***Mood Rings**

Are you anxious or calm?
Find out by gauging your mood with a mood ring.

*Adapted from Product Brochure,
Davis Liquid Crystals Inc., San Leandro, CA.

LIQUID CRYSTALS AND MOOD PATCHES

A lesson plan for Middle School

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Overview

A liquid crystal (lc) compound is an organic material composed of carbon, hydrogen, oxygen, and sometimes nitrogen and a few other elements. At room temperature, this material might look like a powder composed of small crystals, similar in appearance to salt or sugar.

LC's constitute a unique form of matter. Figure 1 shows a picture of a lc chemical as viewed between crossed polarizers (i.e., a polariscope – described in our lesson plan on *Polarizers and Polarized Light*) in a microscope. As temperature increases, the solid powder melts into a liquid fluid that scatters light. This lc phase is the subject of our lesson. As temperature continues to increase, the liquid becomes isotropic (i.e., exhibiting the same properties when examined from all directions), and it looks and behaves like water. It is no longer in its liquid crystal phase. Reducing the temperature returns the fluid to the lc phase.

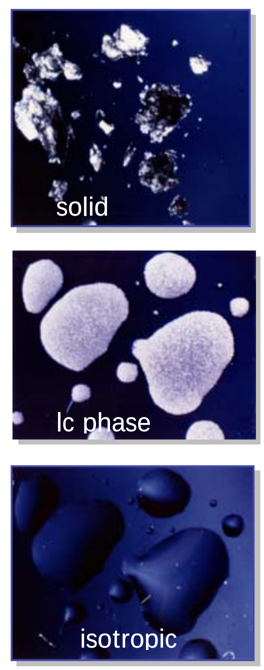


Fig. 1. Behavior of a liquid crystal as temperature increases (top to bottom).

There are many types of liquid crystals. ***Nematic*** liquid crystals are important for building electronic displays for laptops, palm pilots, cell phones, etc. They have low viscosity at room temperature and a very broad lc phase that may extend from -5°F to 200°F. This allows an lc display to work, even in the dashboard of a car parked in the desert or inside of a wrist watch on a climber at the peak of Mt. Everest. We do not discuss nematics and displays in this lesson.

The subject of this lesson is ***Cholesteric*** liquid crystals. They are very sensitive to the environment, and can be used to detect changes in temperature.

High school students participating in an NSF workshop at Kent State University in 1995 arranged themselves on the lawn to copy the shape and arrangement of liquid crystals. We can think of an lc molecule as a very small rod. Liquid crystal molecules and students are both long and narrow. The photographs of "student" lc molecules in Figure 2 show how liquid crystals arrange themselves in a layer with their neighbors: either somewhat randomly (left side), or with higher degrees of order (two examples are shown- middle and right sides). In the lc phase, cholesterics arrange themselves with their molecules aligned in a manner similar to (but not quite the same as) that shown in Figure 2.

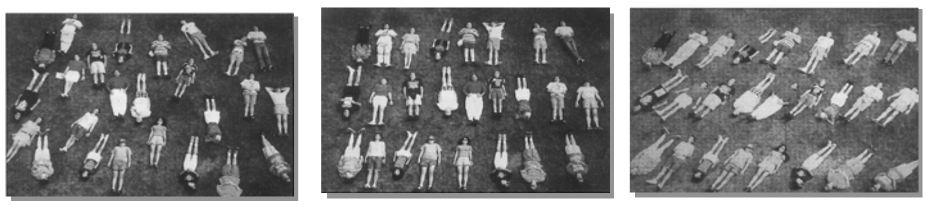


Fig. 2. Students arranged to copy a single layer of lc molecules. [Adapted from G. Crawford, in *Liquid Crystals Today*, vol. **5** (1995).]

A more accurate rendition of cholesteric order in a stack of lc layers is given on the left side of Figure 3. Red arrows whose tips are connected by a blue line show that the direction of orientation for the rod-like molecules (or students) traces out a helical or screw-like pattern. This is the defining characteristic of the cholesteric lc phase. White light passing into a film of this liquid crystal will interact with the screw-like structure in interesting ways.

