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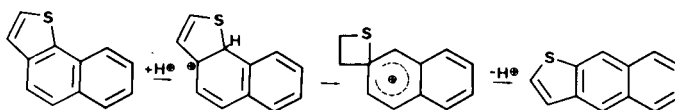
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The synthesis of benzonaphthothiophenes **9** and **10** and of benzophenanthrothiophenes **14-17** through Elbs cyclodehydration of *ortho*-methylated aroylbenzo[*b*]thiophenes is described. The occurrence of a rearrangement of the thiophene ring in the course of the cyclization is discussed as well as the influence of the temperature on a concurrent cyclodehydration process. Several of these poly-condensed thiophenes were found carcinogenic in mice.

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The environmental occurrence of polycyclic aromatic hydrocarbons (PAH) has been widely studied because of the adverse properties, *e.g.* mutagenic and/or carcinogenic, of a number of such compounds [1]. Analogous sulfur heterocycles, in which one aromatic ring has been replaced by a thiophene ring, have been shown to occur concomitantly with PAH in numerous mixtures like coal-derived products [2] and shale oils [3] and the last few years have known a tremendous development in the synthesis of polycyclic aromatic sulfur heterocycles all around the world and particularly in the U. S. with the Lee and Castle group [4a-c]. Although some data suggest that such compounds are carcinogenic in the laboratory animals [5,6] and mutagenic [7,8] we still know very little about the biological properties of these heterocyclic molecules, as compared to those of the related PAH, mostly because of the lack of standards.



Several years ago we mentioned briefly the synthesis of various naphtho- and phenanthrobenzothiophenes through the Elbs pyrolysis of *ortho*-methylated benzoyl- or naphthoylbenzo[*b*]thiophenes [9]. This paper describes these syntheses and various observations related to the course of the Elbs reaction as a function of the temperature conditions. A thermal rearrangement of the thiophene ring during cyclodehydration of 3-(2-methylbenzoyl)benzo[*b*]thiophene (**1**) was known to occur [10,11] leading to benzo[*b*]naphtho[2,1-*d*]thiophene (**9**) instead of benzo[*b*]naphtho[2,3-*d*]thiophene (**10**) whereas 3-(2-methyl-1-naphthoyl)benzo[*b*]thiophene (**5**), one of the naphthalene

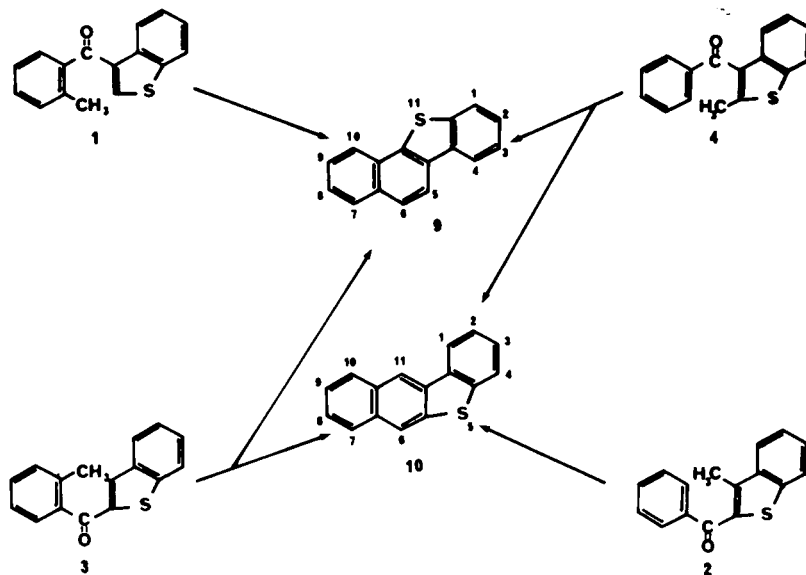


Table 1

Yields in the Various Identified Compounds Obtained from the Elbs Pyrolysis of Ketones 1-4

