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Optically Active Biselenienyls

Synthesis, Resolution and Configuration of Some 4,4′-Substituted 2,2′,5,5′-Tetramethyl-3,3′-biselenienyls

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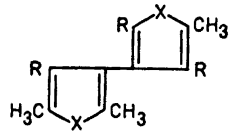
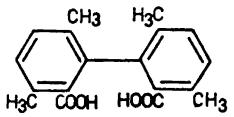
4,4′-Dicarboxy-2,2′,5,5′-tetramethyl-3,3′-biselenienyl (Ib) was synthesized from 3-carbomethoxy-2,5-dimethyl-4-iodoselenophene (V) by means of Ullmann coupling. The acid (Ib) was resolved into its antipodes through fractional crystallizations of the quinine and brucine salts. The configuration of optically active Ib relative to its thiophene analogue 4,4′-dicarboxy-2,2′,5,5′-tetramethyl-3,3′-bithienyl (Ia) was determined by reducing both to the corresponding 4,4′-dihydroxymethyl derivatives (Id and Ie), which could be related to each other by the quasi-racemate method and by circular dichroism studies.

Ib could first be racemized at higher temperatures (140 – 150°C) than Ia. Compared at 120°C, Ia is racemized about 90 times faster than Ib.

During recent years extensive work on optically active 3,3′-bithienyls has been carried out in this laboratory. The main interest has been focused on the influence of configuration and conformation on the CD and ORD curves of these compounds.[1–4] However, some attempts have also been made to study the influence of the substituents *ortho* to the pivot bond on the rate of racemization.[3,5] It was thus found that 4,4′-dicarboxy-2,2′,5,5′-tetramethyl-3,3′-bithienyl (Ia) could be racemized at about 100°C ($k = 0.0258$ min^{-1} at 100.0°C), while for the corresponding benzene analogue 3,3′,6,6′-tetramethyldiphenic acid (II), no racemization was noted after 4 h at 150°C.[3] Considerations of molecular models indicated that the main reason for the much more facile racemization of Ia than of II might be due to the much greater mutual interference between the substituents in a coplanar transition state in the benzene analogue.[3] It was therefore considered of interest to study the analogous selenophene derivative 4,4′-dicarboxy-2,2′,5,5′-tetramethyl-3,3′-biselenienyl (Ib), as the ring geometries are somewhat different. It was also hoped that a study of the ORD and CD curves would facilitate the understand-



I



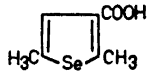
II

a X = S, R = COOH
b X = Se, R = COOH
c X = Se, R = CO_2CH_3
d X = S, R = CH_2OH
e X = Se, R = CH_2OH

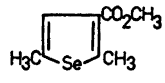
ing of the ORD and CD curves of optically active 4,4′-dicarboxy-3,3′-bithienyls, which show interesting variations with solvents.[2,3,6] Only one optically active 3,3′-biselenienyl, namely 4,4′-dicarboxy-2,2′-dinitro-3,3′-biselenienyl, the analogue of the classical 6,6′-dinitrodiphenic acid, has been synthesized by dell'Erba and co-workers [7] in the same way as the thiophene analogue [8] and resolved into antipodes, which were sterically related to the thiophene analogue.

SYNTHESIS

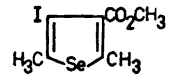
Compound Ib could not be prepared in a manner analogous to the synthesis of the thiophene analogue I, as the coupling of 2,5-dimethyl-3-selenienyllithium with cupric chloride to 2,2′,5,5′-tetramethyl-3,3′-biselenienyl failed. This was shown to be due to the facile ring-opening of the lithium derivative, obtained through halogen-metal exchange between 2,5-dimethyl-3-iodoselenophene and alkyllithium even at −70°C.[9] By carrying out the halogen-metal exchange with ethyllithium at −110°C, it was possible to trap the 2,5-dimethyl-3-selenienyllithium with carbon dioxide, obtaining 2,5-dimethyl-3-selenophenecarboxylic acid (III) in 51 % yield.[10] This acid could be obtained more conveniently in 52 % yield *via* the Grignard reagent from the iodo compound. Thus the Ullman coupling was employed instead for the synthesis of the 3,3′-biselenienyl skeleton. Higher yield of V was achieved by first esterifying III to the methyl ester IV, followed by iodination, than by carrying out the two steps in the opposite order. The iodine-iodic acid method, which has been



