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Juergen L. W. Pohlmann [a]

[a] U.S. Army Electronics Command, Night Vision Laboratory, Fort Belvoir, Virginia

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The Mesomorphic Behavior of Stigmasteryl Carbonates

JUERGEN L. W. POHLMANN
U.S. Army Electronics Command, Night Vision Laboratory,
Fort Belvoir, Virginia

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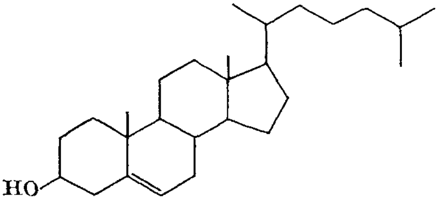
Abstract—Starting from stigmasterol, phosgene and normal alcohols or alkandiols, two homologous series of stigmasteryl derivatives were synthesized, namely, the n-alkyl stigmasteryl carbonates and the α,ω-polymethylen bis(stigmasteryl) carbonates. Some of the chloroformates required as intermediates were prepared and isolated.

Purification of all stigmasteryl carbonates was achieved by column chromatography using silica gel as adsorbent and benzene ligroine mixtures as the developing solvent system. The same combination was employed in thin layer chromatography to monitor the purity of reaction products and to identify side products. Physical and analytical data are compiled in two tables.

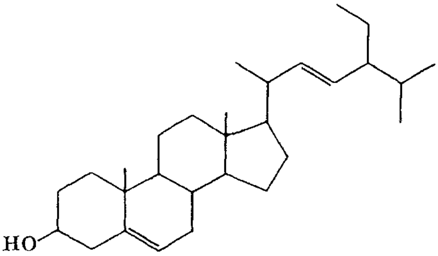
Physical investigations revealed that none of the compounds showed a cholesteric phase, but some of them displayed smectic phases on cooling of their isotropic liquids. A heavily contaminated sample, however, showed iridescent colors, which subsequently could be obtained from pure stigmasteryl carbonates by the addition of stigmasteryl derivatives which by themselves do not show mesophases.

In contrast to the widespread interest in cholesteryl derivatives, little work has been done on stigmasteryl compounds. A few years ago A. Kuksis[1] reported a homologous series of stigmasteryl esters, but no systematic investigation of stigmasteryl carbonates is known.

We chose stigmasterol for our investigations because of its similarity with cholesterol. Both have the identical sterane skeleton and all their structural differences are contained in the side chain; they consist of a C—C double bond in 22 and an additional ethyl group in 24 position. Thus we anticipated merely quantitative differences for corresponding pairs of derivatives.



