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# An Unexpected [2+2]-Cycloaddition Reaction of 4-Methyldithieno-[3,4-*b*:3',2'-*d*]pyridinium Iodide with Dimethyl Acetylenedicarboxylate

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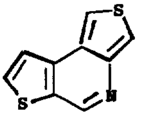
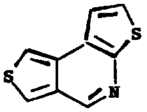
*Dedicated to Professor Hans Suschitzky on the occasion of his 80th birthday*

**Abstract:** An unexpected [2+2]-cycloaddition occured in the reaction of 4-methyldithieno-[3,4-*b*:3',2'-*d*]pyridinium iodide (**3**)with two equivalents of DMAD, giving 4-(*trans*-1,2-dicarbomethoxy-2- iodovinyl)-5-methyl-6,7-dicarbomethoxy-4,5-dihydrothieno[2,3-*c*]quinoline (**4**) in 54 % yield. **4** is formed *via* 4-methyl-5-(*trans*-1,2-dicarbomethoxy-2-iodo-4,5-dihydrothieno[3,4-*b*:3',2'-*d*]pyridine (**16**), followed by [2+2]-cycloaddition. The primary adduct rearranges *via* a thiepin to an episulfide which eliminates sulfur to give **4**.

In a previous paper we have described the cycloaddition reactions of dithieno[3,4-*b*:3',2'-*d*]-pyridine (**1**) and dithieno[2,3-*b*::3',4'-*d*]pyridine (**2**) and their ylides, obtained upon reaction with methyl bromoacetate, chloracetonitrile and tetracyanoethylene oxide, with dimethyl acetylenedicarboxylate.[1] The products obtained, derivatives of dithienoquinolizine and dithienoindolizine, were similar to those formed in the corresponding reactions of phenanthridine.[2-4] In no case 1,4-cycloaddition over the *c*-fused thiophene ring was observed.



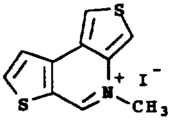
**1**



**2**

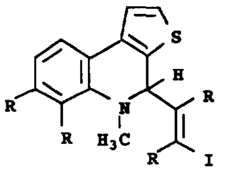
## Results and Discussion

In this work we were interested to find out if 4-methyldithieno[3,4-*b*::3',2'-*d*]pyridinium iodide (**3**), easily prepared in quantitative yield by methylation with methyl iodide in benzene, would give an ylide in a similar way as the 4-methoxycarbonyl and 4-cyanomethyl derivatives, having more acidic

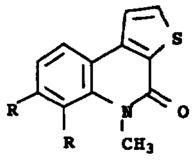


**3**

methylene groups, and undergo 1,3-dipolar cycloaddition to dithienoindolizine derivatives with dimethyl acetylenedicarboxylate (DMAD). To our surprise a quite different reaction occured, when stirring **3** with DMAD and triethylamine in dichloromethane over night. The main component (34 %) was crystalline (m.p 141-143 °C) and had according to its high resolution mass spectrum a composition of $C_{22}H_{20}INO_8S$. Its $^1H$ NMR spectrum showed the presence of five methyl groups, which were not equivalent and did not couple with each other, two thiophenic protons with a coupling constant of 5.3 Hz and two aromatic protons with a coupling constant of 8.05 Hz and a singlet due to one proton at $\delta$ 6.10. The $^1H$ NMR spectrum thus indicated this compound to be 4-(*trans*-1,2-dicarbomethoxy-2-iodo vinyl)-5- methyl-6,7-dicarbomethoxy-4,5-dihydrothieno[2,3-*c*]quinoline (**4**).

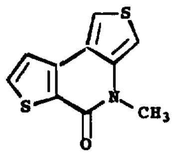


**4** $R{=}CO_2CH_3$

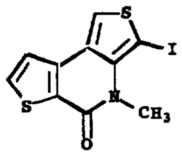


**5** $R{=}CO_2CH_3$

It is known that Michael addition to DMAD followed by protonation yields fumaric acid derivatives.[5] The structure of **4** was proven by an X-ray crystallographic investigation. In addition to **4**, a minor component (12 %), which high resolution mass spectrum gave the composition $C_{16}H_{13}NO_5S$, was formed. $^1H$ NMR spectra indicated the presence of three methyl groups, which did not couple to each other, two thiophenic doublets (J = 5.3 Hz) and two benzenoid doublets (J = 8.1 Hz) showing it to be 6,7-dicarbomethoxy-4-oxo-5-methyl-4,5-dihydrothieno[2,3-*c*]quinoline (**5**). Finally also 10 % of 4-methyldithieno[3,4-*b*:3',2'-*d*]pyridine-5(1H)-one (**6**) was obtained. The structure followed from its $^1H$ NMR spectrum. In deuteriochloroform it showed two pairs of thiophenic doublets with coupling constants of 3.10 Hz and 5.80 Hz, respectively, showing that both the *b*- and *c*-fused rings of **6** were unsubstituted. Furthermore no absorption was observed in the region of $\delta$ 8.95, showing a substituent in the 5-position. In a nuclear Overhauser effect experiment irradiation of the *N*-methyl group at $\delta$ 3.70 enhanced the absorption of the doublet at $\delta$ 6.75 with 20 %, proving it to be the resonance of the proton in the 3-position. Interestingly **6** does not react with DMAD in dichloromethane in the presence of triethyl amine indicating that **5** is not formed from **6**.



