Experiment 1
Liquid Crystals

For the Instructor

The goal of the experiment is to excite students about nontraditional materials while offering an inquiry-based lesson. Students begin by preparing a thermotropic liquid crystal. Small errors in measurements will impact the temperature at which the liquid crystal changes color. This is a good opportunity to discuss quality control and challenges in manufacturing liquid crystal materials.

Next, the students test a liquid crystal that was prepared by another group. (They should not know the temperature activity value for the sample they are testing.) The group is asked to devise a method for measuring the temperature(s) at which the liquid crystal is active. Require the students to submit a plan for approval. Some will initially want to put a thermometer in the liquid crystal or heat the sample with a heat gun. Most heat guns do not have numeric temperature settings. Students should realize that a water bath is a good option because they can measure the temperature and assume the material in the vial has reached the temperature of the water. This is a good opportunity to discuss limits of the experiment. Some of the liquid crystals are active at values below room temperature. Thorough students will realize they must use an ice bath or cool the water to evaluate the liquid crystal at low temperatures.

A good exercise is to have the students write their results on the board. Once all of the results have been submitted, the class evaluates the results. When the test results do not match the prepared liquid crystals, you can discuss possible problems with the testing method and problems with the preparation. This highlights challenges in manufacturing and the importance of good laboratory techniques.

- **Equipment & Glassware:**
  - Vials (opening should be large enough for spatula)
  - Spatula
  - Weigh boat or weigh paper
  - Analytical balance
  - Heat gun
  - Test tube tongs
  - 250 mL or larger beaker
  - Hot plate
  - Thermometer
  - Beaker tongs
  - Ice
  - Disposable glass pipets are best for transferring liquid crystals

- **Chemicals:**
  - Cholesteryl pelargonate
  - Cholesteryl oleyl carbonate
  - Cholesterol benzoate

Pre-Lab Questions

1. Most liquid crystals exhibit polymorphism. Explain *polymorphism*.

Polymorphism is the ability for a substance to crystallize in more than one crystal structure. It exists in more than one three-dimensional framework.

2. Liquid crystals are described as anisotropic. Define *anisotropy*.

Anisotropy is when a substance has properties that vary depending on the direction of the measurement. In liquid crystals, this is due to the alignment and the shape of the molecules.

3. Describe the continuum of liquid—liquid crystal—solid. Discuss the differences in terms of physical properties.

Liquids have less order than solids. Liquids flow and have definite volume but no definite shape. A solid has a definite shape and volume. Crystalline solids are highly ordered with a lattice-like framework. Liquid crystals appear to be fluid and exhibit crystalline properties.

4. Define order parameter, *S*, and relate this value to the structure of each substance: liquid, liquid crystal, and crystalline solid.

S describes the orientational order of the liquid crystalline material, allowing for the individual orientational deviation of the molecules from the director. For liquid crystals, S ranges from 0.3 to 0.9, depending on the temperature. A solid (perfect crystal) has an S value of 1.0, representing complete order. A free-flowing liquid has an S value of 0.

5. Most liquid crystal molecules are rod-shaped and are broadly categorized as either thermotropic or lyotropic. Explain the two categories.

The phase transitions of thermotropic liquid crystals depend on temperature, while those of lyotropic liquid crystals depend on both temperature and concentration. In a lyotropic liquid crystal, one end of the molecule is polar and attracted to water while the other end is nonpolar and attracted to hydrocarbons.

Lyotropic liquid crystals exhibit phase transitions as a function of concentration.
Thermotropic liquid crystals exhibit phase transitions that are dependent on temperature.

6. Cite two to three practical applications of a lyotropic liquid crystal.

soaps and detergents, biological membranes, time-release drugs