III



IV



V

successfully used for the iodination of various thiophene derivatives,[11,12] can also be applied to selenophene derivatives. However, sulphuric acid which is normally used as a catalyst must be used in smaller amounts in order to avoid polymerization and the temperature has to be kept at about 40°C. This method is more convenient than that described earlier.[9]

Using copper bronze (Merck's electrolytic) activated according to Kleiderer and Adams [13] in the Ullmann coupling of V, the dimethyl ester Ic was obtained in 79 % yield. The hydrolysis of Ic with 30 % aqueous potassium hydroxide was slow, but 80 – 90 % yields of Ib were obtained. Like its thiophene analogue Ia, the diacid Ib was difficultly soluble in most solvents and had a very high melting point. It could be recrystallized with great losses from acetic acid. The crude acid was therefore used directly in the resolution.

RESOLUTION AND RELATIVE CONFIGURATION

Inactive Ib was easily resolved into its antipodes using the same alkaloids as for the resolution of Ia. A few recrystallizations of the quinine salts from 50 % aqueous ethanol yielded the pure dextrorotatory form ($[\alpha]_D^{25} = +24°$ (dioxane)) while the levorotatory form was obtained by crystallization of the brucine salt from absolute alcohol.

As in the case of compound Ia, the sign of rotation of optically active Ib changes on going from dioxane to aqueous sodium hydroxide as solvent. The CD curves of Ia and Ib were so different that conclusions concerning the relative configurations of Ia and Ib could not be drawn with certainty. These curves will be discussed in a following paper.

The Fredga quasi-racemate method [14] has successfully been applied to the steric correlation of atropisomeric compounds.[2,15] Due to the high melting points of the acids Ia and Ib, thermal analysis was not attempted with the acids themselves, due to the obvious risk of decarboxylation and racemization. Neither was it convenient to carry out the analyses with the dimethyl esters of Ia and Ib, since these have low melting points. The thermal analyses were therefore carried out on the dihydroxymethyl derivatives Id and Ie.

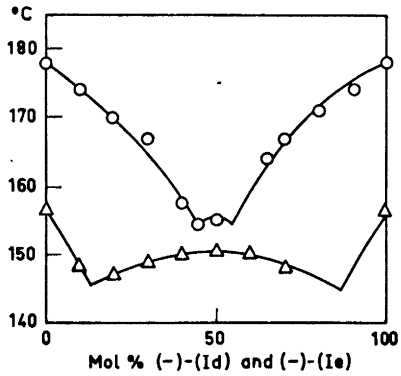


Fig. 1. (+)- and (−)-4,4′-Dihydroxymethyl-2,2′,5,5′-tetramethyl-3,3′-bithienyl (Id) (triangles). (+)- and (−)-4,4′-Dihydroxymethyl-2,2′,5,5′-tetramethyl-3,3′-biselenienyl (Ie) (circles).

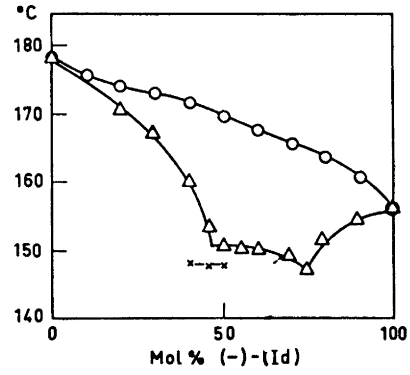


Fig. 2. (−)-4,4′-Dihydroxymethyl-2,2′,5,5′-tetramethyl-3,3′-biselenienyl (Ie) and (−)-4,4′-dihydroxymethyl-2,2′,5,5′-tetramethyl-3,3′-bithienyl (Id) (circles). (+)-4,4′-Dihydroxymethyl-2,2′,5,5′-tetramethyl-3,3′-biselenienyl (Ie) and (−)-4,4′-dihydroxymethyl-2,2′,5,5′-tetra-methyl-3,3′-bithienyl (Id) (triangles).

which were conveniently obtained by reduction of the dimethyl esters. The dihydroxymethyl derivatives obtained showed rotation opposite to that of the acids at the sodium line in dioxane.