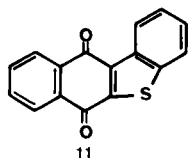
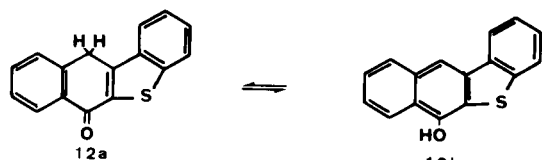
Starting	Temperature °C	Cyclodehydration		Reduced Ketone	Cyclodehydrogenation Products (anthrone + quinone)	Overall Yield % [a]
		<b>9</b>	<b>10</b>			
<b>1</b>	420	64.5 (64.5)	—	11 (3.5)	[b]	27
	390	12 (3.5)	—	2 (0.5)	7 (2)	6
	360	36 (2.5)	—	3 (0.25)	21 (1.5)	4.25
<b>2</b>	420	—	9 (9)	15 (15)	42.5 (42.5)	66.5
	390	—	3 (3)	16 (16)	36.5 (36.5)	55.5
	360	—	1 (1)	13.5 (13.5)	35 (35)	49.5
<b>3</b>	420	2.5 (2.5)	30 (30)	0.5 (0.5)	traces	33
	390	2.5 (2)	5.5 (4.5)	12.5 (10)	28 (22.5)	39
	360	3.3 (3)	2.2 (2)	19.5 (18)	40 (37)	60
<b>4</b>	420	4 (4)	6 (6)	12.5 (12.5)	[b]	22.5
	390	2 (1)	4 (2)	25.5 (9.5)	10.5 (4) [c]	19.5
	360	2 (0.75)	4 (1.5)	40 (14)	24 (8.5) [c]	28.5

Yields were calculated on the basis of the actual amount of reacted ketone (starting material less recovered ketone). Values between brackets refer to the yield based on the amount of starting material. [a] Overall yield of identified products based on the quantity of starting ketone. [b] Present but not isolated. [c] Underestimation because of the difficulties to extract anthrone and quinone from the complex mixture obtained.

Table 2

<sup>1</sup>H NMR Spectra (100 MHz) of Poly-condensed Thiophenes **9**, **10** and **14-17** in Deuteriochloroform, (δ values in ppm relative to TMS)

Structure	H	H	H	H	H	H	H	H	H	H	H	H	Measured resolved coupling
	1	2	3	4	5	6	7	8	9	10	11	12	
Dibenzo[ <i>c,d</i> ]thiophene	8.18	7.47	7.47	7.80									
<b>9</b>	7.92	7.50	8.21	8.17	7.87	8.05	7.61	8.05	—	—	—		J <sub>1,4</sub> = 0.7 Hz, J <sub>5,6</sub> = 8.7 Hz J <sub>6,7</sub> = 0.4 Hz, J <sub>6,10</sub> = 0.2 Hz
<b>10</b>	8.27	7.50	7.83	—	8.28	7.99	7.50	7.99	8.62	—	—		J <sub>1,4</sub> = 0.7 Hz
<b>14</b>	8.04	7.55	8.34	8.44	8.03	7.94	7.87	7.79	9.33	—			J <sub>1,4</sub> = 0.7 Hz, J <sub>5,6</sub> = 8.4 Hz
<b>15</b>	8.41	7.52	7.89	—	8.31	7.77	7.90	7.70	8.88	9.46			J <sub>1,4</sub> = 0.7 Hz, J <sub>6,13</sub> = 0.6 Hz
<b>16</b>	8.26	7.52	7.97	—	8.06	7.92	7.74	8.78	8.77	8.37			J <sub>1,4</sub> = 0.7 Hz, J <sub>12,13</sub> = 8.7 Hz, J <sub>6,7</sub> = 9 Hz, J <sub>6,12</sub> = 0.8 Hz
<b>17</b>	8.30	7.50	7.90	—	9.13	8.77	7.57	7.92	7.67	7.89	8.62		J <sub>1,4</sub> = 0.7 Hz



analogues of **1**, was found to undergo thermal cyclization to benzo[*b*]phenanthro[3,2-*d*]thiophene (**15**) without modification of the heterocycle [12]. On the other hand 2-benzoyl-3-methylbenzo[*b*]thiophene (**2**) cyclodehydration was also shown to occur exclusively following the expected way which leads to benzonaphthothiophene **10** [13]. This rather surprising observation prompted us to study the behaviour, under the Elbs conditions, of all four isomeric *ortho*-methylated benzoyl-2/3-benzo[*b*]thiophenes **1-4** as well as of the four 1-naphthoyl analogues **5-8**.