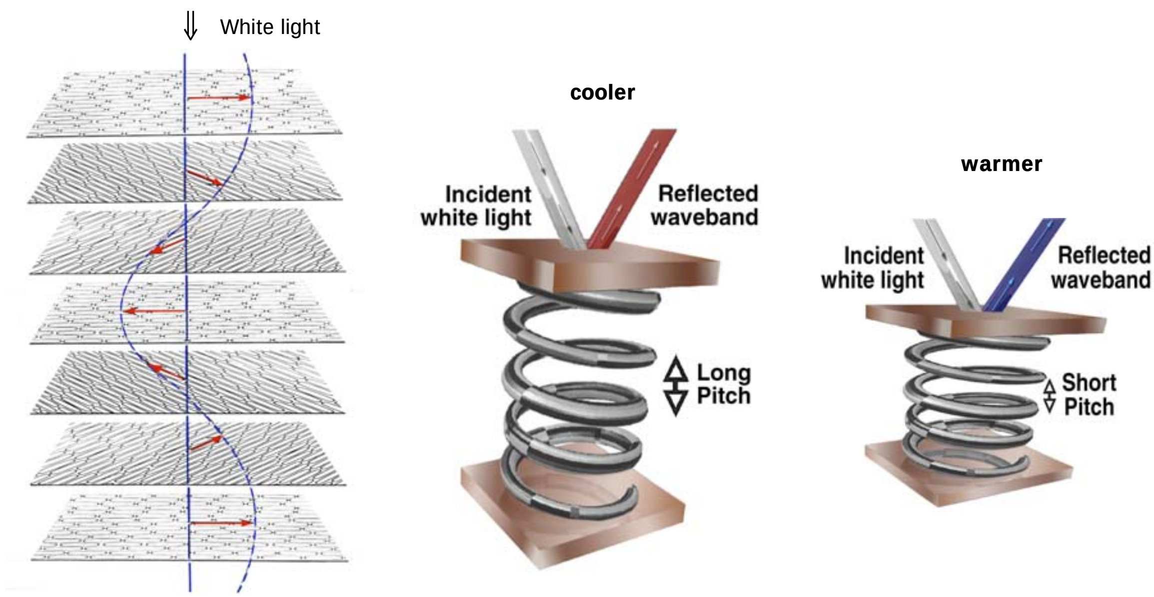


Fig. 3. Cholesteric liquid crystals have a twisted structure like that of a spring. Different colors of white light passing into the lc are reflected as the lc warms up.

The two drawings on the right in Figure 3 depict the cholesteric lc fluid as a spring between two clear plates. When the lc is cool, the spring is elongated (e.g., the pitch, or distance between turns, is large). As the lc warms, the spring tightens up and the pitch becomes smaller. The red color in white light is reflected from the cooler lc structure. As the lc warms, yellow, green, and then blue colors are reflected. This phenomenon is called "selective reflection". Some cholesteric lc chemicals are very sensitive to temperature. These form the basis for lc thermometers and mood rings.

The photographs in Figure 4 show a man's hand that was coated with black paint containing a temperature sensitive cholesteric liquid crystal. His fingers were initially warm and reflected in the blue, due to good blood circulation. His circulation was degraded by nicotine from smoking one cigarette, and his fingers cooled.