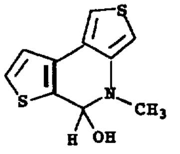
**6**



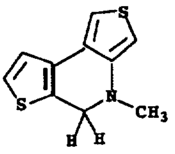
**7**

Oxidation of pyridinium salts to *N*-alkylpyridone with alkaline ferricyanide first described in 1892[6,7] and applied to 5-methylphenanthridinium iodide a year later,[8] has been extensively used for this purpose and the mechanism has been studied.[9] However, already Pictet *et al.* found, that treatment of 5-methylphenanthridinium iodide with alkali gave the pseudobase, which upon steam distillation gave non-volatile 5-methyl-6-phenanthridone and volatile 5-methyl dihydrophenanthridine.[10,11] They also noticed that the pseudobase as well as the dihydro derivative was easily oxidized by air, already on standing. We found that compound **6** was obtained in 58 % yield from **3** by treatment only with potassium hydroxide in methanol, most probably due, in a similar way, to the oxidation of the pseudobase by air, also a disproportionation reaction of the type observed for 5-methylphenanthridinium iodide or 1-methylquinolinium iodide[12,13] might be possible. Reaction of **3** with alkaline potassium ferricyanide did not give higher yields of **6.**

Different conditions to make the cycloaddition reaction more selective were investigated. It was found that no reaction occurred, when refluxing a mixture of **3** with DMAD in dichloromethane for five days. Heating **3** with or without DMAD in dioxane at 50 °C gave **6** in 5 to 18 % yield. However, using a mixture of dioxane and acetic acid as solvent, previously utilized in the study of the reaction of thienopyridazines with DMAD[14] led after two hours at 50 °C to a mixture of 20 % of **6** and 24 % of a compound having the composition $C_{10}H_6INOS_2$. After a reaction time of five hours, the yield of this compound increased to 35 %, and only 6 % of **6** remained. IR and $^1$HNMR spectra proved the iodinated derivative to be 3-iodo-4-methyldithieno[3,4-*b*:3',2'-*d*]pyridine-5(1H)-one (**7**). In its IR spectrum it showed a frequency characteristic for pyridone at 1620 cm$^{-1}$, the $^1$H NMR spectrum showed two thiophenic doublets with a coupling constant of 5.15 Hz, demonstrating that the *b*-fused ring was unsubstituted. Nuclear Overhauser experiments, irradiating the methyl resonance at 4.10 ppm did not have any effect on the singlet at 7.80 ppm indicating that the iodine is in the 3-position. It is interesting to note that no iodinated product was formed when the reaction was carried out under nitrogen. It was also found that **6** was not iodinated with iodine to **7** in dioxane in the presence or absence of acetic acid under these reaction conditions. Neither seems it probable that **3** is iodinated under these conditions. We therefore suggest that **7** is formed by electrophilic iodination of the pseudobase **8** or the reduced intermediate **9** with a species formed by air oxidation of iodide ion. Electrophilic iodination is of course expected to occur in the 3-position.



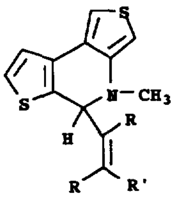
8



9

$$3 + \text{DMAD} \xrightarrow[\text{reflux, 5h}]{\text{dioxane/acetic acid}} \underset{44\%}{4} + \underset{2\%}{6} + \underset{4\%}{7} + \underset{4\%}{10} + \underset{2\%}{11} + \underset{5\%}{12}$$

However, refluxing **3** and DMAD in a mixture of dioxane and acetic acid for five hours lead to quite different results. Trace amounts of **6** and **7** were formed, but the main component was **4**, which was obtained in a yield of 44 %. Refluxing over-night increased the yield of **4** to 54 %. Also 4 % of a compound, mp 124-126 °C, which according to high resolution mass spectrum had a composition of $C_{18}H_{17}NO_6S_2$ was isolated. Its IR spectrum showed carbonyl stretching frequencies characteristic of



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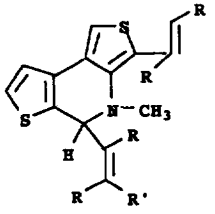
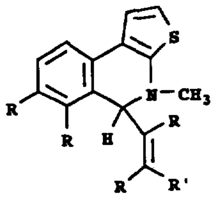


