below is an example of pitch.



http://plc.cwru.edu/tutorial/enhanced/files/lc/phase/phase.htm

As in most atoms and molecules as one applies heat to a molecule there is an increase in randomness and molecules spread further and further apart. In liquid crystals as heat is applied the liquid crystals spread further apart. The angle that is made is larger therefore the pitch length gets shorter. In the spiral stair case model there are less rods involved in the staircase before another rod is in the same parallel position of the pitch.

The liquid crystals change color with heat. The lower the temperature of the liquid crystals the longer the wavelength of light that is reflected because the pitch is equal to one half the wavelength of reflected light. The higher the temperature range, the shorter the wavelength of reflected light is.

Cholesteryl liquid crystal thermometers are made up of different ratios of derivatives of cholesterols. Each ratio change causes a change in the temperature range, **(thus)** to which it ()the color changes. This is because the lengths of each of the liquid crystals created are different, which affects the pitch of the liquid crystal structure.

Materials:

Chemicals

- Cholesteryl oleyl carbonate, Aldrich 15, 115-7
- Cholesteryl pelargonate (Cholesteryl nananoate), Aldrich C7,880-1
- Cholesteryl benzoate, Aldrich C7,580-2

Supplies

- 3 ml vial
- Micro spoonula
- Hot air gun or hair dryer
- Funnel
- Disposable weigh boats
- Clear contact paper
- Scissors
- Infrared thermometer
- Genecon hand-crank generator
- Thermoelectric module

Procedure:

Cholesteryl oleyl carbonate	Cholesteryl pelargonate	Cholesteryl benzoate	Transition range, degrees C
Crystal - isotropic state at 20°C	77 - 82 C	149-150 °C	
0.65 g	0.25 g	0.10 g	17-23
0.70 g	0.10 g	0.10 g	20-25
0.45 g	0.45 g	0.10 g	26.5-30.5
0.43 g	0.47 g	0.10 g	29-32
0.44 g	0.46 g	0.10 g	30-33
0.42 g	0.48 g	0.10 g	31-34
0.40 g	0.50 g	0.10 g	32-35
0.38 g	0.52 g	0.10 g	33-36
0.36 g	0.54 g	0.10 g	34-37
0.34 g	0.56 g	0.10 g	35-38
0.32 g	0.58 g	0.10 g	36-39
0.30 g	0.60 g	0.10 g	37-40

1. Pick one of the ratio combinations of the cholesteryl oleyl carbonate, the cholesteryl pelargonate, and the cholesteryl benzoate from the table above. Each student/group of students should choose a different ratio.
2. Measure out the allotted amounts of each of the cholesterol components and place them in a 3 ml vial.
3. Melt the solid in a sample vial using a hair drier or heat gun. (Make sure the vial lid is off during the melting process because it can ruin the seal on the vial).
4. The product goes from a liquid to a gel as it cools. In addition, as the product cools it changes colors. Different compositions change color over different temperature changes.
5. Cut two pieces of 5x5 cm clear contact paper. Peel the backing off, and lay them sticky side up on a table.
6. Take the vial of the cholesteryl ester mixture, open it and transfer a small spoonula full of the gel to the sticky side of one 5x5 cm piece of contact paper. Spread the gel uniformly in the middle of the contact paper. Be sure to leave a centimeter clearance from the edge of the contact paper. Take the other 5x5 cm contact paper and place it sticky side down on top of other contact paper. Ensure that the sticky sides go together smoothing them out evenly so there are no air bubbles.
7. Trim edges of the contact paper as necessary.
8. Rub your finger across the surface of the contact paper. Do this on top of a white color surface and a black color surface.

9. Do the colors change? What is the difference between seeing the colors on black surface on the white surface? Explain what you see.

10. Connect a hand crank generator to the Peltier square heating and cooling block. Turning the crank of the generator one direction will heat the Peltier square and turning it the other way will cool the Peltier square.
11. Place the prepared liquid thermometer on top of the Peltier Square. Turn the crank on the generator so it warms the square. Use the infrared thermometer to record the temperature and note the color changes. Turn the crank to change the temperature and continue to note the changes in color and temperature.
12. Compare the color of your cholesterol ester thermometer to those of other groups in the lab.
    a. Are the colors different at room temperature?

    b. Write down the differences or similarities that are seen between the thermometers.

    c. Compare your temperature and color results from those of the other groups. Are they the same

Questions: (continued)

1. Define Pitch in your own words.

2. As the color of the liquid crystal changes from red to blue, what is happening to the pitch length?

3. As the color of the liquid crystal changes from blue to red, what is happening to the pitch length?

4. If the color is green and changes to red, chemically/physically explain what has happened to the liquid crystal, be specific. Does this correspond to a temperature increase or decrease? Why?