The disymmetric nature of Id and Ie is also evident in the NMR spectra, which reveal magnetically nonequivalent CH_2-groups. The assignments of the methyl group resonances in the NMR spectra of the compounds described in this paper are tentative, and are based on comparison with bithienyls.[16]

Both Id and Ie give true racemates, as is obvious from Fig. 1. However, the racemate-forming tendency of Ie in particular is very low. The melting point diagram from Id and Ie with the same mode of rotation show that these components form a solid solution, while the melting point diagram derived from Id and Ie with opposite rotation shows the formation of a weak quasi-racemate, which is partly overlapped by one ascending branch in the melting point diagram (Fig. 2). The phase analyses were also confirmed by X-ray powder photographs. It is thus obvious that Id and Ie with the same mode of rotation (in dioxane) have the same configuration. Additional evidence is obtained from the CD curves of Id and Ie. The curves for the antipode with the same mode of rotation have very similar forms (Fig. 3). A bathochromic shift of the UV bands is observed on going from the thiophene to the selenophene derivative.

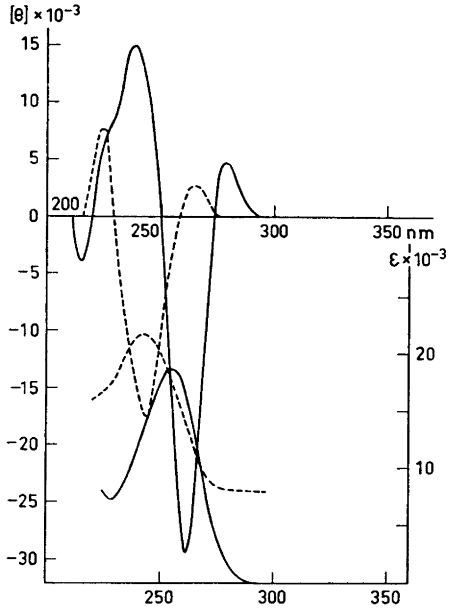


Fig. 3. Circular dichroism curve and UV spectrum of (+)-4,4′-dihydroxymethyl-2,2′,5,5′-tetramethyl-3,3′-bithienyl (Id) (---) and of (+)-4,4′-dihydroxymethyl-2,2′,5,5′-tetramethyl-3,3′-biselenienyl (———) in dioxane solution.

The absolute configurations of Id and Ie and of the corresponding acids Ia and Ib have been recently determined, by relating optically active Ia chemically to hexamethyl-3,3′-bithienyl,[17] the absolute configuration of which is known.[17]

RACEMIZATION

Attempts to racemize optically active Ib in dioxane solution by heating to 90°C for 18 h or in 0.1 N sodium hydroxide solution at 90°C for 1 h did not lead to any change in optical activity. However, at 140 – 150°C in 0.1 N sodium hydroxide racemization of Ib occurred smoothly. The first order plot of the racemization is shown in Fig. 4. The least squares method was used to obtain

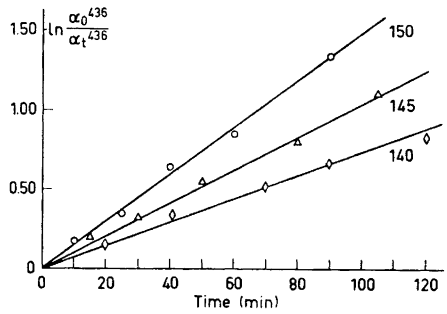


Fig. 4. Rate of racemization of the optically active disodium salt of 4,4′-dicarboxy-2,2′,5,5′-tetramethyl-3,3′-biselenienyl in water at different temperatures (°C).

the best fit of the experimental measurements. The activation functions were determined by plotting ln (k/T) against $1/T$ according to Eyring's equation in the following form:

$$\ln \frac{k}{T} = -\frac{\Delta H^{\ddagger}}{R} \times \frac{1}{T} + \frac{\Delta S^{\ddagger}}{R} + \ln \frac{\varkappa \times K}{h}$$

where T = temp. in K, K = Boltzmann's constant = 1.381×10^{-16} erg deg^{-1} molecule^{-1}, $\varkappa$ = the transmission coefficient = 1, k = Planck's constant = 1.104×10^{-28} erg min and $R = 1.987$ cal deg^{-1} mol^{-1}.

Table 1. Transition state functions for racemization of the optically active disodium salts of 4,4′-dicarboxy-2,2′,5,5′-tetramethyl-3,3′-bithienyl Ia [3] and 4,4′-dicarboxy-2,2′,5,5′-tetramethyl-3,3′-biselenienyl Ib.