11

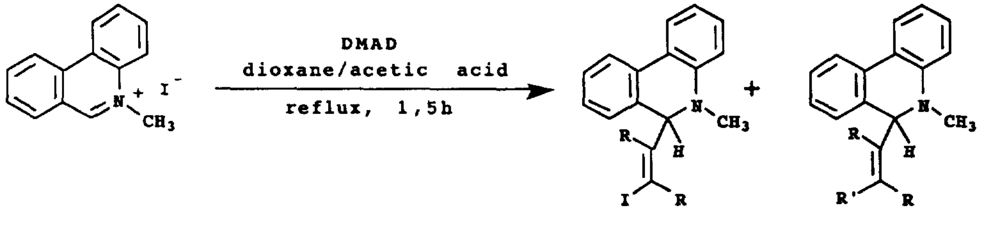


12

R=CO$_2$CH$_3$

R'=OCOCH$_3$

ester functions at 1735 and 1770 cm$^{-1}$. Its $^{1}$H NMR spectrum showed four singlets due to methyl groups and four doublets with coupling constants of 5.35 and 2.80 Hz showing that the thiophene rings are unsubstituted indicating that the compound is 4-methyl-5-(*trans*-1,2-dicarbomethoxy-2-acetoxyvinyl)4,5-dihydrodithieno[3,4-b;3',2',-*d*]pyridine (**10**). In addition small amounts of other compounds could be isolated. One of them, mp 112-114 °C, which according to high resolution mass spectrometry had a composition of $C_{24}H_{23}NO_{10}S_2$, showed CO-stretching frequencies at 1720, 1725 and 1770 cm$^{-1}$ Its $^{1}$H NMR showed six methyl singlets, two thiophenic doublets at 7.25 and 7.15 ppm with a coupling constant of 5.30 Hz showing the presence of an unsubstituted *b*-fused thiophene ring. Two other one proton singlets were observed at δ 7.16 and 6.60. X-ray crystallography proved the structure of this minor component to be 3-(*trans*1,2-dicarbomethoxyvinyl)-4-methyl-5-(*trans*-1,2-dicarbomethoxy-2-acetoxyvinyl)-4,5-dihydrodithienopyridine (**11**). Another minor component (5 %), mp 131-133 °C, which according to high resolution mass spectrometry had the composition $C_{24}H_{23}NO_{10}S$, showed stretching frequencies at 1715, 1730 and 1770 cm$^{-1}$, also showed six methyl singlets in its $^{1}$H NMR spectrum, two benzenic *o*-protons at δ 7.60 and 7.55 with a coupling constant of 8.00 Hz and two thiophenic doublets at 7.35 and 7.30 ppm with a coupling constant of 5.15 Hz in addition to a one proton singlet at δ 6.65 and was thus identified as 4-methyl-5-(*trans*-1,2-dicarbomethoxy-2- acetoxyvinyl)-6,7-dicarbomethoxydihydrothieno- [2,3-*c*]quinoline (**12**).