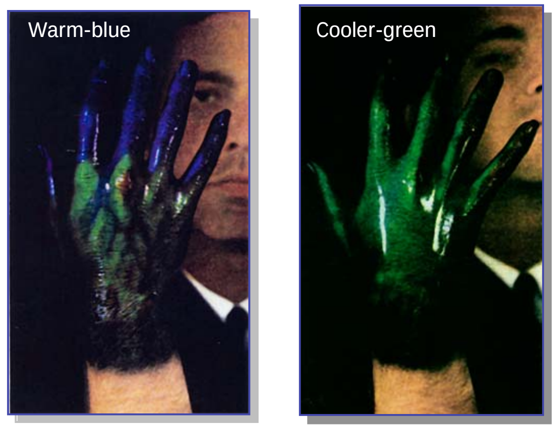


Fig. 4. Liquid crystal paint maps temperature of a hand

Mood Patch Experiment:
Manufacturing Procedure

<u>Materials teacher will need:</u>
*•Glass bottle with a 10g blend of cholesteryl oleyl carbonate **(COC)** and cholesteryl pelargonate **(CP)***
[MSDS sheets are appended to this lesson plan. Students should avoid getting the lc materials on themselves. Washing hands with soap (a form of lc itself) and water after the lesson is advised.]
•Wooden toothpick for stirring (and a tissue)

<u>Materials students will need (kit supplies 20-30 bags):</u>
•One 1 inch square of clear transparency "top"
•One 1.5 inch square of black transparency "bottom"
•Toothpick and a piece of tissue
•One 4 inch long piece of packaging tape [3M Scotch Super Strength, 2 inch width) affixed to outside of bag. [Rolls of this tape are available at the super market – you should buy a roll.]

1) Introduce the subject of cholesteric liquid crystals to the students as described above.

2) Show the bottle containing the blend of COC and CP. In their original forms, COC is a waxy, nearly clear chemical at room temperature, whereas CP is a white powder. The chemical structure of CP is shown in Fig. 5. We heated equal parts (by weight) of these chemicals to 100°C, melting them together to form the blend that is contained in the bottle. Each of these chemicals sells for ~$1/gram. ***Warming the bottle in your hand while speaking is a good idea!***

$CH_3(CH_2)_7COOC_{27}H_{45}$

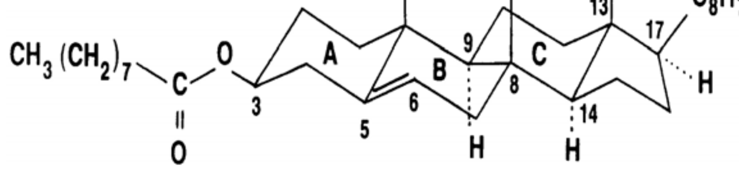


Fig. 5. Chemical structure of cholesteryl pelargonate

3) Pass out one bag to each student. **Students should be at desks or tables from which the wrapping tape can be removed (e. g., a nonporous/nonfibrous surface like Formica).**

4) Ask each student to place the black transparency “base”, shiny side up, on the desk.

5) Pass the bottle around and ask each student to scoop up a ***small*** gob of lc material with a toothpick. The amount required is shown in Figure 6. *Every effort should be taken to minimize the amount of lc fluid taken, so that there is enough to go around*. The gob should be deposited onto the **center** of the shiny side of the blackened “base” of transparency film. Wrap toothpick in tissue and discard.

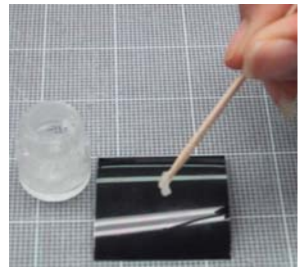
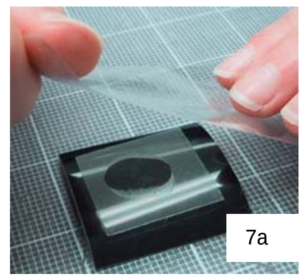


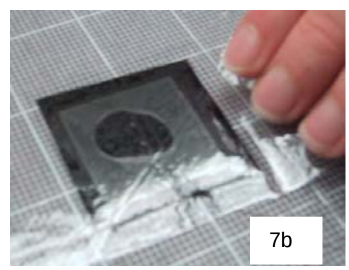
Fig. 6. Place a ***small*** gob of lc onto the center of the black base.

6) Each student should now take the smaller, clear, square transparency “cover” and place it over the gob.