Compound	Temp. °C	$k \times 10^2$ (min^{-1})	$\Delta H^{\ddagger}$ (kcal/mol)	$\Delta S^{\ddagger}$ (e.u.)	$\Delta G^{\ddagger}$ (kcal/mol)
Ia	90	1.12 ± 0.02			
	95	1.73 ± 0.10			
	100	2.58 ± 0.15			
	120	12.5[a]	22.1	−15	27.7
Ib	120	0.141[a]	25	−17	32
	140	0.70 ± 0.02			
	145	1.02 ± 0.02			
	150	1.47 ± 0.05			

[a] Found by extrapolation.

Then k is given in min^{-1}, $\Delta H^{\ddagger}$ in cal/mol, and $\Delta S^{0\ddagger}$ in cal/deg. The functions are given in Table 1. For comparison the data obtained earlier for Ia are also given in the table. Extrapolation to 120°C indicates that the sodium salt of Ia racemizes about 90 times faster than that of Ib. The largest difference between Ia and Ib is in the enthalphy of activation. In order to estimate the differences in racemization rates the distance between the carboxylate carbon and the methyl carbon in a rigid coplanar transition state was calculated for Ia, Ib, and II. The dimensions of Ib were taken from a recent

Table 2. Data from racemization of the optically active disodium salt of 4,4′-dicarboxy-2,2′,5,5′-tetramethyl-3,3′-biselenienyl.

Temp °C	Time (t min)	α_{436}^{27}	$\ln\frac{\alpha_0}{\alpha_t}$
150	0	−0.267	0
	10	−0.225	0.171
	25	−0.190	0.340
	40	−0.141	0.639
	60	−0.115	0.843
	90	−0.070	1.34
145	0	−0.267	0
	15	−0.219	0.198
	30	−0.194	0.319
	50	−0.154	0.550
	80	−0.120	0.800
	105	−0.089	1.10
140	0	−0.267	0
	20	−0.232	0.140
	41	−0.191	0.335
	70	−0.160	0.512
	90	−0.137	0.667
	120	−0.116	0.834

X-ray analysis of inactive Ib [18] and those of Ia and II from data of similar compounds in the literature.[19–21] The distances between the centers of the interfering groups were found to be 1.62 Å. 1.90 Å, and 2.00 Å for II, Ib, and Ia, respectively. Calculations considering only non-bonded interactions in the rigid transition states using Lennard-Jones equation:[22]

$$u_{ij} = \frac{d_{ij}}{r_{ij}^{12}} - \frac{e_{ij}}{r_{ij}^{6}}$$

$e_{ij} = 124$ kcal Å^6 mol^{-1} (H···O interaction)

$d_{ij} = 25 \times 10^3$ kcal Å^{12} mol^{-1} (H···O interaction)

r_{ij} = distance between interacting atoms i and j

gave as expected unrealistic and exaggerated values of the activation energies, since the interacting atoms came too close to each other. Of course such cal-

culations predicted the right order of racemization of the three compounds. It is obvious that in the transition states for racemization stretching of the pivot bond, bending of the *ortho* substituents and deformation of the rings occur in order to minimize the activation energy. For more detailed discussion of these factors, *cf.* Refs. 23 – 25. Obviously more advanced calculations are necessary in order to obtain realistic values of the activation energies.

EXPERIMENTAL

2,5-Dimethyl-3-iodoselenophene. To a mixture of 220 ml of water, 170 ml of acetic acid, 1.1 ml of conc. sulphuric acid, 110 ml of carbon tetrachloride, and 90.0 g (0.566 mol) of 2,5-dimethylselenophene, 25.5 g (0.145 mol) of iodic acid in 100 ml of water and 73.6 g (0.290 mol) of iodine were added in portions with vigorous stirring at 40°C. The addition took 1.5 h and the mixture was stirred at 40°C for 2.5 h and then poured into 150 ml of saturated sodium thiosulphate solution. The organic layer was separated and the aqueous phase extracted with carbon tetrachloride. The combined organic phases were washed with water, dried over magnesium sulphate and fractionated to yield 119.4 g (74 %) of 2,5-dimethyl-3-iodoselenophene, b.p. 87 – 90°C/3 mmHg, having the same physical properties as a sample described earlier.[9]