13

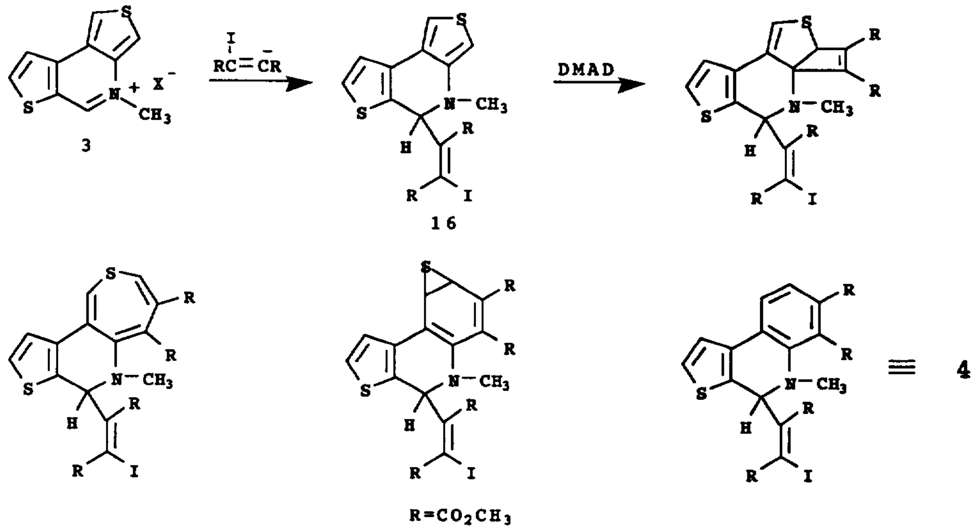
14
54%

15
12%

R=CO$_2$CH$_3$

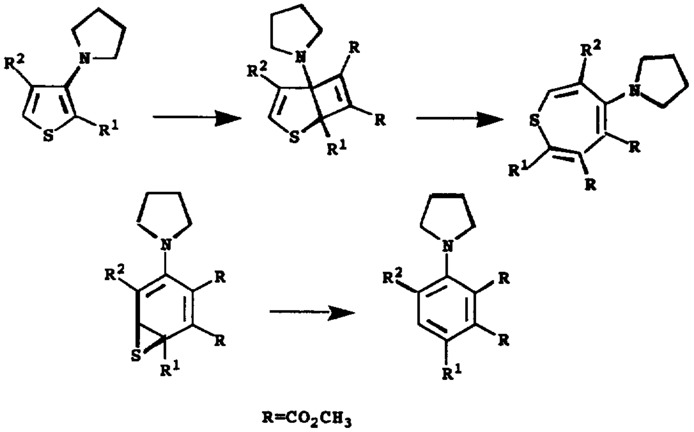
R'=OCOCH$_3$

The reactions of DMAD with six-membered aromatic nitrogen heterocycles, such as pyridine, quinoline and phenanthridine have been studied extensively and several review articles have been published.[5,15] However, we could not find any study on the reactions of simple quaternary derivatives such as 5-methylphenanthridinium iodide (**13**) with DMAD. Therefore we carried out this reaction under the conditions described above and found that 5-methyl-6-(*trans*-1,2-dicarbomethoxy-2- iodovinyl)-5,6-dihydrophenanthridine (**14**) and 5-methyl-6-*trans*-(1,2-dicarbomethoxy-2-acetoxyvinyl)-5,6-dihydro phenanthridine (**15**) are obtained. The structures were proven by $^1$H NMR (cf experimental part). A probable reaction path for the introduction of the side chain in the 5-position of **3** could be a Michael addition of iodide or acetate to DMAD followed by nucleophilic attack on the positive carbon in the 5-position, before protonation of the intermediate vinylic anion occurred. However, also other reaction paths could be imagined.



Scheme 1

Compound **4** is therefore most likely formed from **3** through reaction with DMAD and iodide ion



Scheme 2

as described above, giving 4-methyl-5-(*trans*-1,2-dicarbomethoxy-2-iodovinyl)-4,5-dihydrodithieno-[3,4-*b*:3',2'.*d*]pyridine (**16**), followed by [2+2] cycloaddition. The primary adduct rearranges *via* a thiepin to an episulfide, which eliminates sulfur to give **4** (Scheme 1) The intermediacy of **16** could be demonstrated, when the reaction was stopped after 2.5 h. 28 % of **16** mp 132-134 °C could be isolated. High resolution mass spectrometry showed its composition to be $C_{16}H_{14}INO_4S_2$, and CO-stretching frequencies at 1720 and 1725 $cm^{-1}$. Its $^1H$ NMR spectrum showed that both thiophenic ring-parts were unsubstituted as four doublets with coupling constants of 5.0 Hz and 3.0 Hz, respectively, were observed, in addition to three methyl singlets and a one proton singlet at $\delta$ 6.10.

There is precedence for this type of cycloaddition in the literature. Reinhoudt and coworkers found that 3-*N,N*--dimethylaminothiophenes reacted with DMAD to give cycloadducts, which isomerize to thiepins, which eliminate sulfur *via* the episulfide.[16-18] (Scheme 2). It is obvious that **16** contains structural parts reminiscent of 3-dimethylaminothiophene.

## X-ray crystallographic investigation

The structures of **4** and **11** have been determined by X-ray investigation and the perspective views are give in figure 1 and 2. Bond distances and angles are normal for both compounds. The two thiophene rings in compound **11** are planar with an angle of 9.6° between the least-squares planes. The six membered nitrogen containing ring is twisted with the nitrogen and the $sp^3$ hybridized carbon outside the best plane.

In compound **4** the thiophene and benzene rings are planar within 0.005 and 0.02 Å, respectively with an angle of 9.3° between them. The nitrogen containing ring is twisted in the same way as for compound **11**.

For both compounds atomic coordinates, thermal parameters, molecular geometries and structure factors have been deposited with the Cambridge Crystallographic Data Centre.

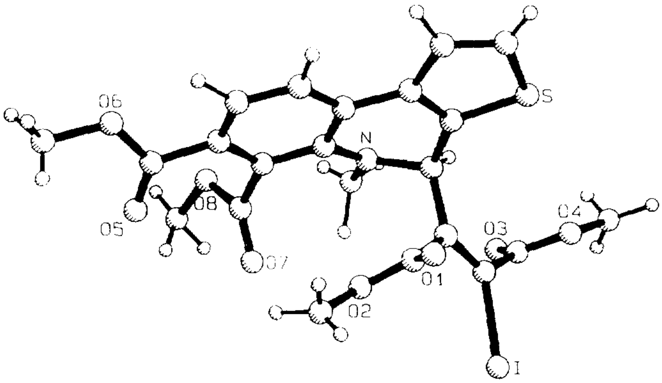


Figure 1. Perspective view of 4-(*trans*-1,2-dicarbomethoxy-2-iodo vinyl)-5- methyl-6,7-di-carbomethoxy-4,5-dihydrothieno[2,3-*c*]quinoline (**4**).

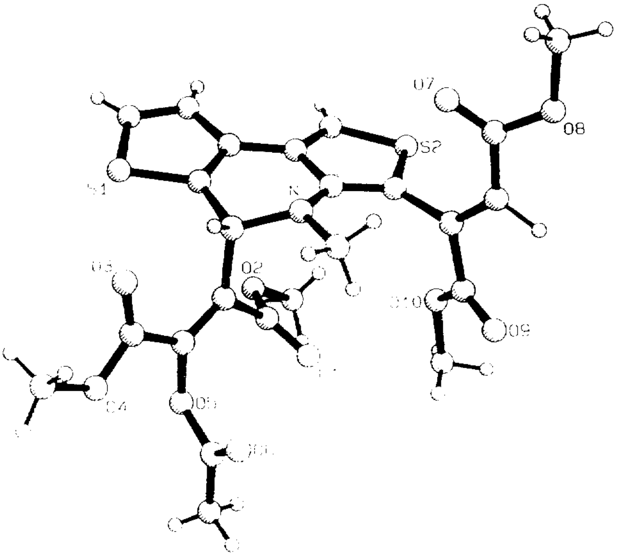


Figure 2. Perspective view of 3-(*trans*-1,2-dicarbomethoxyvinyl)-4-methyl-5-(*trans*-1,2-dicarbomethoxy-2-acetoxyvinyl)-4,5-dihydro- dithieno[3,4-*b*:3',2'-*d*]pyridine (**11**).