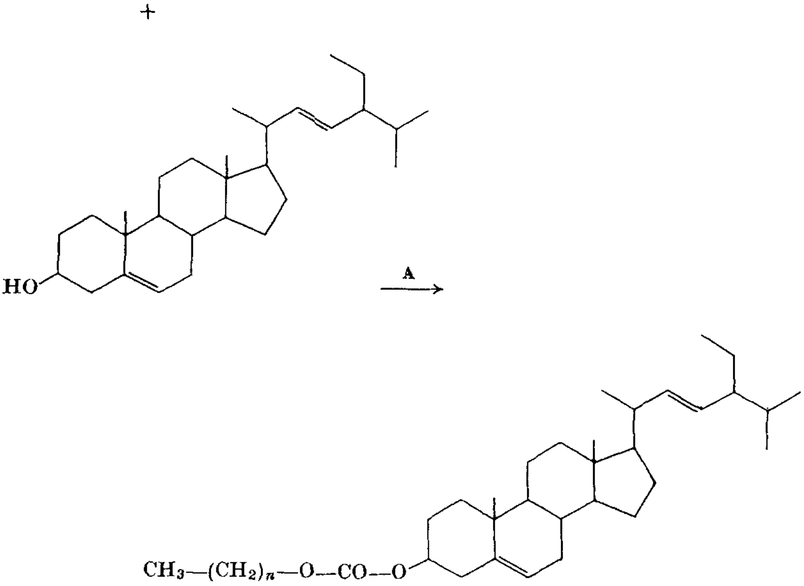
Cholesterol



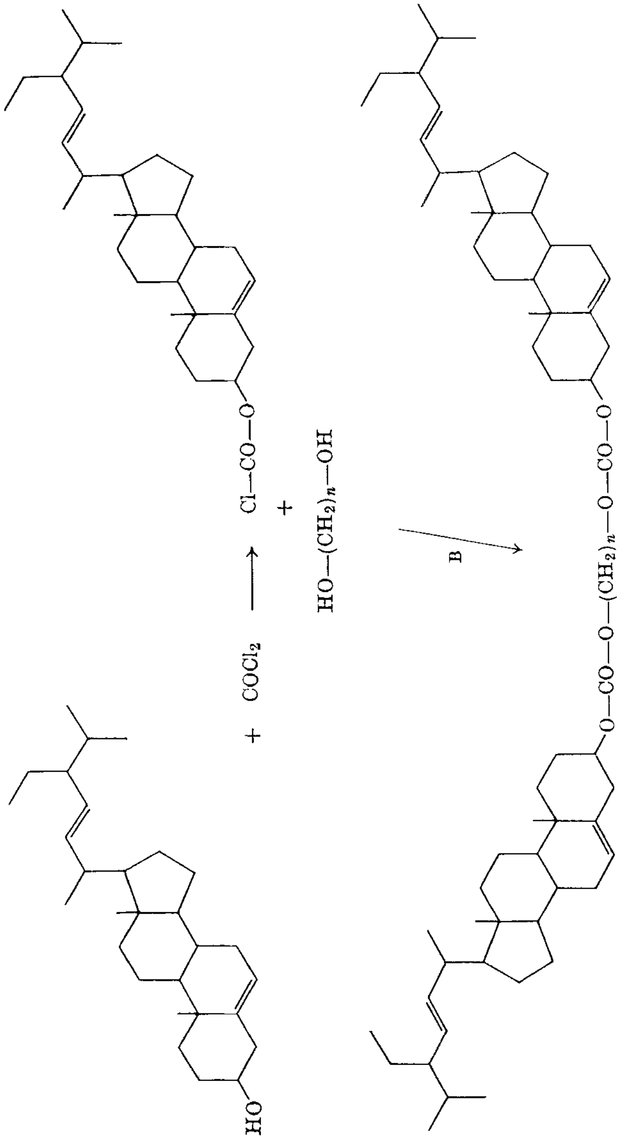
Stigmasterol

Starting from alcohols, stigmasterol and phosgene, unsymmetrical carbonates can be obtained in two ways; chloroformates serve as intermediates:

$$CH_3—(CH_2)_n—O—CO—Cl \longleftarrow COCl_2 + CH_3—(CH_2)_n—OH$$



Route A was successfully utilized for the preparation of all n-alkyl stigmasteryl carbonates. Of the required n-alkyl chloroformates the lower members are commercially available and all the others were prepared in our laboratory. The reaction was carried out in dry benzene using equimolar amounts of starting material and a



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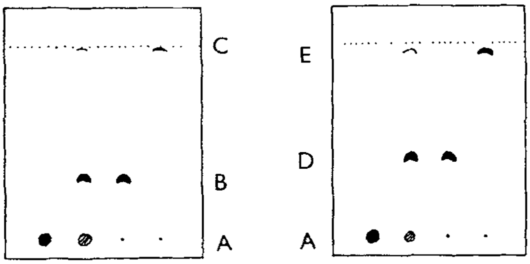
slight excess of pyridine to bind the generated hydrogen chloride.

