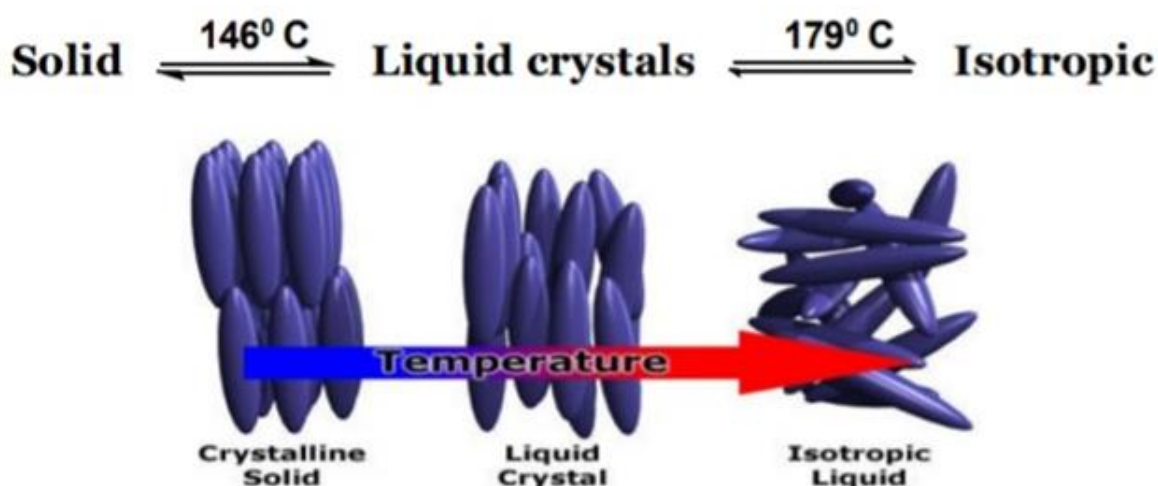


Liquid Crystals

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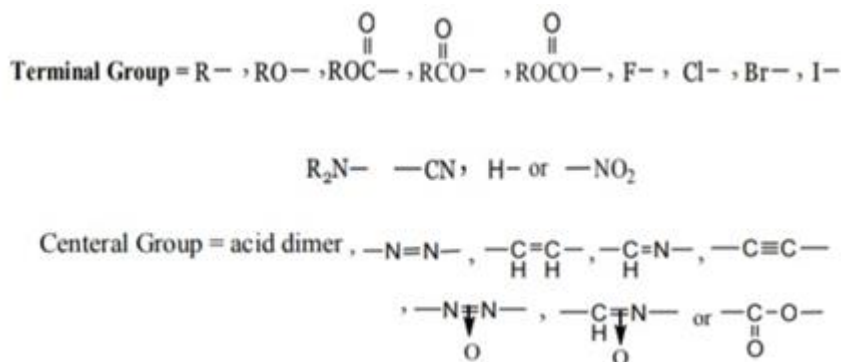
Introduction

Liquid crystals are an intermediate state (3-1) (Mesophase) described as a fourth state of matter. It was first called “flowing crystals” and “fluid crystals.” It appears between the solid phase, in which the movement of molecules is restricted in the triangular lattice. Dimensions and have an integrated molecular organization in location and direction, and the isotropic phase in which the molecules move freely and is considered to have a random organization, as in Figure (1-1). Liquid crystals are solid, linear, rod-like, or lamellar in shape. Although liquid crystals display certain properties that belong to the solid and liquid states, they possess special features that do not exist in both states (solid and liquid). The Austrian botanist Friedrich Reinitzer (4) in 1888 was the first to notice this state when he studied it. For cholesterol benzoate, it was found that this substance melts at a temperature of (146°C), but it does not melt completely until it reaches a temperature of (179°C), and in this intermediate state the substance is opaque.



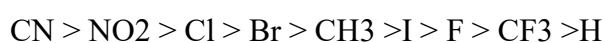
In 1889, the physicist Ottolehman called them liquid crystals (5). As for (Freidel) (6) in (1922) he was the first to study it microscopically and called it the mesophase (mesophase), and therefore the materials that show this property are called liquid crystals), as he was able to distinguish three types of structural compositions of the liquid crystalline phases, describing The structural composition of each class is defined by a term and according to the prevailing regularity in the geometric shape of the phase in question, which is the nematic, cholesteric and smectic structure. Scheme (1-1) shows the general structure of molecules that exhibit a crystalline state, which is called the mesogenic unit (7).