## EXPERIMENTAL

### Chemicals and Instrumentation

The $^1H$ NMR spectra were recorded on a 300 MHz Varian XL-spectrometer. The mass spectra were recorded on a JEOL-SX 102 spectrometer and the IR spectra on a Perkin Elmer 298 infrared spectrophotometer. For X-ray investigations CAD 4 and NICOLET diffractometers were used together with the TEXSAN structure analysis software. Melting points are uncorrected. Column chromatography was performed with Merck silica gel 60. All solvents were distilled and purified according to standard procedures prior to use. Purchased starting materials were used without further purification.

*4-Methyldithieno[3,4-b:3',2'-d]pyridinium iodide* **3**:

To a solution of sublimed dithieno[3,4-*b*:2',3'-*d*]pyridine (**1**)[19,20] (3.82 g, 20.0 mmol) in anhydrous benzene (50 ml), methyl iodide (4.46 g, 30 mmol) was added and the mixture was stirred at room temperature for two days. The formed precipitate was filtered off and washed with benzene. The filtrate was concentrated and again treated with methyl iodide (1.42 g, 10.0 mmol) and stirred for another two days, giving a second crop of the product. The combined fractions were recrystallized from ethanol/benzene giving 6.5 g (98 %) of **3** as yellow crystals, mp 262-264 °C (dec.). IR (potassium bromide): $\nu$ 3460 $cm^{-1}$. $^1H$ NMR (deuterated dimethylsulfoxide): $\delta$ 9.95 (s, 1H, H5), 9.10 (d, 1H, H1, J = 3.35 Hz), 8.95 (d, 1H, H7, J = 5.15 Hz), 8.75 (d, 1H, H3 J = 3.35 Hz), 8.40 (d, 1H, H8, J = 5.15 Hz), 4.45 (s, 3H, $CH_3$).

*Anal.* Calcd. for $C_{10}H_8INS_2$: MW, 333.2. Found: m/z 206 ($M^+$-I)

*4-Methyldithieno[3,4-b:3',2'd]pyridine-5(1H)-one* **6**:

A mixture of 4-methyldithieno[3,4-*b*:3',2'-*d*]pyridinium iodide (**3**) (2.0 g, 6.0 mmole) in methanol (50 ml) was treated with potassium hydroxide (1.68 g, 30.0 mmole) and the solution was stirred at room temperature for three hours. The reaction was followed by thin-layer chromatography. The reaction mixture was diluted with 20 ml of water and extracted with diethyl ether several times. The combined ether phases were washed with ice-cold water and then dried over magnesium sulfate. After evaporation the residue was purified by column chromatography using ethyl acetate/petroleum ether (1:3) as eluent. 769 mg (58 %) of **6** was obtained as white crystals. The substance was sublimed at 131 °C/1.3 mm Hg and mp was 157-159 °C after recrystallization from ethanol. An analytical sample was subjected to preparative HPLC using a nucleosil column (500 x 10 mm) and chloroform/heptane (30:70) as eluent. IR (potassium bromide): ν CO 1625 $cm^{-1}$. $^1H$ NMR (deuteriochloroform): δ 7.70 (d, 1H, H7, J = 5.20 Hz), 7.67 (d, 1H, H1, J = 3.17 Hz), 7.50 (d, 1H, H8, J = 5.20 Hz), 6.75 (d, 1H, H3, J = 3.17 Hz), 3.70 (s, 3H, $CH_3$).

*Anal*. Calcd. for $C_{10}H_7NOS_2$: C, 54.27; H, 3.19; N, 6.33; MW, 221.31. Found: C, 54.32; H, 3.28; N, 6.33; MW 221.

*Reaction of 4-methyldithieno[3,4-b:3',2'-d]pyridinium iodide (3) with DMAD and triethylamine.*

To a suspension of **3** ( 2.33 g, 7.00 mmol) in dichloromethane (100 ml), DMAD (3.0 g, 21 mmol) was added followed by dropwise addition of triethylamine ( 2.8 ml, 19 mmol) under stirring for one hour. The reaction mixture was refluxed for twelve hours and then poured into ice-cold water. Dichloromethane was evaporated and the residue was extracted several times with diethyl ether. The combined ether phases were washed with water, treated with charcoal and dried over magnesium sulfate. After evaporation the solid residue was chromatographed using ethyl acetate/heptane (1:3, 1:1) ethyl acetate as eluents. A complete separation of the components was obtained by HPLC using a diol column (250 x 10 mm) and heptane/chloroform/2-propanol (88:10:2) as eluent.