7) Each student should now gently push on the “cover” with a finger. The heat from the finger warms the cholesteric lc and causes the fluid to spread, filling out the area under the “cover”. The goal here is a uniformly distributed lc layer without too many bubbles.



8) Each student should be working on a hard, lint-free surface. ***A formica-covered classroom table or desk is perfect***. Have each student remove the wrapping tape from the parchment paper and place it, sticky side down, over the center of the cover/base sandwich (see Figure 7a). Again, try to do this without introducing too many air bubbles. The student should apply pressure to smooth the tape down onto the sandwich, sealing it to the table (see Figure 7b). This is ok!



9) Students should now peel the “patch” off of the table *and fold the tape around the back of the “patch” to seal it on all sides*. It may now be placed on the inner wrist (see Figure 7c).

Fig. 7. Manufacture of a cholesteric lc temperature patch.

10) Optional: A well-sealed patch can be contacted to cups filled with hot or cold liquids, ice cubes, and many other surfaces. Note: moisture that penetrates into the lc layer will destroy its properties.

Mood Patch Experiment: Analysis

The temperature-induced color changes of cholesteric liquid crystals are directly related to their chemical structure. As seen in this experiment, several lc chemicals can be blended together to form mixtures that exhibit color changes over a large range of temperatures. In this experiment we chose a 50/50 wt.% mixture of COC and CP. Figure 8 shows this blend to be very good for exploring the range of surface temperatures of the human body, because it goes through the red-to-blue color shift between 89°F and 94°F.

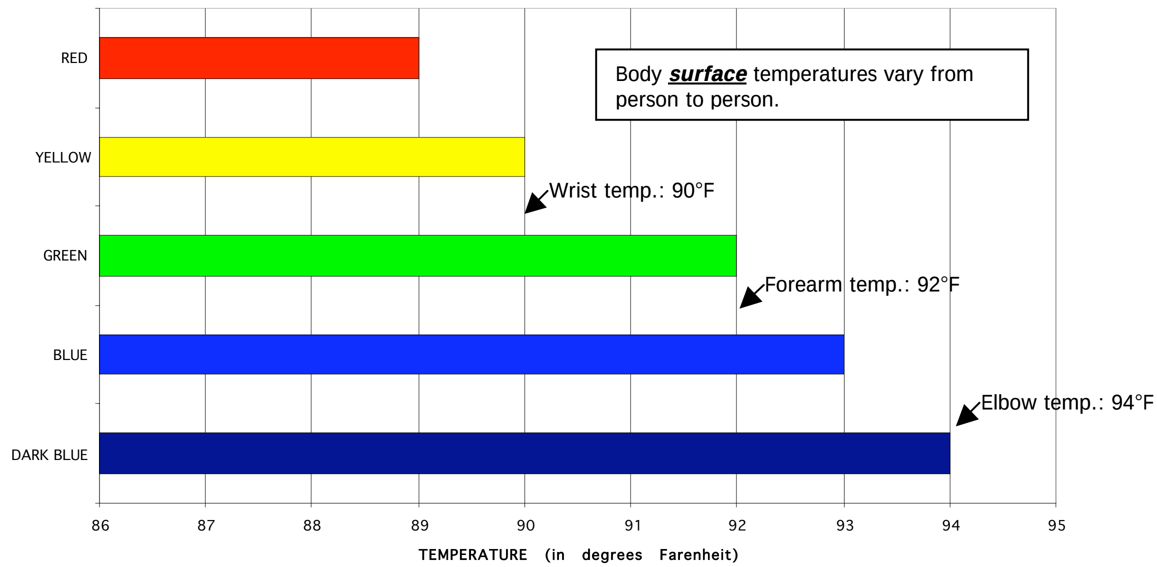


Fig. 8. Bar graph illustrating the color seen in the lc patch as a function of the temperature of the body surface.

Starting in the late 1960's, scientists used cholesteric liquid crystals to map the body for temperature variations related to poor circulation, tumors, or other abnormalities (Figure 9).

Fig. 9. Article by James Fergason, the "father of Liquid Crystals in the USA", written for Life Magazine in 1968.

