Soft Matter exercise, Chapter 2: Liquid Crystals

1. Liquid crystals

What is the difference between a thermotropic and a lyotropic liquid crystal?

2. Structure

What does "short range order" mean? How does that compare to the structure of a crystal and how does it compare to that of a liquid?

3. Thermodynamics

The entropy decreases if a liquid transitions into a nematic phase. Why can the nematic phase of certain compounds, such as 5 CB, nevertheless be stable in a certain temperature range?

4. Quarter-wave plate

A thin slab of a nematic liquid crystal is filled between two parallel glass plates for use as a quarter-wave plate with a 488 nm laser. If the liquid crystal has a birefringence of $\Delta n = 0.22$, how thick does the liquid crystal display (just the part of the liquid crystal) have to be for it to act as a quarter-wave plate?

5. Birefringence

Which of the following liquid crystal samples are birefringent?

a. homeotropically aligned nematic phase
b. planar-aligned smectic A phase
c. cholesteric phase
d. isotropic phase of a discotic material

6. Nematic liquid crystals

a. Mention at least two options how you can increase the transition temperature of a nematic liquid crystal. Explain on a molecular level why the transition temperature increases.
b. How can you quantify the transition temperature? What is the principle behind this measuring technique?

7. Cholesteric liquid crystals

Why can cholesteric liquid crystals be used as temperature sensor? What are their limitations?

8. Twisted nematic liquid crystal

You are asked to design a twisted nematic display using a nematic liquid crystal whose elastic constants are $K_1 = 5.3 \times 10^{-12}$ N, $K_2 = 2.2 \times 10^{-12}$ N, and $K_3 = 7.45 \times 10^{-12}$ N and $\Delta\varepsilon = 0.7\varepsilon_0$. The distance between the plates is 10 μm.

a. What is the switching voltage?
b. What could you do to reduce the switching voltage?

9. Liquid crystal display

N-(4-Methoxybenzylidene)-4-butylaniline (MBBA) is a light responsive nematic liquid crystal with the structure shown in Figure 1. You measured the elastic constants for this material at 22 °C to be

$K_1 = 5.3 \times 10^{-12} N$

$K_2 = 2.2 \times 10^{-12} N$

$K_3 = 7.45 \times 10^{-12} N$

The dielectric permittivity in the direction of the ordinary ray is 4.7, that in the direction of the extraordinary ray is 5.4. You use this material to design a liquid crystal display that is bright if there is no electric field and becomes dark if there is an electric field. The mesogens are initially oriented parallel to the chamber surface. Calculate the electric field required to make the display bright if the chamber is

a. 100 nm thick
b. 1 μm thick
c. 100 μm thick
d. What could be a potential difficulty for displays whose chamber is 100 μm thick?

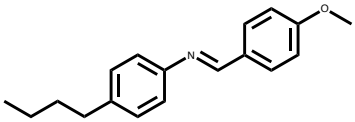

Figure 1: Structure of *N*-(4-Methoxybenzylidene)-4-butylaniline (MBBA).