Compounds **1** and **5** were prepared as described [10,12]; however the Friedel-Crafts acylation of benzo[*b*]thiophene either with 2-methylbenzoyl chloride or with 2-methyl-1-naphthoyl chloride did not occur exclusively at the 3 position of the heterocycle as reported, but rather at both carbons 2 and 3, leading to a mixture of **1** and **3** (66.5%/33.5%) and **5** and **6** (75%/25%).

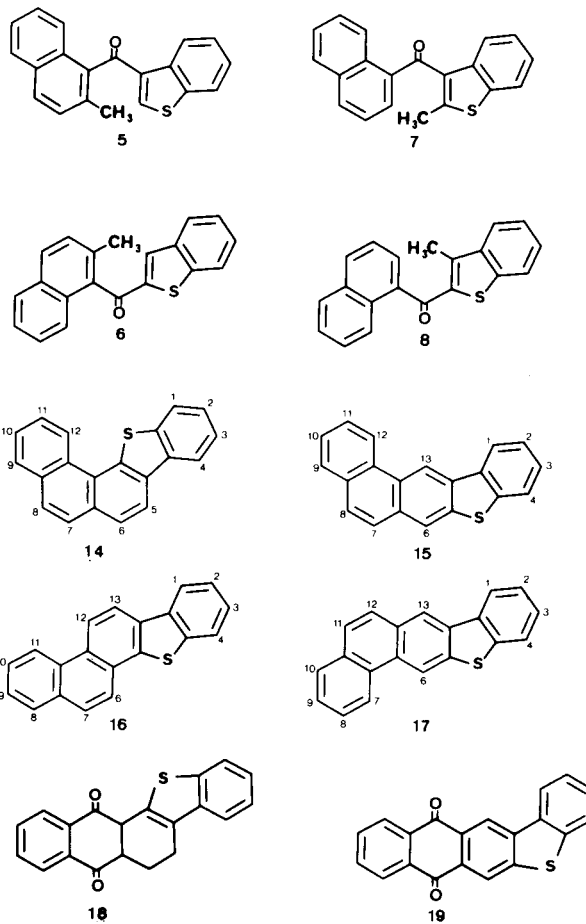
Ketones **2** and **8** were easily obtained following the procedure described by Werner [13] for the synthesis of **2** using direct acylation of 3-methylbenzo[*b*]thiophene, whereas the same reaction applied to 2-methylbenzo[*b*]thiophene led us to compounds **4** and **7**. Finally ketones **3** and **6** were prepared by acylation of 4,5,6,7-tetrahydrobenzo[*b*]thiophene (this substrate has been shown to react at the 2 position [14]) and subsequent dehydrogenation by heating with sulfur. In addition to the expected cyclodehydrated molecules the Elbs pyrolysis is known to produce numerous side products [15-17] among which the diaryl methane resulting from the reduction of the starting material [16]. The formation of such compounds is in good agreement with the occurrence of a competitive cyclodehydrogenation reaction leading to anthrone analogues which can be subsequently oxidized to the corresponding quinones [17]. The whole process was clearly summarized by the general scheme proposed by Faller in 1966 [16].

Since the competition between the two cyclization processes appears to be markedly dependent on the temperature, ketones **1-4** were pyrolyzed at three different temperatures (360, 390 and 420°).

Ketones **1** and **2** confirmed previous observations by Badger and Christie [10] and by Werner [13] affording respectively benzo[*b*]naphtho[2,1-*d*]thiophene (**9**) and benzo[*b*]naphtho[2,3-*d*]thiophene (**10**), whereas ketones **3** and **4** gave a mixture of these two compounds, in almost constant proportions in the case of **4** and in a strongly temperature dependent ratio in the case of **3** for which the highest temperature afforded mainly the "normal" cyclization product **10**.

Besides these cyclodehydration products, various compounds resulting from the competitive cyclodehydrogenation pathway also occurred (e.g. cyclized molecules as well as reduced ketone) which became preponderant at the lowest temperature especially in the case of benzoyl methylbenzo[*b*]thiophenes **2** and **4** (Table 1). Among these products benzo[*b*]naphtho[2,3-*d*]thiophene-6,11-dione (**11**) was identified by comparison with an authentic sample obtained by phthaloylation of benzo[*b*]thiophene [18]. Besides this quinone we obtained another type of compound whose microanalytical and mass spectral characteristics were consistent with structures **12** and **13**. Although the strong polarity of these molecules involves probably structures **12b** and **13b**, the complexity of the nmr spectrum and the variation of the relative intensity of each signals from one experiment to one another clearly show an equilibrium between the ketonic structures **12a** or **13a** and the phenolic ones **12b** or **13b**.

