Name:______________________________Date:_______________Class:________________

Student Worksheet

Making a Liquid Crystal Thermometer

Safety
Hot water can cause severe burns.

Introduction:
Liquid crystals are called the fourth state of matter because they have properties between those of a liquid and a solid. Liquid crystals may flow like a liquid but have crystals like a solid. Liquid crystals are all around us. They are in the shining exoskeleton of the jewel beetle; they are in the fish tank thermometer; they are in the color-changing labels of some drinks; they are in digital displays; and they are in security labels of many secure documents like checks. All these color changing phenomenon use the same principle. There are nanosize helical structures that reflect light differently depending on the tightness of the helix.

The colors of the objects are the outcome of various light properties: absorption, refraction, or reflection. Any opaque or non-transparent object shows color due to different wavelengths in a visual spectrum being reflected, refracted, or absorbed. The ultimate color depends on the wavelength of light and its interaction with the matter. In the case of liquid crystals, the reflection and refraction takes place from the nanosize helices. As the stimulus changes (temperature, humidity, etc.) the pitch of the helix changes and so does the reflection. These helices are actually stacks of layers of liquid crystals that rotate in response to temperature. The different rotations result in different pitch and, hence, a different color.

Colored plastic strips containing liquid crystals can be used to measure temperature. The thermochromic liquid crystals change color with temperature. This is usually over a range of about 0.1ºC. Different liquid crystals change color at different temperatures. They have been used to measure, for example, the temperature of a person, a room, a refrigerator, a freezer, and even a fish tank. But how do scientists find the right liquid crystals for a particular application?

Materials
- 3 × 5 cm liquid crystal sheets, one each with different temperature
- 3 pieces of card stock paper with visible light spectrum
- Beaker with approximately 300 mL water
- Beaker 250 mL (to warm water)
- hot plate
- 250 ml beaker to test the temperature strip
- two-sided tape to tape the crystal sheet onto beaker
- large plastic spoon (tablespoon size)
- iCelsius° thermometer probe or any other thermometer
- Plastic cup with about 8-10 ice cubes

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Question: How does a liquid crystal change color and how can we find the right type of crystal for a specific temperature range?

Make a Prediction for the question:

*Liquid crystals change color because the helical structure of the crystal formation changes, and temperature that causes the change depends on the composition of the liquid crystal.*__________

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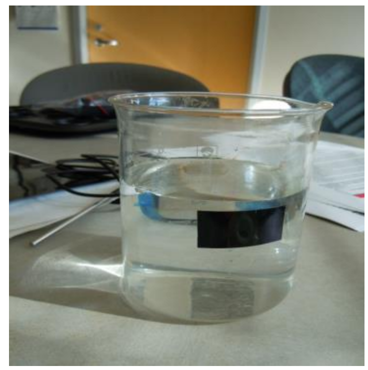
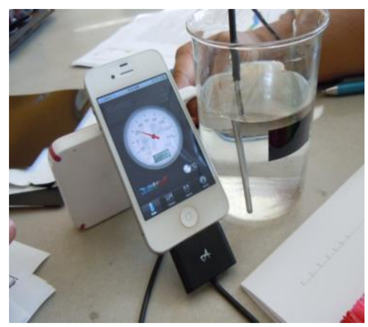
Procedure Checkpoints

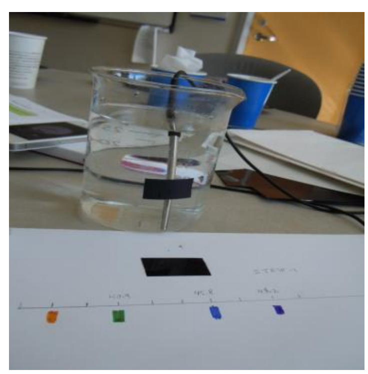
1. Put a pot or large beaker of water on a hot plate and warm to 75-90°C.
2. Tape one piece of the liquid crystal sheet onto the outside of a beaker about 1/3 way up from bottom using double sided tape.
3. Pour water into the beakerto a level that is higher than the liquid crystal strip.
4. Place the temperature probe into the water.



5. Check the colors of the liquid crystal strip. If the strip has a color other than black, put some ice in the water until it turns black.
6. Add one spoon of hot water to the beaker at a time and stir. Wait a few seconds until the temperature equilibrates and see if the color of the liquid crystal changes.



7. Be sure to look straight on at the liquid crystal when making observations. If the color does not change after 30–45 seconds, add one tablespoon more until you observe a change.
8. Observe any color change, record the temperature on the first division mark of the card stock above the corresponding color.
9. Continue to add water to the beaker (one tablespoon at a time) recording the liquid crystal color changes and the temperature of each change until the liquid crystal does not change anymore.



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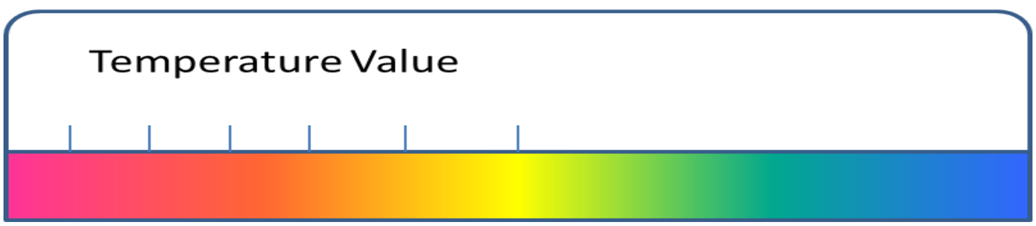
10. Repeat steps 2–9 with the same liquid crystal strip, and make any adjustment in color on the spectrum chart as needed until you feel that you have accurately calibrated a liquid crystal strip. This is your liquid crystal thermometer.
11. Repeat steps 2–10 with two more liquid crystal strips for different temperature ranges.
12. Arrange the three pieces of thermometer in increasing order of temperature.
13. Can you heat the water to a particular temperature as indicated by your liquid crystal temperatures? Check the accuracy of your liquid crystal thermometer by using the iCelsisu^{o} or other thermometer.
14. Tape all the liquid crystal strips (your thermometer) on the beaker and test changes in temperature using both your thermometer and a lab thermometer.

Cleanup:

Pour the water from all the beakers in sink and put beakers in assigned place in lab.

Record Observations:

Mark changes in temperature corresponding to color on color chart like this for all three liquid crystals.



Analyze the Results:

Compare your results (measuring range, display accuracy, display resolution) with other groups and lab thermometer.

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Draw Conclusions:

1. As the color of the liquid crystal changes, what is happening to the pitch length? (Is the helix getting tighter or loser?)

   The helix is getting tighter as the color changes from red to violet.

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

   As the temperature changes from red to green the temperature is increasing. This makes the liquid crystal to orient tighter. If it is cold, the crystals are more ordered and closely spaced. As the crystals get warm, the spacing increases. The change in reflected color is, in fact, primarily due to this increase in angle of the twisting and corresponding decrease in the pitch distance as the liquid crystal is heated up.

3. Does the color sequence correspond to a wavelength sequence?

   The color change corresponds to the visible light spectrum with red being coolest and violet being hottest.

4. How can you explain the observed order of color change?

   The change in the color corresponds to gradual changes in the packing of crystals.

5. Why these observed changes are considered nanotechnology? The changes are the result of the nanosize helices responding to the stimulus – in this case temperature. The crystals are at the nanoscale.

6. How would you use the observed changes to create a product or an application? Responses will vary.

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