This field of science is called thermography, and images are taken today with infrared cameras that can "see" the heat generated by the body.

Mood Patch Experiment: Applications

Proctor and Gamble sells a *disposable* oral thermometer, manufactured under their VICKS® trademark, which contains small, individual drops of cholesteric liquid crystal material sealed in clear plastic. **Each** drop of this cholesteric lc changes color from green to clear (isotropic phase) at a **different temperature**. [Note: clear appears black, because the base plastic under the lc drop is painted black.] The chemical composition is controlled **so precisely** that temperature changes as small as 1/10th of a degree F can be detected. Figure 10 shows two thermometers. The one on the bottom was just removed from Katie's (lesson plan co-author) mouth, indicating that her internal body temperature was 97.2°F. The instructions in the middle of Figure 10 state that a normal reading will be from 97-99°F for this product, depending upon the person being tested. A fever would be easily detected.

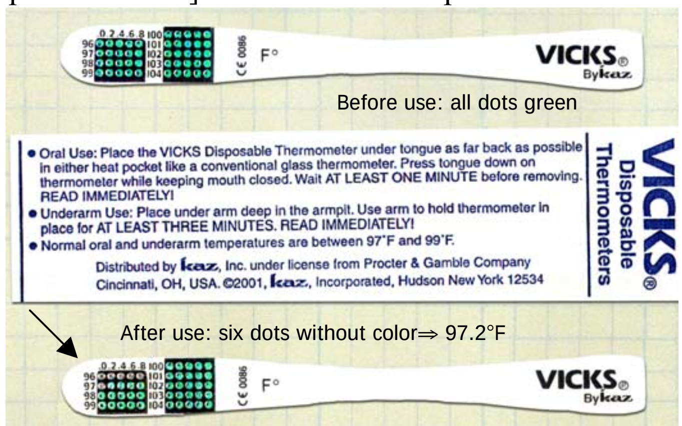
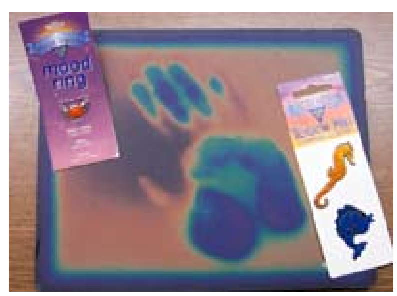


Fig. 10. Commercial disposable thermometer product based upon cholesteric liquid crystals and precise control of the temperature-induced phase change from lc to isotropic fluid.

Mood Patch Experiment: Encapsulated Sheets

Ask the students to take out the 5 inch by 5 inch sheet of ***encapsulated*** lc, and ask them how it works.

Ans: The temperature sensitive lc material is encapsulated (i.e., encased or confined) in tiny voids or holes in a plastic film. This film is supported by a sheet of black plastic. In this manner, the lc cannot leak out, it is protected against moisture, and it can bend. When this sheet is cool (at or below 72°F), it appears black, because the selective reflection occurs in the near infrared. At these "low" temperatures, the lc is transparent to visible light and one sees the black plastic. This lc chemical undergoes a color change from red to deep blue between 72°F and 75°F. It would not be a good material for measuring body temperature, because it changes color in a temperature range below that of the body. It is still fun to examine with an ice cube. Encapsulated lc's are found in all sorts of consumer products. How about an lc mouse pad?



References:

- For a series of scientific tutorials put together by Case Western Reserve University: http://plc.cwru.edu/tutorial/enhanced/main.htm.
- James L. Fergason, "Experiments with Cholesteric Liquid Crystals, in *American Journal of Physics*, **Vol. 38**, No. 4, 425-428, April 1970.
- P. J. Collings, Liquid Crystals: Nature's Delicate Phase of Matter, Princeton University Press, NJ, 1990.
- Linda Hamilton, "Liquid Crystals", in *American Heritage of Invention & Technology*, pp. 20-29, Spring, 2002.
- Michael R. Fisch, Liquid Crystals, Laptops and Life, World Scientific Series in Contemporary Chemical Physics – **Vol. 23**, Singapore, 2004.