These last compounds were quantitatively converted to quinone **11** either by chromic acid oxidation or by chromatography on alumina. They also underwent very easily a molecule doubling by loss of a hydrogen atom leading to strongly colored compounds whose structure has not been



established. Although diarylmethanes produced by reduction of the starting ketones were the only hydro compounds identified, by comparison with authentic samples, several other molecules with very close retention time by gc were also detected. From the point of view of the overall reaction, it appears that the temperature has a predominant effect since only a few of the starting ketones are transformed at 360° and 390° whereas it completely disappears at 420°. Qualitatively the cyclodehydrogenation is clearly predominant at low temperature whereas it does not appear at 420°, except in the case of 2-benzoyl-3-methylbenzo[*b*]thiophene (**2**).

The yields of cyclodehydration products **9** and/or **10** are better starting from (2-methylbenzoyl)benzo[*b*]thiophenes than from benzoylmethylbenzo[*b*]thiophenes and are maximal at the boiling point of the ketones. On the other hand the yields of by-products (anthrone/phenol, quinone, reduced ketone) based on the reacted ketone are lower in the case of **1** and **3** than in the case of **2** and **4** (Table 1). Since our primary goal was the synthesis of poly-condensed thiophenes, the Elbs pyrolysis of ketones **5-8** was carried out under the conditions expected to furnish the highest yield in cyclodehydration products. In other words, the reaction was carried out at 430-440° which is the temperature re-

quired for a gentle reflux of the starting material.

Cyclization of 3-(2-methyl-1-naphthoyl)benzo[*b*]thiophene (**5**) afforded a mixture of three compounds in the proportion of 91%, 6.5% and 2.5% from which only the major component was isolated. Its nmr spectrum shows the presence of two AB systems, easily identified by double resonance techniques [19] and particularly by INDOR [20], and consistent with the structure of benzo[*b*]phenanthro[3,4-*d*]thiophene (**14**). The complete assignment of the nmr spectrum was made starting from the observation of the unresolved long range coupling between H8, one of the component of one of the identified AB systems, and H12 and H9. Protons H4 and H5 are deshielded by their mutual interaction as observed in phenanthrene and in the unsubstituted dibenzothiophene (Table 2). The strong deshielding of H12 (9.33 ppm) is also consistent with structure **14** in which this proton is sterically hindered by the sulfur atom. Additionally this compound underwent easy chromic acid oxidation to a red quinone which reacted with *ortho*-phenylenediamine to form a phenazine either at the 5,6 or at the 7,8 positions and its melting point is in good agreement with those given by Lee and coworkers for **14** obtained by photocyclization of 1-[3-(1)benzothieryl]-2-(2-naphthyl)ethylene [4a].

On the basis of pyrolysis of ketone **2**, 2-(1-naphthoyl)-3-methylbenzo[*b*]thiophene (**8**) was expected to lead exclusively to benzo[*b*]phenanthro[2,3-*b*]thiophene (**17**) and we found actually a single cyclization product whose nmr spectrum was consistent with structure **17**. This spectrum showed a single AB system and two protons of the meso acenic type. One of these resonances, deshielded by interaction with proton H7, exhibits a resolved coupling of 0.5 Hz which was assigned, by selective decoupling experiments, to the spin-spin coupling with a component of the AB system, *i.e.* proton H12. However both the melting point and the uv spectrum were different from those reported for **17** obtained either by pyrolysis of 3-(1-methyl-2-naphthoyl)benzo[*b*]thiophene [12] or by reduction of the corresponding "anthrone" [21]. This compound was found chromatographically (by gc) identical to the minor product formed by cyclization of ketone **15**.

Under the same conditions, ketone **6** afforded three products in the relative proportions of 58%, 23% and 19% from which benzo[*b*]phenanthro[2,1-*d*]thiophene (**16**) was easily isolated on account of its very low solubility and was identified by comparison with an authentic sample obtained by photosynthesis [22]. This compound was the minor component of the mixture and, as expected for structure **16**, its nmr spectrum showed two AB systems (Table 2). The major compound in this pyrolysis (58%) was identified by gc as the expected benzophenanthrothiophene **17** which was obtained previously in the cyclodehydration of ketone **8**.