Terminal Group:

Its benefit is to maintain polarity within the molecule and stabilize its linearity. The difference in the groups or the length of the chains affects the properties of the molecule, especially the transition temperature between the different phases, and the presence of terminal groups (8) follows the following order:



The terminal groups have a significant impact on thermal stability and increase the probability of the appearance of liquid crystalline phases.

Aromatic Ring: It causes high polarization as a result of resonance and stabilization of hardness (9)(Rigidity).

Central Group: They represent intermediate bonds that work to stabilize two main properties that must be present, linearity and hardness. The presence of these groups enhances the rigidity of the molecule as a result of the presence of a high resonance state. It also works to expand the electronic sequence along the axis of the molecule, and the presence of these groups follows the following order in The possibility of the emergence of liquid crystalline phases and an increase in their thermal stability (10).



Liquid crystals have special characteristics that distinguish them from the liquid state and the solid state, as molecules that possess liquid crystalline properties are described as having a cylindrical shape, and the ratio of the length of the particle to its average diameter is equal to: ($L/d \geq 4.0-6.4$).

So: L = length of the particle, d = average diameter of the particle

There are some general structural characteristics in most organic molecules that make it possible for them to have a liquid crystalline character. For example, linear liquid crystals are characterized by the following:

1. Linearity
2. Polarizability
3. Rigidity

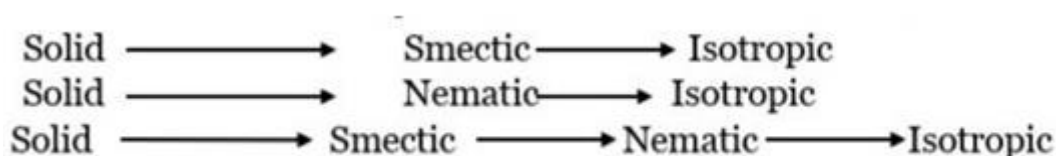
How liquid crystalline phases form

Studies (12, 13) have shown that a large number of organic compounds show more than one step when passing from the solid state to the liquid state, and that this step is located in the range located between the state of high three-dimensional order (the crystalline state) and the disordered state (the liquid state). Through X-ray studies of the compounds that show these intermediate phases, it was found that there is a discrepancy in the geometric shape, and this is explained by the unequal intermolecular forces in all directions due to the elongation of the molecules and their parallel arrangement. From what was stated above, we can realize that the liquid crystalline phases are

formed by moving the order of arrangement of molecular bonds to a less regular level than in the crystalline state, and this occurs in two cases:

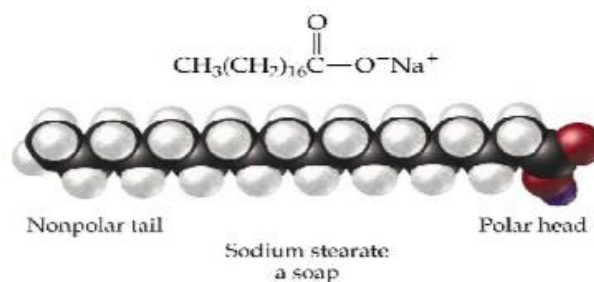
1. The first case: adding specific volumes of suitable polar solvents to specific amounts of organic compounds. These solvents work to rearrange the order of bonds between molecules to a less regular state and give liquid crystalline phases based on the change in concentration and the attraction that occurs between the solute and the solvent. The crystals resulting from these are called the case with lyotropic liquid crystals.
2. The second case: It involves the rearrangement of the intermolecular forces of the crystalline state due to the gradual increase in temperature. Accordingly, the quality of the intermediate phase formed depends on the amount of thermal energy necessary to change the parallel arrangement of the molecules within the crystalline network, as the destruction of one of the three dimensions of the crystalline network leads to the formation of The smectic phase is a two-dimensional system. When heating continues, either one of the remaining two dimensions is destroyed, giving a one-dimensional system (Nematic Phase), or all the intermolecular forces of the remaining two dimensions are destroyed simultaneously, leading to the formation of the liquid phase (Isotropic Phase).