Methyl 2,5-dimethyl-3-selenophenecarboxylate. A solution of 8.9 g (0.044 mol) of 2,5-dimethyl-3-selenophenecarboxylic acid[10] in 250 ml of methanol containing 10 ml of conc. sulphuric acid was refluxed for 5 h. The mixture was cooled and neutralized with sodium bicarbonate solution, and most of the solvent evaporated. Water was added and the mixture extracted with ether. The combined ether phases were washed with sodium carbonate solution and water and dried over magnesium sulphate. Evaporation of the solvent left 9.5 g (99 %) of crude ester, b.p. 128 – 130°C/16 mmHg. NMR (CCl_4): $\tau_{2\text{-}CH_3} = 7.27$ ppm; $\tau_{5\text{-}CH_3} = 7.54$ ppm; $\tau_{CO_2CH_3} = 6.25$ ppm; $\tau_4 = 2.84$ ppm; $J_{CH_3\text{-}CH_3} = 0.6$ Hz; $J_{5\text{-}CH_3\text{-}4} = 1.2$ Hz. [Found: C 44.64; H 4.74; O 14.72. Calc. for $C_8H_{10}O_2Se$ (217.1): C 44.25; H 4.64; O 14.74.]

2,5-Dimethyl-3-iodo-4-selenophenecarboxylic acid. A solution of 40.5 g (0.199 mol) of 2,5-dimethyl-3-selenophenecarboxylic acid[10] in 200 ml of carbon tetrachloride was added to a stirred mixture of 100 ml of acetic acid, 120 ml of water, 29.2 g (0.115 mol) of iodine and 10.6 g (0.0602 mol) of iodic acid, and the mixture heated to 70°C for 24 h. After cooling, the mixture was poured with stirring into 500 ml of 5 % aqueous sodium bisulphite solution. The carbon tetrachloride layer was separated and the aqueous phase extracted with ether. The combined organic phases were washed with sodium thiosulphate solution and water, and then extracted with 1 M potassium hydroxide solution. The combined alkaline solutions were acidified with 2.5 N hydrochloric acid and the precipitate (40.0 g) filtered off. Recrystallization from 1.5 l cyclohexane yielded 16.0 g (24 %) of the title compound, m.p. 188°C. Partial evaporation of the mother liquor yielded an additional 2.5 g of less pure acid. 13.8 g of the starting acid was recovered after evaporation of the mother liquor. NMR ($CDCl_3$): $\tau_{5\text{-}CH_3} = 7.39$ ppm; $\tau_{2\text{-}CH_3} = 7.58$ ppm; $J_{2\text{-}CH_3,5\text{-}CH_3} = 0.6$ Hz. [Found: C 25.62; H 2.07; O 9.88. Calc. for $C_7H_7IO_2Se$ (329.0): C 25.56; H 2.14; O 9.73.]

Methyl 2,5-dimethyl-3-iodo-4-selenophenecarboxylate. Method 1. The ester was prepared quantitatively in the usual manner by the reaction of the acid with diazomethane. Recrystallization from petroleum ether (b.p. 40 – 60°) at −15°C yielded the pure methyl ester, m.p. 40.5 – 41.5°C, with the same spectroscopic properties (IR, NMR) as the sample described below.

Methyl 2,5-dimethyl-3-iodo-4-selenophenecarboxylate. Method 2. A solution of 29.9 g (0.138 mol) of methyl 2,5-dimethyl-3-selenophenecarboxylate in 150 ml of carbon tetrachloride was added to a stirred mixture of 75 ml of acetic acid, 80 ml of water, 1 ml of conc. sulphuric acid, 17.8 g (0.0701 mol) of iodine, and 6.16 g (0.0350 mol) of iodic acid, and the mixture heated at 70°C for 24 h. After cooling, the mixture was poured into aqueous sodium thiosulphate solution. The organic phase was separated and the aqueous phase extracted with ether. The combined organic phases were washed with thiosulphate solution and water and dried over magnesium sulphate. The solvents were evaporated

and the residue recrystallized from petroleum ether (b.p. 40 – 60°C), yielding 25.0 g (53 %) of the title compound, m.p. 40.5 – 41.5°C. NMR (CCl_4): $\tau_{2\text{-}CH_3} = 7.72$ ppm; $\tau_{5\text{-}CH_3} = 7.35$ ppm; $\tau_{CO_2CH_3} = 6.09$ ppm; $J_{2\text{-}CH_3,5\text{-}CH_3} = 0.6$ Hz. [Found: C 28.09; H 2.85; O 9.81. Calc. for $C_8H_9IO_2Se$ (343.0): C 28.01; H 2.64; O 9.33.]