Finally, 3-(1-naphthoyl)-2-methylbenzo[*b*]thiophene (**7**) underwent thermal cyclization to a mixture of three polycondensed thiophenes among which **14** (18%) and **17** (16%) have been identified by comparison with authentic samples obtained in the preceding experiments. The major product of the reaction (66%) was isolated by fractional crystallization. Its nmr spectrum (Table 2) shows two protons of the meso acenic type, one of which is strongly shifted downfield. Between these two signals appear two protons belonging to two different ABCD systems. This figure strongly supports structure **15** with respectively H13, H12, H1 and H6 in the order of increasing field. However this compound was different, on the basis of its melting point and absorption spectrum, of benzo[*b*]phenanthro[3,2-*d*]thiophene **15** described previously [12,21]. These last data allowed the identification of the third component in the mixture resulting from the Elbs pyrolysis of ketones **5** and **6** as benzo[*b*]phenanthro[3,2-*d*]thiophene (**15**).

Table 3 summarizes these results as well as the overall yield of benzophenanthro thiophenes obtained through cyclodehydration of ketones **5-8**.

The formation of **17** and **15** by pyrolysis either of ketones **5** and **7** or of ketone **6** respectively was unexpected, however, by analogy with the conversion of phenanthrene to anthracene [23] we can conceive the same mechanism for the transformation of the central naphtho[1,2-*b*]thiophene ring of **14** and **16** to the naphtho[2,3-*b*]thiophene system of **17** and **15** (Scheme 1). This hypothesis is also in good agreement with the oxidative conversion of 4a,6a,7,12,12a,12b-hexahydrobenzo[*b*]anthraceno[2,1-*d*]thiophene-7,12-dione (**19**) [24].

In no case, did the present observation result from a simple thermal rearrangement of **14** and **16** since these two compounds were not modified by heating 30 minutes at 440-450° in sealed tube.

Duplication of the synthesis of **15** and **17** described by Tilak and coworkers [21] in fact afforded respectively **14** and **16** [25]. On the basis of our results we suggest that Badger and Christie [12] obtained also **14** and **16** rather than **15** and **17** through the Elbs pyrolysis of 3-(2-methyl-1-naphthoyl)benzo[*b*]thiophene (**5**) and 3-(1-methyl-2-naphthoyl)benzo[*b*]thiophene respectively. Our observations, in

Table 3

Yields in Benzophenanthrothiophenes Starting from Ketones **5-8**

Starting ketone	Overall Yield%	Relative proportions in benzophenanthrothiophenes			
		<b>15</b>	<b>17</b>	<b>16</b>	<b>14</b>
<b>5</b>	39	6.5	2.5	—	91
<b>6</b>	17.5	23	58	19	—
<b>7</b>	37	67	15.5	—	17.5
<b>8</b>	20.5	—	100	—	—

terms of the occurrence of Badger's rearrangement of the thiophene ring, can be interpreted by considering the preferential conjugation of the carbonyl group either with the heterocycle or the homocycle on the one hand and the site of substitution of the thiophene ring on the other. It clearly appears that when the methyl group is on the homocycle, in other words when the CO group is conjugated with the heterocycle, and the aroyl residue is attached to the  $\beta$  position of the thiophene system, then the rearrangement occurs almost completely (case of **1** and **5**). On the other hand, conjugation of the carbonyl with the homocycle associated with substitution at the  $\alpha$  position of the heterocycle led exclusively to a "normal" cyclization (case of **2** and **8**). In all other cases which associate either CO conjugation with the heterocyclic system and  $\alpha$  substitution (case of **3** and **6**) or CO conjugation with the homocycle and  $\beta$  substitution (case of **4** and **7**) the cyclization occurred following both pathways.

With regard to the Elbs reaction, our results confirmed previous ones [16,17] related to the competition between the expected cyclodehydration process and a cyclodehydration mechanism affording anthronic molecules, which can undergo further oxidation to quinones, and various reduced derivatives of suitable substrates present in the medium upon hydrogenation by H<sub>2</sub> release by this mechanism.