Acknowledgement:

James Fergason, Menlo Park, CA arranged for the donation of the lc chemicals and microencapsulated lc sheets used in this lesson. Starting in 1963, Jim paved the way for innovations ranging from forehead thermometers and mood rings, to digital watches and computer monitors. Jim holds over 130 U. S. patents that form the foundation of the multibillion dollar Liquid Crystal Display (LCD) industry. He was inducted into the National Inventor's Hall of Fame in Akron, OH, on September 19th, 1998. Jim was honored on May 3, 2006 during a ceremony at the Museum of Contemporary Art Chicago with the $500,000 Lemelson-MIT Prize, the largest cash prize given in the United States for invention. According to Merton Flemings, director of the Lemelson-MIT Program, "(Jim) is also a staunch advocate for independent inventors and has dedicated countless hours to this cause." This annual award has been dubbed "the Oscar for inventors."

M A T E R I A L S A F E T Y D A T A S H E E T S

SECTION 1. - - - - - - - - - - CHEMICAL IDENTIFICATION- - - - - - - - - -
CATALOG #: C78801
NAME: **CHOLESTERYL PELARGONATE**, 97%
SECTION 2. - - - - - COMPOSITION/INFORMATION ON INGREDIENTS - - - - - -
CAS #: 1182-66-7
MF: C36H62O2
EC NO: 214-658-3
SECTION 3. - - - - - - - - - - - HAZARDS IDENTIFICATION - - - - - - - - - -
DATA NOT AVAILABLE
SECTION 4. - - - - - - - - - - - FIRST-AID MEASURES- - - - - - - - - - -
IN CASE OF CONTACT, IMMEDIATELY FLUSH EYES WITH COPIOUS AMOUNTS OF
WATER FOR AT LEAST 15 MINUTES.
IN CASE OF CONTACT, IMMEDIATELY WASH SKIN WITH SOAP AND COPIOUS

AMOUNTS OF WATER.
IF INHALED, REMOVE TO FRESH AIR. IF NOT BREATHING GIVE ARTIFICIAL RESPIRATION. IF BREATHING IS DIFFICULT, GIVE OXYGEN.
IF SWALLOWED, WASH OUT MOUTH WITH WATER PROVIDED PERSON IS CONSCIOUS.
CALL A PHYSICIAN.
WASH CONTAMINATED CLOTHING BEFORE REUSE.

SECTION 5. - - - - - - - - - - FIRE FIGHTING MEASURES - - - - - - - - - -

EXTINGUISHING MEDIA
WATER SPRAY.
CARBON DIOXIDE, DRY CHEMICAL POWDER OR APPROPRIATE FOAM.

SPECIAL FIREFIGHTING PROCEDURES
WEAR SELF-CONTAINED BREATHING APPARATUS AND PROTECTIVE CLOTHING TO
PREVENT CONTACT WITH SKIN AND EYES.

SECTION 6. - - - - - - - - - ACCIDENTAL RELEASE MEASURES- - - - - - - - -

CHEMICAL SAFETY GOGGLES.
USE PROTECTIVE CLOTHING, GLOVES AND MASK.
SWEEP UP, PLACE IN A BAG AND HOLD FOR WASTE DISPOSAL.
AVOID RAISING DUST.
VENTILATE AREA AND WASH SPILL SITE AFTER MATERIAL PICKUP IS COMPLETE.

SECTION 7. - - - - - - - - - - - HANDLING AND STORAGE- - - - - - - - - - -

REFER TO SECTION 8.

SECTION 8. - - - - - - EXPOSURE CONTROLS/PERSONAL PROTECTION- - - - - -

CHEMICAL SAFETY GOGGLES.
RUBBER GLOVES.
NIOSH/MSHA-APPROVED RESPIRATOR.
SAFETY SHOWER AND EYE BATH.
MECHANICAL EXHAUST REQUIRED.
AVOID CONTACT AND INHALATION.
DO NOT GET IN EYES, ON SKIN, ON CLOTHING.
WASH THOROUGHLY AFTER HANDLING.
KEEP TIGHTLY CLOSED.
STORE IN A COOL DRY PLACE.