4-Methyldithieno[3,4-*b*:3',2'-*d*]pyridine-5(1H)one (**6**) was separated in a yield of 155 mg (10 %) and with the same physical data as described above. The next fractions gave 278 mg (12 %) of 6,7-dicarbomethoxy-4-oxo-5-methyl-4,5-dihydrothieno[2,3-*c*]quinoline (**5**) as white crystals, mp 152-154 °C after recrystallization from ethanol. IR (potassium bromide): ν CO 1720 and 1635 $cm^{-1}$; $^1H$ NMR (deuteriochloroform): δ 8.10 (d, 1H, H9, J = 8.50 Hz), 7.85 (d, 1H, H8, J = 8.50 Hz), 7.80 (d, 1H, H2, J = 5.30 Hz), 7.75 (d, 1H, H1, J = 5.30 Hz), 4.00 (s, 3H, $CH_3$), 3.95 (s, 3H, $CH_3$), 3.80 (s, 3H, $CH_3$). Peak matching for $M^+$. Calcd. for $C_{16}H_{13}NO_5S$: 331.0515. Found: 331.0516.

The last fractions gave 1.40 g (34 %) of 4-(*trans*-1,2-dicarbomethoxy-2-iodovinyl)-5-methyl-6,7-dicarbomethoxy-4,5-dihydrothieno[2,3-*c*]-4-quinoline (**4**) as pale yellow crystals, mp 141-143 C° after recrystallization from ethanol. IR (potassium bromide): ν CO 1720, 1730, 1740 and 1770 $cm^{-1}$. $^1H$ NMR (deuteriochloroform): δ 7.60 (d, 1H, H8, J = 8.05 Hz), 7.55 (d, 1H, H9, J = 8.05 Hz), 7.34 (d, 1H, H2, J = 5.30 Hz), 7.35 (d, 1H, H1, J = 5.30 Hz), 6.10 (s, 1H, H4), 3.92, 3.90, 3.88, 3.23, 2.96 (s, 3H, $CH_3$). Peak matching for $M^+$. Calcd. for $C_{22}H_{20}INO_8S$: 584.9954. Found 584.9931.

*Collection and refinement of X-ray diffraction data:* A yellow crystal of dimensions 0.15x 0.25x0.55 mm obtained by recrystallization from ethanol was used for the data collection on a CAD 4 diffractometer equipped with $MoK_\alpha$ radiation. Of the 4715 independent reflections, 3858 with $I>3\sigma$ (I) were used in the refinements. The structure was solved by direct methods and refined to R = 0.044 and $R_w$ = 0.059 with 378 parameters. $C_{22}H_{20}INO_8S$, M = 585.37, space group P1, a = 8.263 (1), b = 11.205(1), c = 13.787(1) Å, $\alpha$ = 112.81(1), $\beta$ = 93.13(1), $\gamma$ = 99.68(1)°, V = 1164.9(4) Å$^3$, Z = 2, $D_c$ = 1.669 gcm$^{-3}$, $2\theta_{max}$ = 52°, temp 25 °C.

*Reaction of 4-methyldithieno[3,4-b:3′,2′-d]pyridinium iodide (3) with DMAD and acetic acid in dioxane at 50 °C.*

To a suspension of **3** (1.00 g, 3.0 mmol) in dioxane (25 ml), DMAD (1.3 g, 9.0 mmol) and acetic acid (1.0 ml) were added and the mixture was heated at 50 °C under stirring for five hours. The solution was then poured into ice-cold water at room temperature. The phases were separated and the aqueous phase was extracted several times with diethyl ether. The combined ether phases were washed with sodium hydrogen carbonate solution, treated with charcoal and dried over magnesium sulfate. After evaporation the solid residue was chromatographed on silica using ethyl acetate/petroleum ether (1:1) as eluent. The first fractions gave 40 mg (6 %) of 4-methyldithieno[3,4-*b*:3',2'-*d*]pyridine-5(1H)-one (**6**) with the same physical data as described above. The following fractions gave 330 mg (35 %) of 3-iodo-4-methyldithieno[3,4-*b*:3',2'-*d*]pyridine-5(1H)-one (**7**) as white crystals from dichloromethane/heptane, mp 183-185 °C. An analytical sample was obtained through preparative HPLC using a nucleosil column (500 x 10 mm) and chloroform/heptane (10:90) as eluent. IR (potassium bromide): ν CO 1620 cm$^{-1}$, $^1$H (deuteriochloroform): δ 7.80 (s, 1H, H1), 7.70 (d, 1H, H7, J = 5.15 Hz), 7.45 (d, 1H, H8, J = 5.15 Hz), 4.10 (s, 3H, $CH_3$).

*Anal.* Calcd. for $C_{10}H_6INOS_2$: C, 34.56; H, 1.73; N, 4.03; MW, 347.20. Found: C, 34.65; H, 1.95; N, 3.93; MW, 347.