4,4'-Dicarbomethoxy-2,2',5,5'-tetramethyl-3,3'-biselenienyl. 24.9 g (0.0726 mol) of methyl 2,5-dimethyl-3-iodo-4-selenophenecarboxylate was heated to 180°C, and 24 g of copper bronze pretreated according to Ref. 13 was added in small portions. After addition was complete, the mixture was heated at 180°C for 1 h. After cooling, the solid mixture was carefully extracted with ether and the combined ether phases dried over magnesium sulphate. Evaporation of the solvent yielded 13.0 g (83 %) of the crude title compound. Distillation at 5×10^{-3} mmHg (b.p. 117 – 148°C) gave 10.4 g (66 %) of crystalline product. Recrystallization from aqueous ethanol yielded the analytical sample, m.p. 56.0 – 57.5°C. NMR (CCl_4): $\tau_{2\text{-}CH_3} = 7.84$ ppm; $\tau_{5\text{-}CH_3} = 7.32$ ppm; $\tau_{CO_2CH_3} = 6.54$ ppm; $J_{2\text{-}CH_3,5\text{-}CH_3} = 0.6$ Hz. [Found: C 44.20; H 4.74. Calc. for $C_{16}H_{18}O_4Se_2$ (432.2): C 44.46; H 4.74.]

4,4'-Dicarboxy-2,2',5,5'-tetramethyl-3,3'-biselenienyl. 9.00 g (0.0208 mol) of 4,4'-dicarbomethoxy-2,2',5,5'-tetramethyl-3,3'-biselenienyl in 100 ml of 30 % aqueous potassium hydroxide solution was refluxed with vigorous stirring for 72 h. The reaction mixture was diluted with 500 ml of ice-water and acidified with 2 N hydrochloric acid, which caused the precipitation of 6.9 g (82 %) of the title acid. The analytical sample was recrystallized from acetic acid, m.p. 290°C with decomposition. NMR (CD_3SOCD_3): $\tau_{2\text{-}CH_3} = 7.91$ ppm; $\tau_{5\text{-}CH_3} = 7.37$ ppm; $J_{2\text{-}CH_3,5\text{-}CH_3} = 0.6$ Hz. [Found: C 41.98; H 3.46; O 15.35. Calc. for $C_{14}H_{14}O_4Se_2$ (404.2): C 41.60; H 3.49; O 15.83.]

Optical resolution of 4,4'dicarboxy-2,2',5,5'-tetramethyl-3,3'-biselenienyl. 6.00 g (0.0148 mol) of racemic acid and 9.65 g (0.0297 mol) of quinine were dissolved in 55 ml of boiling ethanol, and 55 ml of hot water was added. After filtration, the solution was allowed to stand at room temperature for 48 h. The quinine salt was filtered off and recrystallized from 50 % aqueous ethanol. The progress of the resolution is shown below. Additional recrystallizations did not increase the rotation and the resolution has been repeated successfully several times.

Crystallization	1	2	3
ml 50 % ethanol	110	80	70
g, salt	7.10	6.53	5.55
$[\alpha]_D^{25}$ of acid [dioxane]	+20°	+24°	+24°

The mother liquor from the first recrystallization was evaporated *in vacuo* and the residue (8.3 g) decomposed with acid to give 2.22 g (0.00549 mol) of acid having $[\alpha]_D^{25} = -23°$. This acid and 4.34 g (0.0110 mol) of brucine were dissolved in 170 ml of absolute ethanol and allowed to stand at room temperature for 48 h. The progress of the resolution is shown below.

Crystallization	1	2
ml ethanol	170	150
g, salt	6.02	5.50
$[\alpha]_D^{25}$ of acid (dioxane)	−24°	−24°

(+)-4,4'-Dicarboxy-2,2',5,5'-tetramethyl-3,3'biselenienyl. 5.40 g of the quinine salt was decomposed with 2 N hydrochloric acid and the aqueous phase extracted with ether, yielding after recrystallization from a mixture of ethyl acetate – petroleum ether (40 – 60°C) 1.9 g of the title compound, m.p. 203 – 204°C. $[\alpha]_D^{25}$ (dioxane) = +24°. $[\alpha]_D^{25} = -10°$ (0.1 N NaOH). [Found: C 41.75; H 3.64; O 15.58. Calc. for $C_{14}H_{14}O_4Se_2$ (404.2): C 41.60; H 3.49; O 15.83.]