It is also possible to convert the solid crystalline lattice directly into the nematic phase. Liquid crystals resulting from a change in temperature are called thermotropic liquid crystals, as in diagram (1-2):



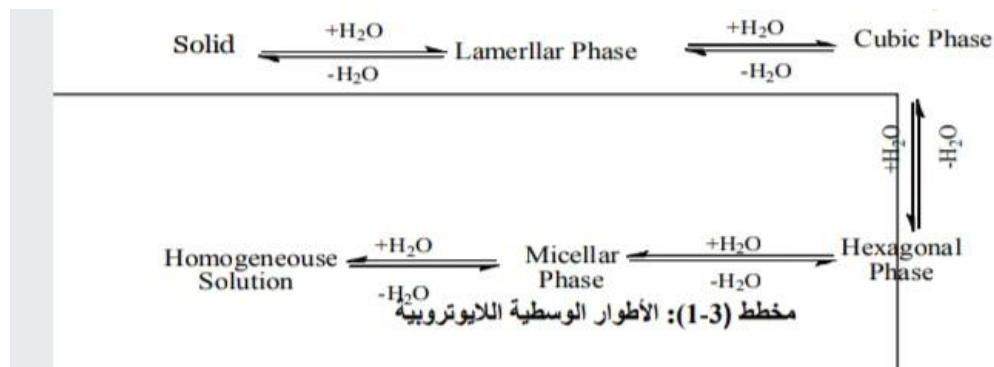
The liquid crystalline state is classified into:

1- Lyotropic liquid crystals



This class of liquid crystals arises when specific volumes of a polar solvent such as water and alcohol are added to measured amounts of amphiphilic organic compounds at room temperature or higher temperatures. As is known, the molecular structural structure of an amphiphilic compound consists of an ionic head that is attracted to the polar solvent (Hydrophilic) and a paraffinic (non-polar) tail that is repulsed by the Polar (Hydrophobic) solvent. An example of these compounds is the salts of fatty acids in water. Aqueous solutions of soap are lyotropic systems. Multicomponent, the paraffinic tails of the fatty acid salt molecules dissolved in each other are arranged to have as little contact as possible with water molecules, thus forming a bilayer.

It is possible to obtain a series of non-entropic intermediate phases whose appearance is limited to the range between the solid state and the liquid state by increasing the concentration of the solvent. Then, the reversal of the system of formation of these intermediate phases occurs by gradually extracting the solvent, that is, the concentration of the organic compounds in the solvent and the nature of the attraction between them. It is the factor influencing the transition from one phase to another. Diagram (1-3) illustrates this case



➤ Thermotropic liquid crystals

This type of liquid crystal depends on the temperature and the amount of change that occurs in it, so it is called the temperature-induced mesophase. Many scientists have contributed to the diagnosis of a large number of compounds with thermotropic systems, including the scientist Sakman in 1966 and the scientist Demus. In 1973, he found that a large number of these compounds pass through several intermediate phases when the temperature increases from the solid state to the azeotropic (liquid) state, and such compounds were called multiphase.

A - Calamictic liquid crystals

This type of mesogen (20) has an elongated shape that is responsible for the appearance of the anisotropic characteristics (i.e. variation in physical characteristics) that are important in the molecular shape of thermotropic mesogens. In order for phased thermal fusion of the mesogen to occur, the underlying molecular forces must differ in physical characteristics. In an appropriate amount, this is the result

Rod thermotropic liquid crystals can be classified based on their molecular organization into:

- Smectic Phase).
- Nematic Phase.
- Cholesrtric Phase.

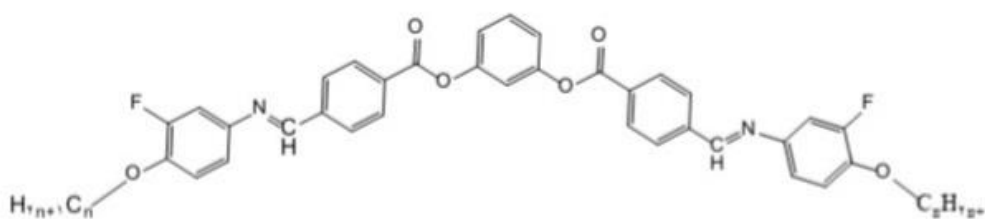
Figure (1-3) shows the arrangement of the longitudinal axes of the molecules in these phases.