Compounds **9**, **14**, **15** and **17** were found more carcinogenic in mice, by subcutaneous injection, than the analogous hydrocarbons (chrysene, benzo[*e*]chrysene, dibenzo[*a,j*]anthracene, dibenz[*a,h*]anthracene respectively). Benzo[*b*]phenanthro[3,4-*d*]thiophene (**14**) was actually as potent as benz[*a*]pyrene [26].

## EXPERIMENTAL

The control of the starting materials and of the reaction products was carried out by tlc (Silicagel G Merck, 0.25 mm) or by gc using a Girdel 75 CS gas chromatograph (flame ionization detector, nitrogen as carrier gas) fitted either with 2 m (od 1/8") stainless steel column packed with 5% SE 30 on chromosorb W or with a capillary column (15 m, ID 0.5 mm) packed with OV 17. The relative proportion of the components of the various mixtures was established using a LTT 1103 integrator. The nmr spectra were recorded either on a Varian T60 (60 MHz) or on a Varian XL 100 (100 MHz) and, unless other specification, in deuteriochloroform solution. The chemical shifts are given in ppm downfield, TMS used as internal standard ( $\delta = 0$ ). The uv visible absorption curves were measured in cyclohexane solution on a spectrophotometer Leres S66. Wavelengths are given in nm and log  $\epsilon$  is given between brackets after each value. Mass spectra were recorded on a AEI MS9 apparatus. Melting points were determined either on a Maquenne block or on a Buchi apparatus and are not corrected. Separation of the reaction mixtures after pyrolysis were done by liquid chromatography (Kieselgel Merck 60) eluting first with cyclohexane (non-functional compounds) and enriching progressively the liquid phase with benzene (starting ketone) to reach 100% benzene (quinone) and finally with acetone (phenols/anthrones). Final purification of poly-condensed thiophenes was achieved by chromatography on silicagel (eluting with hexane) and repeated crystallization.

## General Technique of Acylation.

A solution of 0.01 mole of stannic chloride in 50 ml of anhydrous benzene was added dropwise to 0.01 mole of the thiophene compound and 0.01 mole of the acylating agent in 100 ml of anhydrous benzene. After addition the mixture is refluxed for 2 hours, cooled to room temperature and poured on ice. The benzenic phase is washed with water, with 5% sodium hydroxide and then with water again and finally dried over sodium sulfate. After removing the solvent by rotary evaporation the residual product is distilled under reduced pressure.

This procedure allowed the preparation of the following compounds:

### 2-Benzoyl-3-methylbenzo[*b*]thiophene (**2**).

This compound had bp<sub>12</sub> 235-236°, colorless prismatic crystals (methanol) mp 68° (lit [8] 58-59°), yield 72%; nmr: (100 MHz) [27] 2.56 (s, 3H, CH<sub>3</sub>), 7.47 (m, 2H, H<sub>5,6</sub>), 7.58 (m, 3H, H<sub>3',4',5'</sub>), 7.85 (m, 2H, H<sub>4,7</sub>), 7.9 (m, 2H, 2',6').

### 2-[1-Naphthoyl]-3-methylbenzo[*b*]thiophene (**8**).

This compound had bp<sub>15</sub> 290-292°, colorless prismatic crystals (methanol) mp 92°, yield 89%; nmr: (100 MHz) 2.46 (s, 3H, CH<sub>3</sub>), 7.44 (m, 2H, H<sub>5,6</sub>), 7.55 (m, 1H, H<sub>3'</sub>), 7.56 (m, 2H, H<sub>6',7'</sub>), 7.73 (m, 1H, H<sub>2'</sub>), 7.85 (m, 2H, H<sub>3,7</sub>), 7.95 (m, 1H, H<sub>5</sub>), 8.03 (m, 1H, H<sub>4'</sub>), 8.14 (m, 1H, H<sub>8'</sub>).

Anal. Calcd. for C<sub>20</sub>H<sub>14</sub>OS: C, 79.4; H, 4.7; S, 10.6. Found: C, 79.4; H, 4.7; S, 10.4.