(−)-4,4'-Dicarboxy-2,2',5,5'-tetramethyl-3,3'-biselenienyl. 5.5 g of the brucine salt was decomposed with 2 N hydrochloric acid and the acid purified as described above, yielding a product (1.78 g) with the same IR spectrum as the (+)-form; m.p. 203 – 204°C. $[\alpha]_D^{25} = -24°$ (dioxane). $[\alpha]_D^{25} = +10°$ (0.1 N NaOH).

(−)-4,4'-Dihydroxymethyl-2,2',5,5'-tetramethyl-3,3'-bithienyl. 2.62 g (8.45 mmol) of (+)-4,4'-dicarboxy-2,2',5,5'-tetramethyl-3,3'-bithienyl [1] was methylated with ethereal diazomethane in the usual way, yielding 2.52 g of crude methyl ester, which was dissolved in 25 ml anhydrous ether and added dropwise to 0.285 g (7.51 mmol) of lithium aluminium

hydride covered with anhydrous ether. After the addition the mixture was refluxed for 2 h. After ice-cooling the mixture was decomposed with dropwise addition of ice-cold water followed by 2 N hydrochloric acid. The aqueous phase was extracted with ether and the combined ether phases washed with 2 N hydrochloric acid, dilute sodium hydroxide solution, and finally with water. After drying over magnesium sulphate, evaporation yielded 1.63 g (68 %) of the title compound, m.p. 156 – 157°C, after recrystallization from a benzene – pentane mixture. $[\alpha]_D^{25} = -23°$ (dioxane). [Found: C 59.40; H 6.28; S 24.0. Calc. for $C_{14}H_{18}O_2S_2$ (282.4): C 59.54; H 6.42; S 22.71.]

(+)-4,4'-Dihydroxymethyl-2,2',5,5'-tetramethyl-3,3'-bithienyl. This compound, m.p. 156 – 157°C, was obtained in the same way as described above from (–)-4,4'-dicarboxy-2,2',5,5'-tetramethyl-3,3'-bithienyl. $[\alpha]_D^{25} = +23°$ (dioxane) CD in dioxane (*c* 0.0330). $[\theta]_{275}$ 0, $[\theta]_{265}$ +2700, $[\theta]_{258}$ 0, $[\theta]_{243}$ −17 500, $[\theta]_{229}$ 0, $[\theta]_{225}$ +7700, $[\theta]_{217}$ 0. UV (dioxane): λ_{max} 243 nm, ε 13 800. NMR ($CDCl_3$): $\tau_{2-CH_3} = 8.00$ ppm; $\tau_{5-CH_3} = 7.60$ ppm; $\tau_{OH} = 6.17$ ppm; $\tau_{CH_2} = 5.72$ ppm and 6.08 ppm; $J_{CH_2} = 11.4$ Hz. [Found: C 59.10; H 6.25; S 22.4. Calc. for $C_{14}H_{18}O_2S_2$ (282.4) C 59.54; H 6.42; S 22.71.]

(+)-4,4'-Dihydroxymethyl-2,2',5,5'-tetramethyl-3,3'-biselenienyl. From 1.063 g of (–)-4,4'-dicarboxy-2,2',5,5'-tetramethyl-3,3'-biselenienyl, 0.68 g (69 %) of the title compound was obtained after recrystallization from benzene – pentane in the same way as described above. $[\alpha]_D^{25} = +27°$ (dioxane). CD in dioxane (*c* 0.0326) $[\theta]_{295}$ 0, $[\theta]_{278}$ +4730, $[\theta]_{273}$ 0, $[\theta]_{261}$ −29 400, $[\theta]_{250}$ 0, $[\theta]_{238}$ +15 000, $[\theta]_{225}$ +6930, $[\theta]_{220}$ 0, $[\theta]_{215}$ −4050, $[\theta]_{212}$ 0. UV (dioxane): λ_{max} 255 nm, ε 18 500. NMR ($CDCl_3$): $\tau_{2-CH_3} = 7.87$ ppm, $\tau_{5-CH_3} = 7.47$ ppm; $\tau_{OH} = 6.55$ ppm; $\tau_{CH_2} = 5.73$ and 6.12 ppm; $J_{CH_2} = 11.4$ Hz. [Found: C 44.60; H 4.89; O 8.91. Calc. for $C_{14}H_{18}O_2Se_2$ (376.2): C 44.69; H 4.82; O 8.51.]