5. Predict what the temperature range would be if 0.80g of Cholesteryl pelargonate, 0.10g Cholesteryl oleyl carbonate, and 0.10g Cholesteryl benzoate were used as a crystal thermometer.

6. If a crystal thermometer was reflecting green light at 35 ^{o}C what would most likely be its ratio of cholesteryl components.

References:

Boatman, E & Lisensky, G (2007). Preparation of liquid crystal thermometer. *Interdisciplinary Education Group*, Retrieved May 26, 2008, from http://mrsec.wisc.edu/Edetc/nanolab/LC_prep/index2.html

Case Western Reserve University , (2004). Polymers and liquid crystals . Retrieved June 4, 2008, from Case Western Reserve University Virtual Lab and textbook Web site: http://plc.cwru.edu/tutorial/enhanced/main.htm

Lisensky, G (2007). Preparation of cholesteryl ester liquid crystals. *Interdisciplinary Education Group*, Retrieved May 26, 2008, from http://mrsec.wisc.edu/Edetc/nanolab/LC_prep/index.html

Lisensky, G, & Boatman, E (2005). Colors in liquid crystals . *Journal of Chemical Education*, *82, 1360A*, Retrieved June 4, 2008, from http://www.jce.divched.org/Journal/Issues/2005/Sep/abs1360A.html.

Answers:
Questions: (continued)

1. Define Pitch in your own words.

Pitch is the distance between two consecutive parallel cholesteryl esters oriented in the same direction

2. As the color of the liquid crystal changes from red to blue, what is happening to the pitch length?

The pitch length decreases

3. As the color of the liquid crystal changes from blue to red, what is happening to the pitch length?

The pitch length increases

4. If the color is green and changes to red, chemically/physically explain what has happened to the liquid crystal, be specific. Does this correspond to a temperature increase or decrease? Why?

The atoms in the cholesteryl are relaxing and the pitch angle decreases, which in turn increases the length of the pitch. This corresponds to a temperature decrease because the pitch length is equal to one half the wavelength of reflected light.

5. Predict what the temperature range would be if 0.80g of Cholesteryl pelargonate, 0.10g Cholesteryl oleyl carbonate, and 0.10g Cholesteryl benzoate were used as a crystal thermometer.

47- 50 ^{o}C

6. If a crystal thermometer was reflecting green light at 35 ^{o}C what would most likely be its ratio and temperature range of cholesteryl components.

0.38g of Cholesteryl pelargonate, 0.52g Cholesteryl oleyl carbonate, and 0.10g Cholesteryl benzoate is the likely ratio combination that would produce a color change between the 33-36 ° C. When considering the wavelengths of the electromagnetic spectrum, from red to yellow, to orange, to green to blue range if going on the wavelength of light. Red yellow orange green blue. The 35° C is in the upper portion of this range and would be the more probable answer to the question. It is definitely not the 35-38 or the 32-35 because those would reflect red and blue light respectively. The 34- 37 range is possible but unlikely.

Suggestions for lab placement:

This lab could go in any of the lower level lab courses, but some adjustment would have to be made to reach the level of understanding required for this lab.

Prelab Suggestions for teachers:

There are a couple of options that can be suggested for students to fully understand the concept of pitch. There can be a pre-lab made where there can be a stretchable DNA molecule made that resembles the picture of pitch shown above.

Or look at this sight below for the picture of the pitch.
This hyperlink will take you to the picture
http://plc.cwru.edu/tutorial/enhanced/files/lc/phase/phase.htm
This hyperlink will take you to the Virtual text book and lab manual webpage.
http://plc.cwru.edu/tutorial/enhanced/main.htm

Pre-lab suggestion (Has not been tested by the authors of this lab).
Take a large rubber band and stager 10 paperclips around in a spiral staircase model.
Twist the string until the first and last paperclip are parallel in direction to one another.
Have a partner measure the distance from the first paper clip to the last paperclip.

Then continue to rotate the string in the same direction and record what happens? Rotate until the 7^{th} paperclip is going in the same direction and parallel to the first.

Do the same until the 5^{th} is parallel.

What happens to the distance

Questions or comments about lab that need to be addressed:

Is there a typo in the chart for the 20-25 temperature range for the amount of the Cholesteryl benzoate required? The lab says to add 0.20g, but all of the other ones require 0.10g. We did a separate experiment to see if there was a difference between the 0.10g and 0.20g. When the colors were observed there was a difference between the two. The 0.10g seemed to coincide with the pattern of the other ratios when changing.

Supplies for 10 students

7.0 g Cholesteryl oleyl carbonate

6.0 g Cholesteryl pelargonate

2.0 g Cholesteryl benzoate

5 - Hand crank generators

5 - infrared thermometers } can be shared among students

2 - hot air guns

10 – 3 ml glass vials with caps

25 cm x 20 cm of contact paper (or if precut have 20 - 5 x 5 cm squares)