B- Discotic liquid crystals

This type of mesogens was discovered in 1977 AD. Disc liquid crystal molecules are characterized by the fact that their diagonal axis is larger than the longitudinal axis. Figure (1-7) represents the general drawing of disc liquid crystals, when $d \gg t$, where (d) represents the diagonal axis of the molecule. (t) thickness molecule

C- Bent-core Liquid Crystals (Banana)

Banana mesogens are symbolized by the symbol b-LC. This type of liquid crystals has been prepared since 1930 by the scientist Vorlander (42), but the scientist Matsunaga, (43) and his group in 1994 AD



Applications of liquid crystals

Liquid crystals (82) are currently considered a basic and important material in many industrial and medical applications, thanks to the presence of some important physical properties in liquid crystals, including electro-optic, electro-chromic, magneto-optic, and thermoelectric properties. (Thermo-Chromic), which can be used in wide areas, including:

Industrial Applications

Liquid crystals are used in display devices due to their important advantages, including their small size, high adaptability to rapid display changes, low power consumption, and variation in physical properties (83).

The nematic phase is used, which is more sensitive to the electric field, and this property is used to benefit in advanced display systems because the nematic phase is one-dimensional, so it can respond directly to the electrical stimulus (84).

Research has shown that chiral smectic liquid crystals have a high photoelectric response, which is one of the popular technologies that has a future in display media applications (85).

One of the important industrial applications of liquid crystals is their use in smart windows, as they work in smart windows to control the amount of light passing through them by changing the response of the liquid crystals to electrical charges, as the electrical charge works to arrange the liquid crystals in a way that allows light to pass through and when the electrical charge disappears The borates return to their random position and prevent the passage of light (86).

Medical Applications

Most thermotropic liquid crystals show a consistent or harmonious color change with temperature, and this thermotropic characteristic can be used to determine the area with high temperature under the skin due to various diseases, most notably cancerous diseases (87).

Most cholesteric liquid crystals are commonly used in medical thermometers due to their ability to be slightly sensitive to temperature, as the sensitivity of some cholesteric liquid crystalline materials reaches ($C^{\circ}0.3$), that is, their color changes with a slight change in temperature (88).

There are vital applications for non-chirotopic liquid crystals widely in nature. It is known that non-chirotopic crystal phases are formed by the action of certain volumes of polar solvents on the binding forces of certain organic compounds. Therefore, the structure of this type of liquid crystal phases is closer to the surroundings of life systems, which include: DNA. (DNA), certain viruses, anti-asthma medications, brain tissue and blood vessels

References

1. O.Dlaverentovich, G.Pcarawford, "Liquid Crystal". Colby-Sawyer College New London, Ch. 1, P(1-2) (2005) J.P.Schroeder, J.Org.Chem., Vol. 33, P(591-597) (1968).
2. J.Thisaykf and H.Takezoe, J.Jpn.Appl.Phys., Vol. 40, P(3277) (2001).
3. F.Reinitzer, Monatch. Chem. ,Vol. 9, p(421) (1888).
4. O.Lehman, Z. Phys. Chem. (Leipzig). ,Vol. 4, p(462) (1889). G.Freidel, Ann. Physik., Vol.19, p(273) (1922).
5. G.H.Brown, J.J.Wolken, "Liquid Crystals and Biological Structures", Academic press, London, Ch.1 (1979). Mahsen Abood, M.Sc.Thesis, Babylon University, Iraq, (1997).
6. A.Klozkowiki and G.R.Luckurst, Liq. Cryst., Vol. 3, P(185) (1988). S.Haddawi, S.Diele, H.Kresse and Wessflog, "The Molecular Phay. Of Liquid Crystal" New York, Ch.1 (1979).
7. E.B.Priestly, "Introduction of Liquid Crystals", Pienum Press, NewYork, Ch.1 (1976)
8. G.L.Hand, J.Fluid Mech. ,Vol. 33, p(46) (1962). S.T.Gfriberg, Mol.Cryst.Liq.Cryst., Vol. 40, p(49) (1977).