SECTION 9. - - - - - - - PHYSICAL AND CHEMICAL PROPERTIES - - - - - - -

APPEARANCE AND ODOR
OFF-WHITE CRYSTALLINE CHUNKS

PHYSICAL PROPERTIES
MELTING POINT: 74 C TO 77 C

SECTION 10. - - - - - - - - - -STABILITY AND REACTIVITY - - - - - - - - -

INCOMPATIBILITIES
STRONG OXIDIZING AGENTS
STRONG ACIDS
STRONG BASES
STRONG REDUCING AGENTS

HAZARDOUS COMBUSTION OR DECOMPOSITION PRODUCTS
TOXIC FUMES OF:
CARBON MONOXIDE, CARBON DIOXIDE
SECTION 11. - - - - - - - - - TOXICOLOGICAL INFORMATION - - - - - - - -
ACUTE EFFECTS
MAY BE HARMFUL BY INHALATION, INGESTION, OR SKIN ABSORPTION.
MAY CAUSE IRRITATION.
TO THE BEST OF OUR KNOWLEDGE, THE CHEMICAL, PHYSICAL, AND
TOXICOLOGICAL PROPERTIES HAVE NOT BEEN THOROUGHLY INVESTIGATED.
SECTION 12. - - - - - - - - - ECOLOGICAL INFORMATION - - - - - - - - - -
DATA NOT YET AVAILABLE.
SECTION 13. - - - - - - - - - DISPOSAL CONSIDERATIONS - - - - - - - - - -
DISSOLVE OR MIX THE MATERIAL WITH A COMBUSTIBLE SOLVENT AND BURN IN A
CHEMICAL INCINERATOR EQUIPPED WITH AN AFTERBURNER AND SCRUBBER.
OBSERVE ALL FEDERAL, STATE AND LOCAL ENVIRONMENTAL REGULATIONS.
SECTION 14. - - - - - - - - - - TRANSPORT INFORMATION - - - - - - - - -
CONTACT ALDRICH CHEMICAL COMPANY FOR TRANSPORTATION INFORMATION.
SECTION 15. - - - - - - - - - REGULATORY INFORMATION - - - - - - - - - -
DATA NOT AVAILABLE
SECTION 16. - - - - - - - - - - OTHER INFORMATION- - - - - - - - - - - -
THE ABOVE INFORMATION IS BELIEVED TO BE CORRECT BUT DOES NOT PURPORT TO
BE ALL INCLUSIVE AND SHALL BE USED ONLY AS A GUIDE. SIGMA, ALDRICH,
FLUKA SHALL NOT BE HELD LIABLE FOR ANY DAMAGE RESULTING FROM HANDLING
OR FROM CONTACT WITH THE ABOVE PRODUCT. SEE REVERSE SIDE OF INVOICE OR
PACKING SLIP FOR ADDITIONAL TERMS AND CONDITIONS OF SALE.

SECTION 1. - - - - - - - - - CHEMICAL IDENTIFICATION- - - - - - - - - -
CATALOG #: 151157
NAME: **CHOLESTERYL OLEYL CARBONATE**
SECTION 2. - - - - - COMPOSITION/INFORMATION ON INGREDIENTS - - - - - -
CAS #: 17110-51-9
MF: $C_{46}H_{80}O_3$
EC NO: 241-179-7
SECTION 3. - - - - - - - - - - HAZARDS IDENTIFICATION - - - - - - - - -
DATA NOT AVAILABLE
SECTION 4. - - - - - - - - - - FIRST-AID MEASURES- - - - - - - - - - -

IN CASE OF CONTACT, IMMEDIATELY FLUSH EYES WITH COPIOUS AMOUNTS OF
WATER FOR AT LEAST 15 MINUTES.
IN CASE OF CONTACT, IMMEDIATELY WASH SKIN WITH SOAP AND COPIOUS AMOUNTS OF WATER.
IF INHALED, REMOVE TO FRESH AIR. IF NOT BREATHING GIVE ARTIFICIAL RESPIRATION. IF BREATHING IS DIFFICULT, GIVE OXYGEN.
IF SWALLOWED, WASH OUT MOUTH WITH WATER PROVIDED PERSON IS CONSCIOUS.
CALL A PHYSICIAN.
WASH CONTAMINATED CLOTHING BEFORE REUSE.