*Reaction of 4-methyldithieno[3,4-b:3′,2′-d]pyridinium iodide (3) with dimethyl acetylenedicarboxylate and acetic acid under reflux.*

To a suspension of **3** ( 2.0 g, 6.0 mmol) in dioxane (50 ml), DMAD (2.55 g,18 mmol) and acetic acid (2.0 ml) were added and the mixture was refluxed under stirring for five hours. The solution was poured into ice-cold water. The phases were separated and the aqueous phase was extracted several times with diethyl ether. The combined ether phases were washed with sodium hydrogen carbonate solution, treated with charcoal and dried over magnesium sulfate. After evaporation the solid residue was chromatographed using ethyl acetate/heptane (1:4, 1:2, and 1:1) as eluents. Further purification by HPLC using a diol column (250 x 10 mm) and heptane/chloroform/2-propanol (88:10:2) as eluent gave seven compounds of which six were characterized. 3-Iodo-4-methyldithieno[3,4-*b*:3',2'-*d*]pyridine-5(1H)-one (**7**) was obtained in a yield of 83 mg (4 %) with the same physical properties as described above. 27 mg (2 %) of 4-methyldithieno[3,4-*b*:3',2'-*d*]pyridine-5(1H)-one (**6**) with the same physical data as described above were then obtained.

4-Methyl-5-(1,2-dicarbomethoxy-2-acetoxyvinyl)-4,5-dihydrodithieno[3,4-*b*:3',2',-*d*]pyridine (**10**) was obtained in a yield of 98 mg (4 %) as pale yellow crystals mp 124-126 C° after recrystallization from ethanol. IR (potassium bromide): ν CO 1735 and 1770 cm$^{-1}$; $^1$H NMR (deuteriochloroform): δ 7.26 (d, 1H, H7, J = 5.35 Hz), 7.18 (d, 1H, H8, J = 5.35 Hz), 7.14 (d, 1H, H1, J = 2.80 Hz), 6.63 (s, 1H, H5), 5.82 (d, 1H, H3, J = 2.80 Hz), 3.90, 3.23 (s, 3H, OCH$_3$), 3.01 (s, 3H, NCH$_3$), 2.13 (s, 3H, COCH$_3$). Peak matching for M$^+$. Calcd. for $C_{18}H_{17}NO_6S_2$: 407.0498. Found: 407.0498.

3-(*trans*-1,2-Dicarbomethoxyvinyl)-4-methyl-5-(*trans*-1,2-dicarbomethoxy-2-acetoxyvinyl)-4,5-dihydrodithieno[3,4-*b*::3',2'-*d*]pyridine (**11**) was obtained in a yield of 66 mg (2 %) as yellow crystals, mp 112-114 °C after recrystallization from ethanol. IR (potassium bromide): ν CO 1720, 1725 and 1770 cm $^{-1}$. $^1$H NMR (deuteriochloroform): d 7.25 (d, 1H, H7, J = 5.30 Hz), 7.16 (s, 1H, H1), 7.15 (d, 1H, H8, J = 5.30 Hz) 7.10 (s, 1H, H-vinyl), 6.60 (s, 1H, H5), 3.88, 3.83, 3.70 3.40 (s, 3H, OCH$_3$), 2.98 (s, 3H, NCH$_3$), and 2.13 (s, 3H, COCH$_3$). Peak matching for M$^+$. Calcd. for $C_{24}H_{23}NO_{10}S_2$ 549.0764. Found: 549.0770.

*Collection and refinement of X-ray diffraction data:* A crystal of dimension 0.100x0.06x0.35 mm was used for the data collection on a NICOLET difractometer equipped with CuK$_\alpha$ radiation. Of the 3946 independent reflections, 2654 with $I>3\sigma(I)$ were used in the refinements. The structure was solved by direct methods and refined to R = 0.044 and R$_w$ = 0.055 with 414 parameters. $C_{24}H_{23}NO_{10}S_2$, M = 549.57, space group P1, a = 7.713(1), b = 8.521(2), c = 20.891(4) Å, α = 99.07(2), β = 92.28(2), γ = 102.79(3) °, V = 1318.1(4) Å$^3$, D$_c$ = 1.385 gcm$^{-3}$, Z = 2, $2\theta_{max}$ = 120°, temp 25 °C.

The next fractions contained 1.5 g (44 %) of **4** as pale yellow crystals with the same physical properties as the sample described above.

4-Methyl-5-(*trans*-1,2-dicarbomethoxy-2-acetoxyvinyl)-6,7-dicarbomethoxy-4,5-dihydro[2,3-*b*]-*iso*quinoline (**12**) was obtained from the last fractions in a yield of 264 mg (5 %), mp 131-133 °C after recrystallization from ethanol. IR (potassium bromide): ν CO 1715, 1730, 1770 cm-$^1$ . $^1$H NMR (deuteriochloroform): δ 7.60 (d, 1H, H8 or 9, J = 8.0 Hz), 7.55 (d, 1H, H 8 or 9, J = 8.0 Hz), 7.35 ( d, 1H, H2, J = 5.15 Hz), 7.30 (d, 1H, H1, J = 5.15 Hz), 6.55 (s, 1H, H5), 3.91, 3.89, 3.86, 3.23 (s, 3H, OCH$_3$), 3.00 (s, 1H, NCH$_3$), 2.12 (s, 3H, COCH$_3$). Peak matching for M$^+$. Calcd. for $C_{24}H_{23}NO_{10}S$: 517.1043. Found: 517.1038.