Route B leads to the same unsymmetrical carbonate but it offers a real advantage where rare or sensitive alcohols are employed since the chloroformate of stigmasterol[2] is prepared in the first step. The reaction then is carried out under the same conditions; a slight excess of pyridine takes care of the hydrogen chloride and the eventual decomposition products of the chloroformate. All of our α,ω-polymethylen bis(stigmasteryl) carbonates were synthesized via the second path of reaction, using n-alkandiols and stigmasteryl chloroformate. In a side reaction some distigmasteryl carbonate is formed, but modification of the reaction conditions reduced its share from initial 10% to 1% or less.



benzene : ligroine = 15 : 85 benzene : ligroine = 1 : 1

A: stigmasterol
B: n-nonyl stigmasteryl carbonate
C: stigmastatriene
D: 1,7-heptamethylen bis(stigmasteryl) carbonate
E: distigmasteryl carbonate

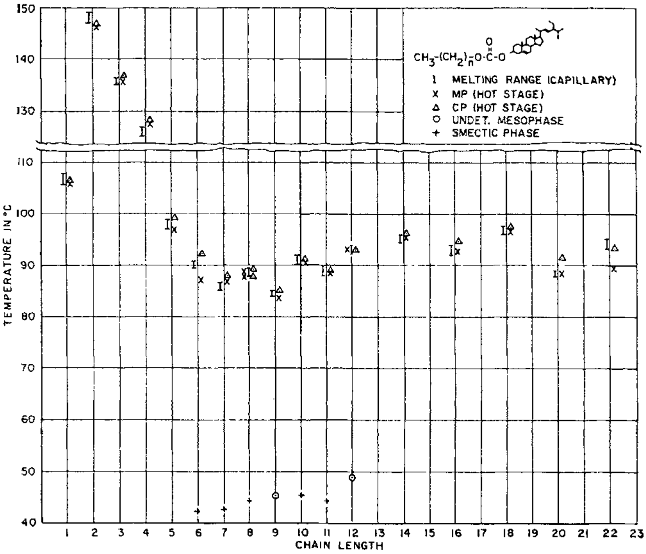
Figure 1. Thin layer chromatograms.

The crude carbonates were purified. As it was reported for n-alkyl cholesteryl carbonates[3] recrystallizations are not sufficient and the only feasible way is purification by column chromatography. The proper conditions were established by thin layer chromatography and the fractions were monitored by the same technique. Silica gel was used as adsorbent and benzene ligroine mixtures as the developing solvent system. The ratio 15 : 85 worked well for the separation of n-alkyl stigmasteryl carbonates, as shown for n-nonyl stigmasteryl carbonate (Fig. 1). The heavier 1,7-heptamethylen bis(stigmasteryl) carbonate and its homologous derivatives required a solvent ratio 1:1 to give a sufficient separation. Most of the side products could be identified by the same means.

Physical Investigations

Contrary to n-alkyl cholesteryl carbonates none of the stigmasteryl carbonates reported here showed iridescent colors, neither on heating or cooling in a capillary, nor on temperature cycling on a cover slide. Investigations with a polarizing microscope gave the same result. The melting and clearing temperatures of n-alkyl stigmasteryl carbonates follow the same pattern as those of the cholesteryl derivatives: the lower members show the highest melting range which finally levels off for the higher homologues. There is fairly good agreement between the measurements made with a capillary and determinations carried out on a hot stage.

Figure 2: Transition Temperatures of n-Alkyl Stigmasteryl Carbonates



In the molten state n-alkyl stigmasteryl carbonates display some turbidity, which slowly disappears with increasing temperature, but still is noticeable at 250 to 265° where the carbonates start to decompose. It was found that tiny air bubbles imbedded into the viscous melt cause the turbid appearance. They move out when vacuum is applied. Moreover the molten carbonates retract from glass surfaces, which complicates the work with cover slides.

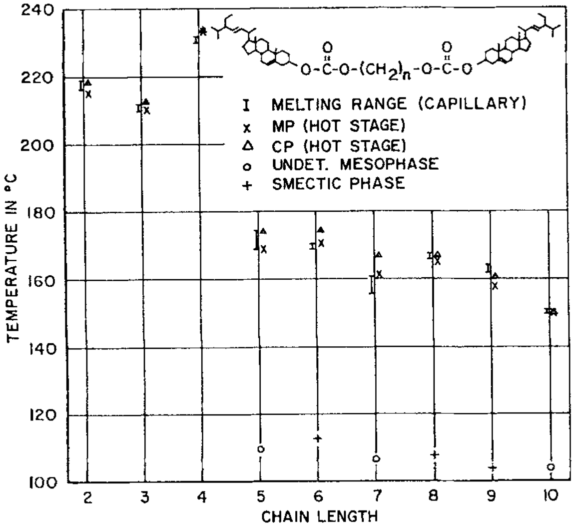
Whereas the n-alkyl cholesteryl carbonates show mesophases above the melting point, the n-alkyl stigmasteryl carbonates feature other solid phases instead. n-Octyl stigmasteryl carbonate, for example, has two different crystal forms which melt in succession, whereby the higher melting crystals float in the clear melt of the lower melting form. The presence of impurities can be ruled out, since the starting material and the carbonate were chromatographically pure compounds.