### 3-Benzoyl-2-methylbenzo[*b*]thiophene (**4**).

This compound had bp<sub>13</sub> 227-228° colorless crystals (methanol), mp 76° (lit [13] mp 74.5-76.5°) yield 61%; nmr (100 MHz) 2.51 (s, 3H, CH<sub>3</sub>), 7.25 (m, 1H, H<sub>6</sub>), 7.27 (m, 1H, H<sub>5</sub>), 7.50 (m, 1H, H<sub>7</sub>), 7.53 (m, 3H, H<sub>3',4',5'</sub>), 7.78 (m, 1H, H<sub>4</sub>), 7.86 (m, 2H, H<sub>2',6'</sub>).

This last compound has also been obtained in 40% yield by sulfur dehydrogenation (250°) of 3-benzoyl-2-methyl-4,5,6,7-tetrahydrobenzo[*b*]thiophene (pale yellow oil, bp 208-210°).

### 3-[1-Naphthoyl]-2-methylbenzo[*b*]thiophene (**7**).

This compound had bp<sub>14</sub> 277-278°, thin colorless needles (methanol) mp 96°, yield 81%; nmr: (100 MHz) 2.35 (s, 3H, CH<sub>3</sub>), 7.30 (m, 2H, H<sub>5,6</sub>), 7.46 (m, 1H, H<sub>3</sub>), 7.58 (m, 2H, H<sub>6',7'</sub>), 7.64 (m, 1H, H<sub>2'</sub>), 7.76 (m, 2H, H<sub>4,7</sub>), 7.92 (m, 1H, H<sub>5</sub>), 8.03 (m, 1H, H<sub>4'</sub>), 8.50 (m, 1H, H<sub>8'</sub>).

Anal. Calcd. for C<sub>20</sub>H<sub>14</sub>OS: C, 79.4; H, 4.7; S, 10.6. Found: C, 79.2; H, 4.8; S, 10.4.

### 2-[2-Methylbenzoyl]-4,5,6,7-tetrahydrobenzo[*b*]thiophene.

This compound was obtained as a yellow oil, bp<sub>22</sub> 243-248°, yield 80%; nmr: (60 MHz) 1.78 (m, 4H, CH<sub>2</sub>(5,6)), 2.33 (s, 3H, CH<sub>3</sub>), 2.66 (m, 4H, CH<sub>2</sub>(4,7)), 7.05 (s, 1H, H<sub>3</sub>), 7.05-7.50 (env 4H, Har).

Anal. Calcd. for C<sub>16</sub>H<sub>16</sub>OS: C, 74.95; H, 6.3; S, 12.5. Found: C, 74.8; H, 6.2; S, 12.35.

Treatment of this compound (9 g) with sulfur (2.6 g) at 260° for 2 hours and distillation of the resulting mixture afforded the following:

### 2-[2-Methylbenzoyl]benzo[*b*]thiophene (**3**).

This compound had bp<sub>12</sub> 158-160°, colorless needles (cyclohexane), mp 95°, yield 50%; nmr: (100 MHz), 2.43 (s, 3H, CH<sub>3</sub>), 7.36 (m, 4H, H<sub>3',4',5',6'</sub>), 7.43 (m, 1H, H<sub>5</sub>), 7.49 (m, 1H, H<sub>6</sub>), 7.63 (m, 1H, H<sub>3</sub>), 7.82 (m, 1H, H<sub>4</sub>), 7.92 (m, 1H, H<sub>7</sub>).

Anal. Calcd. for C<sub>16</sub>H<sub>12</sub>OS: C, 76.2; H, 4.8; S, 12.7. Found: C, 76.0; H, 4.8; S, 12.9.

### 2-[2-Methyl-1-naphthoyl]-4,5,6,7-tetrahydrobenzo[*b*]thiophene.

This compound had bp<sub>18</sub> 294°, colorless crystals (ethanol), mp 110-111°, yield 78.5%.

Anal. Calcd. for C<sub>20</sub>H<sub>18</sub>OS: C, 78.4; H, 5.9; S, 10.5. Found: C, 78.4; H, 5.8; S, 10.6.

This compound, treated as above with sulfur, afforded, after chromatography on silicagel (eluting with a mixture of benzene:cyclohexane, 1:1) the following compound:

2-[2-Methyl-1-naphthoyl]benzo[*b*]thiophene (6).