9. S.Asnforth-Frost and U.W.Rudel, International J. of Fluid Dynamics, Article 1(2003).
10. G.W.Brown and P.P.Crooker, Chemical and Engineering News, Vol 24 (1983).
11. G.H.Brown, J.J.Wolken, "Liquid Crystals and Biological Structures", Academic press, London, Ch.3 (1979).
12. K.Fodor-Csorba, E. Szabo, A. Vajda, Liq. Cryst. Vol. 24, p(861) (1998).
13. Y.Seogchung and J.Samkang, Mol.Cryst.Liq.Cryst., Vol. 82, p(261-266) (1982).
14. G.W.Gray, "Influence of Composition and Structure on The Liquid Crystal Formed by Non-Amphiphilic Systems", "Liquid Crystals and Plastic Crystals" Ellis Horwood, New York, Ch.4 P(82) (1974).
15. D.Coates and G.W.Gray, Microscope, Vol 24, p(117) (1976). E.Sackmann, S.Meiboom and L.C.Cynder, J.Amer. Chem. Soc., Vol. 89, p(5981) (1987).
16. G.R.Lukurst and A.Sanson, Mol.Cryst.Liq.Cryst., Vol. 48, p(179) (1978).
17. E.M.Parrall, J.W.Goodby and G.W.Gray, Mol., Cryst Liq. Cryst., Vol. 49, p(319) (1979).
18. C.Druon and J.M.Wacrenier, Mol. Cryst.Liq.Cryst., Vol. 98 P(201-208) (1983).
19. G.Moro, P.Nordio and U.Sere, Mol. Cryst.Liq.Cryst., Vol. 114, P(113-118) (1984).
20. A.M.Levelut, J.Phys.(Paris), Vol. 37, P(51) (1976).
21. T.Carlsson and I.Dahl, Mol. Cryst.Liq.Cryst., Vol. 95, P(373-400) (1983).
22. H.Sackmaan, Mol. Cryst.Liq.Cryst., Vol. 5, P(43) (1984).
23. W.Elser and R.D.Ennulat, " Selective Reflection of Cholestric Liquid Crystals", Ch. 2, p(53-54) (1976).
24. J.L.Ferguson, J.Amer. Chem. Soc., Vol. 77, P(211) (1969).
25. K.Chanderasekhar, B.K.Sadashira and K.A.Suresh, Pragma, Vol.32, P(471-780) (1977).
26. M.Baron, Pur.Appl.Chem., Vol.95, P(845-895) (2001).
27. K.J.Donavan, T.K.reouzis, N.Boden and J.Clements, J.Chem.Physics, Vol.109, P(10400) (1998).
28. J.Billad, J.C.Dubols, C.Vaucher, and A.M.Levelut, Mol.Cryst.Liq.Cryst., Vol. 66, P(115-122) (1981).
29. Denis Andrienko, "Introduction to liquid crystals", Ch.1, P(6) (2006).
30. C.Golther, D.Prssner, K.Mullen and H.W.Spiess, Angew.Chem., Vol.32, P(1660-1662) (1993).
31. J.M.Lohar and U.Urvashi, Mol.Cryst.Liq.Cryst., Vol. 70, P(29-38) (1981).
32. M.T.Allen, S.Diele, K.D.Harris, and B.M.Kariuki, J.Mater.Chem., Vol.11, P(302-311) (2001).
33. R.Popuko, Z.Luz, N.Spielberg and H.Zimmermann, J.Am.Chem.Soc., P(6094-6105) (1989).
34. Niori, T.Sekine, T.Watanabe, J. Furukawa and T.Takezoe, J. Mater. Chem. Vol.6, P(1231) (1996).
35. G. Pelzl, I. Wirth and W. Weissflog, Liq. Cryst., Vol. 28, P(969) (2001).
36. S.Matsunaga and Y.Miyamoto, Mol. Cryst. Liq. Cryst., Vol. 237, P(311) (1994).
37. J.Thisayukta, J.Nakayama, Y.Kawauchi, S.Takezoe and H.Watanabe, J. Am. Chem. Soc., Vol. 122, P(7441) (2000).
38. Antal Jákli, "Bent-core liquid crystals", Kent State University, Ch.1, P(8) (2007).