Some n-alkyl stigmasteryl carbonates became turbid on cooling in a capillary or showed a strongly birefringent pattern under a polarizing microscope. These transitions are reversible and occur in the range of 40 to 45°. Due to the fact that these transitions take place far below the melting point the mesophase is swallowed by the constantly progressing front of solid crystals. In some instances the mesophases were observed long enough and were tentatively classified as smectic phases on account of their focal conic texture.

α,ω-Polymethylen bis(stigmasteryl) carbonates show the same pattern of transition temperatures. They did not display mesophases above their melting point, but other solid phases were observed. On fast cooling monotropic mesophases were detected far below the melting point; according to their focal conic texture they were tentatively classified as smectic phases. The lower members of this series usually crystallized so fast that in most cases all material solidified before the temperature range of the mesophase was reached.

The complexity of the phase sequence of these compounds was studied with 1,7-heptamethylen bis(stigmasteryl) carbonate. Upon heating the pure, crystallized material in a capillary, melting occurred between 142 and 144°. On repeated runs with the same sample the carbonate melted in the temperature range from 156 to 161°. On very slow heating fresh material melted at 142° yielding a clear melt at 144°, but at 145° crystallization began and was completed at about 150°; above 156° the carbonate melted again.

Figure 3: Transition Temperatures of α,ω-Polymethylen Stigmasteryl Carbonates



Cooling the isotropic melt the probe suddenly became turbid at 115° and solidified below 80°. When the sample was reheated before crystallization started, the turbidity disppeared at the same temperature. This cycle could be repeated until the carbonate crystallized.

Investigations carried out on the hot stage of a polarizing microscope confirmed the observations, but revealed a change of the birefringent texture reversible with temperature between 109 and 110° thus indicating a phase transition. The latter was confirmed by differential thermal analysis. Two small, distinct transition heats were found; they were completely reversible in the temperature range of the phase transition and the clearing point. This experience again points out the shortcomings of identifying mesomorphic compounds by their melting points, since they depend on the history of the samples. The reversible transition temperatures of mesophases might be best suited for characterizing this class of compounds.[4]

While pure 1,7-heptamethylen bis(stigmasteryl) carbonate did not display any iridescent colors on temperature cycling, a head fraction which contained 10% or more distigmasteryl carbonate showed brilliant colors. Investigations revealed the whole spectrum to be reversible between 107 and 80°. Pure 1,7-heptamethylen bis(stigmasteryl) carbonate gave the same effect by adding about 10% stigmasteryl chloride, stigmasteryl acetate or stigmastatriene, all of which show no mesomorphic behavior by themselves.

Using distigmasteryl carbonate as an additive it was possible to obtain iridescent colors with most of our stigmasteryl carbonates, even with those which showed no mesophase when pure (for example, ethyl stigmasteryl carbonate). The question arises whether this finding parallels the behavior of certain nematic compounds for which Friedel[5] obtained a cholesteric phase on addition of an optical enantiomer.

Summary and Conclusion

In sharp contrast to n-alkyl cholesteryl carbonates the corresponding stigmasteryl derivatives and α,ω-polymethylen bis(stigmasteryl) carbonates did not show mesophases above their melting point, but some of them displayed monotropic mesophases. According to their focal conic texture they were tentatively classified as monotropic smectic.

Comparing these results with the findings for cholesteryl derivatives it must be concluded that most likely the differences in the side chain of the sterols are responsible for the different mesomorphic behavior.