SECTION 5. - - - - - - - - - FIRE FIGHTING MEASURES - - - - - - - - - -

EXTINGUISHING MEDIA
WATER SPRAY.
CARBON DIOXIDE, DRY CHEMICAL POWDER OR APPROPRIATE FOAM.

SPECIAL FIREFIGHTING PROCEDURES
WEAR SELF-CONTAINED BREATHING APPARATUS AND PROTECTIVE CLOTHING TO
PREVENT CONTACT WITH SKIN AND EYES.

SECTION 6. - - - - - - - - ACCIDENTAL RELEASE MEASURES- - - - - - - - -

WEAR RESPIRATOR, CHEMICAL SAFETY GOGGLES, RUBBER BOOTS AND HEAVY
RUBBER GLOVES.
ABSORB ON SAND OR VERMICULITE AND PLACE IN CLOSED CONTAINERS FOR DISPOSAL.
VENTILATE AREA AND WASH SPILL SITE AFTER MATERIAL PICKUP IS COMPLETE.

SECTION 7. - - - - - - - - - - HANDLING AND STORAGE- - - - - - - - - -

REFER TO SECTION 8.

SECTION 8. - - - - - - EXPOSURE CONTROLS/PERSONAL PROTECTION- - - - -

CHEMICAL SAFETY GOGGLES.
COMPATIBLE CHEMICAL-RESISTANT GLOVES.
NIOSH/MSHA-APPROVED RESPIRATOR.
SAFETY SHOWER AND EYE BATH.
MECHANICAL EXHAUST REQUIRED.
AVOID INHALATION.
AVOID CONTACT WITH EYES, SKIN AND CLOTHING.
AVOID PROLONGED OR REPEATED EXPOSURE.
WASH THOROUGHLY AFTER HANDLING.
KEEP TIGHTLY CLOSED.
STORE IN A COOL DRY PLACE.

SECTION 9. - - - - - - - PHYSICAL AND CHEMICAL PROPERTIES - - - - - - -

APPEARANCE AND ODOR
MOIST WHITE SOLID

PHYSICAL PROPERTIES
FLASHPOINT >230

109C

SECTION 10. - - - - - - - - -STABILITY AND REACTIVITY - - - - - - - - -
INCOMPATIBILITIES
STRONG OXIDIZING AGENTS
HAZARDOUS COMBUSTION OR DECOMPOSITION PRODUCTS
TOXIC FUMES OF:
CARBON MONOXIDE, CARBON DIOXIDE

SECTION 11. - - - - - - - - - TOXICOLOGICAL INFORMATION - - - - - - - -
ACUTE EFFECTS
MAY BE HARMFUL BY INHALATION, INGESTION, OR SKIN ABSORPTION.
MAY CAUSE EYE IRRITATION.
MAY CAUSE SKIN IRRITATION.
TO THE BEST OF OUR KNOWLEDGE, THE CHEMICAL, PHYSICAL, AND TOXICOLOGICAL PROPERTIES HAVE NOT BEEN THOROUGHLY INVESTIGATED.

SECTION 12. - - - - - - - - - ECOLOGICAL INFORMATION - - - - - - - - - -
DATA NOT YET AVAILABLE.

SECTION 13. - - - - - - - - - DISPOSAL CONSIDERATIONS - - - - - - - - -
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SECTION 16. - - - - - - - - - - OTHER INFORMATION- - - - - - - - - - - -
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