39. J.A.Olivares, S.Stojadinovic, T.Dingemans and S.Sprunt, Phys.Rev., Vol.68, p(41707) (2004).39- J.T.Gleeson, N.Eber, K.Fodor-Csorba, and A.Jakli, Phys.Rev., Vol.72, p(41712) (2005).
40. J.L.Marcos, P.J.Alsono, J.L.Marcos and P.J.Alsono, Advanced Materials, Vol. 7, P(173-176) (1995).
41. G.W.Gray, "Influence of Composition and Structure on the Liquid Crystal", Ch.4, p.(1-2) (1974).
42. G.W.Gray, G.R.Luckhurst " Liquid Crystals and Molecular Structure" , The Molecular Physics of Liquid Crystal, Academic Press , London, Ch.1 (1979).
43. W.Elser and R.D.Ennulat, "Advances in Liquid Crystals", Academic Press, NewYork, Ch.2 P(6) (1976).
44. G.W.Gray, "Molecular Structure and the Properties of Liquid Crystals" ,Academic press, England, Ch.1 P(42) (1962)
45. G.W.Gray and P.A.Winsor, "Liquid Crystals and Plastic Crystals" Ellis Horwood , New york, Ch.4 P(110) (1974)45- V.Kalyvas and J.E.Mcintyre, Mol.Cryst.Liq.Crst., Vol.80, P(105) (1981).
46. Y.A.Yousif and K.S.Abas, Dirasat, Vol. 20, P(45) (1993).
47. Y.A.Yousif and W.A.Al-Masoudi, Liq. Cryst., Vol. 12, P(363) (1992).
48. A.H.Al-Dujaili, N.Y.Jerjies and T.A.Al-Salim, Mu'tah J. for Research and Studies, Vol. 10, P(47) (1995).
49. J.Barbera, E.Castel, R.Gimenez,M.Marcos and J.L.Serrano, Mol.Cryst.Liq.Crst. ,Vol. 363, P(89) (2001).
50. F.H.Hussien, E.S.Al-Lami and R.E.Al-Hamadany, National of J. Chem., Vol. 7, P(397) (2002).
51. S.S.Kwon, T.S.Kim and C.K. lee, Bull. Korean Chem. Soc. , Vol.24, P(274) (2003).
52. S.Y.Zhang, K.K.He and S.J.Zhang, Chinese J. of Chem. , Vol. 22, P(395) (2004).
53. Y.Z.Yousif and A.J.Hamdani, Liq. Cryst. ,Vol. 15, P(451) (1993).
54. D.Byron, D.Keating, M.Oeill, RWillimson, J.Goodby and G.Gray, Mol.Cryst.Liq.Crst. ,Vol. 179, P(58) (1998).
55. Iassm A.M. and Abu Bakar M., Molecules .p(3261-3269), 10 (2010).
56. M.J.Gautherie, Phys. Radium, Vol. 30, P(122) (1969).
57. M.Yoshiyama, Mol.Cryst.Liq.Crst. , Vol. 68, P(247) (1981).
58. S.Chandrasekhar, Liq. Crys. , Vol. 3, P (42) (1977).
59. S.Eren San, O.Koysal, S.Ozder and F.Ecevit, Turk J. Phys., Vol. 27 P(279) (2003).
60. D.Dunmur, A.Fukuda and G.Luckhurst, "Phys. Prop. Of Liq. Cryst." Institution of Electrical Engineers, London, Ch.5 P (277) (2001).
61. H.Gleeson, "Introduction to Liquid Crystal", University of Manchester U.K. Ch.2 P(12) (1998).
62. J.M.Brake, M.K.Daschner and Yan-Young Luk, "Biomolecular Interaction at Phospholipid-Decorated Surface of Liquid Crystals", Materials Science and Engineering, Ch.5 (2003).
63. E.S.Selawry, Mol.Cryst.Liq.Crst. ,Vol. 1, P(175) (1966).