Unfortunately it is not yet known, how parameters such as molecular shape, polarity, polarizability, packing density and other factors cause the different alignment of molecules for a certain mesophase. Since Stuart-Briegleb models demonstrate the slightly higher space requirement for the side chain of stigmasterol compared to that of cholesterol, this very likely is one parameter responsible for a different mesomorphic behavior of corresponding pairs of derivatives. Another factor of apparent influence is the dipole moment introduced by the C—C double bond in 22 position of stigmasterol. At this point, however, it is evident that more laboratory work is needed before firm conclusions can be drawn.

Another interesting result of our investigations is the existence of cholesteric mesophases for constituents, which in themselves are not mesomorphic. It seems to imply a tendency of stigmasteryl carbonates to form cholesteric mesophases.

Acknowledgment

I would like to thank Mr. R. Sherman for the microscopical investigations and Mr. T. Tidd for general assistance, also to express my appreciation to Drs. R. Ennulat and J. Muller for fruitful discussions and guidance in the physical part of this work.

Experimental

All operations were carried out in standard glassware. The reactions were run in an atmosphere of purified nitrogen which was free of oxygen. For both reaction routes used one typical example of each is given.

Route A: *n-hexyl stigmasteryl carbonate*

In 80 ml of dry benzene 4.13 g (10 mmoles) of stigmasterol and 1.65 g (10 mmoles) of n-hexyl chloroformate were dissolved. At room temperature 1 ml (12.5 mmoles) of pyridine was added in 20 ml of benzene. A white precipitation appeared immediately and resulted in a thick slurry when all pyridine was added. Stirring was maintained for 1 hr at room temperature and for an additional 4 hr under reflux.

Pyridinium chloride was filtered off and the benzene solution was concentrated. Ligroine was added and purification was achieved by column chromatography, using silica gel as adsorbent and a 15:85 mixture of benzene and ligroine as the developing system.

The head fraction which contained some stigmastatriene was disposed of. The main fractions were combined and concentrated.

TABLE 1 n-Alkyl Stigmasteryl Carbonates

N	Name	Yield (%)	M.p. °C	Formula	Mol. wt.	% C		% H		% O	
						Calcd	Found	Calcd	Found	Calcd	Found
1	methyl-	88	106–108	$C_{31}H_{50}O_3$	470.71	79.09	78.97	10.71	10.65	10.20	10.14
2	ethyl-	89	147.5–149.5	$C_{32}H_{52}O_3$	484.74	79.28	79.20	10.81	10.79	9.91	10.02
3	propyl-	80	135–136.5	$C_{33}H_{54}O_3$	498.80	79.46	79.56	10.91	10.81	9.62	9.87
4	butyl-	51	125–127	$C_{34}H_{56}O_3$	512.83	79.63	79.53	11.00	10.81	9.36	9.20
5	pentyl-	81	97–99	$C_{35}H_{58}O_3$	526.85	79.79	79.56	11.10	11.21	9.11	9.23
6	hexyl-	77	89.5–91	$C_{36}H_{60}O_3$	540.88	79.94	80.07	11.18	11.16	8.87	8.68
7	heptyl-	81	85–86.5	$C_{37}H_{62}O_3$	554.90	80.09	79.80	11.26	11.31	8.65	8.45
8	octyl-	79	88–89.5	$C_{38}H_{64}O_3$	568.93	80.22	79.93	11.34	11.44	8.44	8.44
9	nonyl-	71	84–85	$C_{39}H_{66}O_3$	582.96	80.35	80.59	11.41	11.55	8.23	8.44
10	decyl-	67	90–92	$C_{40}H_{68}O_3$	596.99	80.48	80.51	11.48	11.67	8.04	8.28
11	undecyl-	78	88–90	$C_{41}H_{70}O_3$	611.02	80.60	80.41	11.55	11.34	7.86	7.98
12	dodecyl-	73	92.5–94	$C_{42}H_{72}O_3$	625.04	80.71	80.84	11.61	11.78	7.68	7.73
14	tetradecyl-	80	94.5–96	$C_{44}H_{76}O_3$	653.10	80.92	81.05	11.73	11.78	7.35	7.50
16	hexadecyl-	80	92–94	$C_{46}H_{80}O_3$	681.15	81.11	81.11	11.84	12.01	7.05	6.83
18	octadecyl-	78	96–98	$C_{48}H_{84}O_3$	709.21	81.29	81.49	11.94	12.11	6.77	6.72
20	eicosyl-	54	88–90	$C_{50}H_{88}O_3$	737.26	81.46	81.23	12.03	12.12	6.51	6.47
22	docosyl-	85	93–95	$C_{52}H_{92}O_3$	765.31	81.61	81.72	12.12	12.05	6.27	6.38