*5-Methylphenanthridinium iodide* **13**:

To a solution of phenanthridine[21] (1.79 g, 10.0 mmol) in anhydrous benzene (150 ml) methyl iodide (2.13 g, 15.0 mmol) was added and the reaction mixture was stirred at room temperature for two days. The formed precipitate was filtered off and washed with benzene. After evaporation 2.80 g (95 %) of the title compound was obtained, mp 206 °C (lit.[10] mp 202 °C).

*Reaction of 5-methylphenanthridinium iodide (13) with dimethyl acetylenedicarboxylate and acetic acid in dioxane:*

To a suspension of **13** (1.55 g, 5.00 mmol) in dioxane (50 ml), DMAD (2.15g, 15 mmol) and acetic acid (1.5 ml ) was added and the reaction mixture was stirred under reflux for 1.5 h, after which the reaction mixture was poored into ice-cold water, diethyl ether was added, the phases separated and the water phase extracted several times with diethyl ether. The combined ether phases were washed with sodium hydrogen carbonate solution and dried over magnesium sulfate. After evaporation the residue was chromatographed using ethyl acetate/heptane (1:6 and 1:1) as eluents. The first fractions gave 1.25 g (54 %) of 5-methyl-6-(*trans*-1,2-dicarbomethoxy-2-iodovinyl)-5,6-dihydrophenanthridine (**14**) as yellow crystals, mp 179 - 181 °C after recrystallization from ethanol. IR (potassium bromide): ν CO 1730 and 1770 $cm^{-1}$. $^1H$ NMR (deuterated acetone) δ 7.82 (q, 1H, H7, J = 7.70, 1.10 Hz), 7.74 (q, 1H, H10, J = 7.75, 1.50), 7.40-7.16 (m, 4H, H1, 3, 8, 9), 6.77 (t, 1H, H2, J = 7.50 Hz), 6.70 (d, 1H, H4, J = 8.35 Hz), 6.59 (s, 1H, H6), 3.94 , 3.04 (s, 3H, $OCH_3$), 3.00 (s, 3H, $NCH_3$). Peak matching for $M^+$. Calcd. for: $C_{20}H_{18}INO_4$: 463.0281. Found: 463.0279.

The later fractions contained 237 mg (12 %) of 5-methyl-6-(***trans***-1,2-dicarbomethoxy-2-acetoxyvinyl)5,6-dihydrophenanthridine (**15**) as yellow crystals mp 108-110 °C after recrystallisazation from ethanol. IR (potassium bromide): ν CO 1725, 1730 and 1750 $cm^{-1}$. $^1H$ NMR (deuterated acetone): δ 7.82 (d, 1H, H7, J = 7.70 Hz), 7.73 (q, 1H, H10, J = 7.85, 1.20 Hz), 7.40 - 7.16 (m, 4H, 1, 3, 8, 9), 6.78 (d, 1H, H2, J = 7.45 Hz), 6.70 (d, 1H, H4, J = 8.10 Hz), 6.59 (s, 1H, H6), 3.94, (s, 3H, $OCH_3$), 3.04 (s, 3H, $OCH_3$), 3.00 (s, 3H, $NCH_3$), 2.25 (s, 3H, $COCH_3$).

*Anal.* Calcd. for $C_{22}H_{21}NO_6$: C, 66.83; H,4.58; N, 3.54, MW 395 . Found: C, 66.47; H, 4.35; N, 3.51; MW 395.

*4-Methyl-5-(trans-1,2-dicarbomethoxyx2-iodovinyl)-4,5-dihydrodithieno[3,4-b:3',2'-d]pyridine* **16:**

To a solution of **3** (333 mg, 1.00 mmol) in dioxane (10 ml) DMAD (420 mg, 3.00 mmol) and acetic acid (0.33 ml) were added. The reaction mixture was refluxed for 2.5 h. The solution was poured into ice-cold water. The phases were separated and the aqueous phase was extracted several times with diethyl ether. The combined ether phases were washed with sodium hydrogen carbonate solution, treated with charcoal and dried over magnesium sulfate. After column chromatograghy and recrystallization from ethanol 133 mg (28 %) of the title compound was obtained, mp 132-134 °C. IR (potassium bromide): ν 1720 and 1725 $cm^{-1}$. $^1H$ NMR (deuteriochloroform): δ 7.30 (d, 1H, H7, J = 5.0 Hz), 7.20 (d, 1H, H8, J = 5.0 Hz), 7.10 (d, 1H, H1, J = 3.0 Hz), 7.02 (d, 1H, H3, J = 3.0 Hz), 6.10 (s, 1H, H5), 3.90 (s, 3H, $OCH_3$), 3.25 (s, 3H, $OCH_3$), 2.95 (s, 3H, $NCH_3$). Peak matching for $M^+$. Calcd. for $C_{16}H_{14}INO_4S_2$ : 475.0364. Found: 475.0391

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