(–)-4,4'-Dihydroxymethyl-2,2',5,5'-tetramethyl-3,3'-biselenienyl. From 1.032 g of (+)-4,4'-dicarboxy-2,2',5,5'-tetramethyl-3,3'-biselenienyl, 0.65 g (68 %) of the title compound, m.p. 176 – 178°C, was obtained after recrystallization from benzene – pentane with the same IR spectrum as the (+)-isomer. $[\alpha]_D^{25} = -27°$ (dioxane). [Found: C 44.50; H 4.66; O 9.09. Calc. for $C_{14}H_{18}O_2Se_2$ (376.2): C 44.69; H 4.82; O 8.51.]

Melting point diagrams. From acetone solutions of known concentrations, mixtures of known compositions were obtained. The solvent was evaporated at room temperature and the residue carefully powdered and dried in a desiccator. The melting points were determined using a hot-stage microscope.

Racemization experiments. The racemization experiments were carried out as described before.[3] The results are collected in Table 2.

Optical rotations were measured with a Perkin-Elmer model 141 spectropolarimeter. The *CD curves* were obtained at 27°C with a Cary 60 recording spectropolarimeter equipped with a circular dichroism accessory.

UV spectra were recorded on a Unicam SP 800 spectrophotometer.

IR spectra were recorded on a Perkin-Elmer 257 grating infared spectrophotometer.

NMR spectra were obtained on a Varian A-60 spectrometer.

Mass spectra were obtained with an LKB 9000 mass spectrometer using an ionization energy of 70 eV.

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REFERENCES

1. Gronowitz, S. and Beselin, R. *Arkiv Kemi* **21** (1963) 349.
2. Gronowitz, S. *Arkiv Kemi* **23** (1965) 307.
3. Gronowitz, S. and Skramstad, J. E. *Arkiv Kemi* **28** (1967) 115.
4. Håkansson, R. and Wiklund, E. *Acta Chem. Scand.* **25** (1971) 2109.
5. Gronowitz, S. and Frostling, H. *Acta Chem. Scand.* **16** (1962) 1127.
6. Håkansson, R. and Wiklund, E. *Unpublished results.*
7. Dell'Erba, C., Spinelli, D., Garbarino, G. and Leandri, J. *J. Heterocycl. Chem.* **5** (1968) 45.

8. Gronowitz, S. and Gustafson, P. *Arkiv Kemi* **20** (1963) 289.
9. Gronowitz, S. and Frejd, T. *Acta Chem. Scand.* **23** (1969) 2540.
10. Gronowitz, S. and Frejd, T. *Acta Chem. Scand.* **24** (1970) 2656.
11. Gronowitz, S. and Vilks, V. *Arkiv Kemi* **21** (1963) 191.
12. Wiersema, A. and Gronowitz, S. *Acta Chem. Scand.* **24** (1970) 2593.
13. Kleiderer, E. C. and Adams, R. *J. Am. Chem. Soc.* **55** (1933) 4219.
14. Fredga, A. *Tetrahedron* **8** (1960) 126.
15. Siegel, M. and Mislow, K. *J. Am. Chem. Soc.* **80** (1958) 473.
16. Håkansson, R. and Wiklund, E. *Private communication.*
17. Håkansson, R. and Wiklund, E. *To be published.*
18. Aurivillius, B. *Chem. Scripta* **1** (1971) 25.
19. Visser, G. J., Heeres, G. J., Wolters, J. and Vos, A. *Acta Cryst.* **B 24** (1968) 467.
20. Trotter, J. *Acta Cryst.* **14** (1961) 1135.
21. Ferguson, G. and Sim, G. A. *Acta Cryst.* **15** (1962) 346.
22. Sheraga, H. A. *Advan. Phys. Org. Chem.* **6** (1968) 103.
23. Chua Cheung King Ling and Harris, M. M. *J. Chem. Soc.* **1964** 1825.
24. Howlett, K. E. *J. Chem. Soc.* **1960** 1055.
25. Westheimer, I. H. and Mayer, J. E. *J. Chem. Phys.* **14** (1946) 733.

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