TABLE 2 α,ω-Polymethylen Bis(stigmasteryl) Carbonates

N	Name	Yield (%)	M.p. °C	Formula	Mol. wt.	% C		% H		% O	
						Calcd	Found	Calcd	Found	Calcd	Found
2	bi-	52	217–219	$C_{62}H_{98}O_6$	939.47	79.27	79.48	10.51	10.46	10.22	10.24
3	tri-	61	210–212	$C_{63}H_{100}O_6$	953.50	79.36	79.54	10.57	10.80	10.07	9.97
4	tetra-	70	230–232	$C_{64}H_{102}O_6$	967.52	79.45	79.54	10.63	10.72	9.92	9.90
5	penta-	76	169–175	$C_{65}H_{104}O_6$	981.55	79.54	79.54	10.68	10.77	9.78	9.98
6	hexa-	80	169–171	$C_{66}H_{106}O_6$	995.58	79.63	79.71	10.73	10.94	9.64	9.85
7	hepta-	79	156–161	$C_{67}H_{108}O_6$	1009.61	79.71	79.56	10.78	10.74	9.51	9.57
8	octa-	82	166–167.5	$C_{68}H_{110}O_6$	1023.64	79.79	79.88	10.83	10.88	9.38	9.53
9	nona-	78	162–164	$C_{69}H_{112}O_6$	1037.66	79.87	79.71	10.88	10.77	9.25	9.34
10	deca-	75	149.5–151	$C_{70}H_{114}O_6$	1051.69	79.95	80.14	10.93	10.96	9.13	9.03

n-Hexyl stigmasteryl carbonate was secured as a white solid. It was twice recrystallized from acetone: yield 4.15 g (77%). Analytical and physical data are listed in Table 1 together with those for homologous compounds.

ROUTE B: 1,7-*heptamethylen bis(stigmasteryl) carbonate*

In 60 ml of dry benzene 0.66 g (5 mmoles) of 1,7-heptandiol was dissolved. It was combined with a solution of 4.75 g (10 mmoles) of stigmasteryl chloroformate in 40 ml of benzene. While stirring, 1 ml (12.5 mmoles) of pyridine in 20 ml of benzene was slowly added, resulting in a white slurry. Stirring was continued overnight at room temperature, whereby the precipitate changed into a few hard crystals. To complete the reaction it was refluxed for 2 hr. Pyridinium chloride was filtered off and the solvent was evaporated. The crude carbonate was extracted with acetone. The solid was dissolved in some benzene, ligroine was added and purification was attempted by column chromatography. Silica gel was employed as adsorbent and a 1:1 mixture of benzene and ligroine as the developing solvent. The head fraction contained distigmasteryl carbonate. The main fractions were combined and concentrated; the purified 1,7-heptamethylene bis(stigmasteryl) carbonate was crystallized twice from butanone; yield 4.0 g (79%). Analytical and physical data of all homologous carbonates of this series are compiled in Table 2.

REFERENCES

1. Kuksis, A. and Beveridge, J. M. R., *J. Org. Chem.* **25**, 1209 (1960).
2. Campbell, J. A., Shepherd, D. A., Johnson, B. A., and Ott, A. C., *J. Amer. Chem. Soc.* **79**, 1127 (1957).
3. Elser, W., *Molecular Crystals* **2**, 1 (1966).
4. Gray, G. W., *Molecular Structure and the Properties of Liquid Crystals*, Academic Press, London and New York, (1962), p. 146.
5. Friedel, G. and Friedel, E., *Z. Kristallogr.* **79**, 44 (1931).