This compound was obtained as pale yellow needles (methanol), mp 145-146°, yield 40.5%; nmr (100 MHz) 2.43 (s, 3H, CH<sub>3</sub>), 7.40 (m, 1H, H<sub>3</sub>), 7.43 (m, 2H, H<sub>6</sub>, 7'), 7.44 (m, 1H, H<sub>3</sub>), 7.55 (m, 2H, H<sub>5</sub>, 6), 7.65 (m, 1H, H<sub>8</sub>), 7.71 (m, 1H, H<sub>5</sub>'), 7.89 (m, 1H, H<sub>4</sub>'), 7.90 (m, 2H, H<sub>4</sub>, 7).

*Anal.* Calcd. for C<sub>20</sub>H<sub>14</sub>OS: C, 79.4; H, 4.7; S, 10.6. Found: C, 79.35; H, 4.7; S, 10.6.

3-[2-Methylbenzoyl]benzo[*b*]thiophene (1).

This compound was isolated from the mixture of isomers obtained by direct acylation of benzo[*b*]thiophene by two consecutive fractional distillations (bp<sub>13</sub> 140°) and further crystallization from methanol (the mixture was dissolved in the minimum amount of boiling methyl alcohol and crystals of **1** were separated before complete cooling of the solution), thin colorless needles, mp 96° (lit [3], mp 94°); nmr: (100 MHz) 2.39 (s, 3H, CH<sub>3</sub>), 7.33 (m, 4H, H<sub>3</sub>, 4', 5', 6'), 7.45 (m, 1H, H<sub>6</sub>), 7.55 (m, 1H, H<sub>5</sub>), 7.87 (m, 1H, H<sub>2</sub>), 7.90 (m, 1H, H<sub>7</sub>), 8.78 (m, 1H, H<sub>4</sub>).

3-[2-Methyl-1-naphthoyl]benzo[*b*]thiophene (5).

This compound was isolated free of the  $\alpha$ -isomer by two crystallizations from ethyl alcohol of the mixture obtained by direct acylation of benzo[*b*]thiophene, colorless leaflets, mp 161° (lit [6] mp 160-161°), yield 63%; nmr: (100 MHz) 2.40 (s, 3H, CH<sub>3</sub>), 7.39 (m, 1H, H<sub>3</sub>'), 7.41 (m, 2H, H<sub>6</sub>, 7'), 7.48 (m, 1H, H<sub>6</sub>), 7.63 (m, 2H, H<sub>5</sub>, 5'), 7.73 (m, 1H, H<sub>2</sub>), 7.84 (m, 1H, H<sub>8</sub>'), 7.87 (m, 1H, H<sub>4</sub>'), 7.91 (m, 1H, H<sub>7</sub>), 9.01 (m, 1H, H<sub>4</sub>).

## Elbs Pyrolysis.

As mentioned in the text ketones **1-4** were pyrolyzed at three different temperatures. At 420° and 390° the reaction was complete within 30 minutes and prolongation of the time of reaction led only to a partial destruction of the side products whereas at 360° the same reaction time did not modify significantly the starting ketone. In this last case we used a heating time of 2.5 hours however, even under these conditions the overall yields remained very low. Ketones **5-8** were pyrolyzed at 430-440° for 15 minutes and only the poly-condensed thiophenes formed were investigated. In all cases the reaction was carried out under a slight stream of nitrogen to prevent oxidation of the side products as well as to remove water formed during the cyclodehydration process.

## Poly-condensed Thiophenes.

Benzo[*b*]naphtho[2,1-*d*]thiophene (9).

This compound was obtained as colorless leaflets (hexane) mp 185° (lit [10] mp 185°); for nmr see Table 2.

Benzo[*b*]naphtho[2,3-*d*]thiophene (10).

This compound was obtained as colorless needles (ethanol); mp 163° (lit [12] mp 160°, lit [19] mp 155°); for nmr see Table 2.

6-Hydroxybenzo[*b*]naphtho[2,3-*d*]thiophene (12a) and/or (12b).

This compound was obtained as long colorless needles (toluene), mp 255-260°; ms: (200°) *m/z* 250 (100%), 125 (15%); ms: (300°) *m/z* 498 (100%), 249 (10%).

*Anal.* Calcd. for C<sub>16</sub>H<sub>10</sub>OS: C, 76.8; H, 4.0; S, 12.8. Found: C, 76.5; H, 3.8; S, 12.7.

By melting the compound it underwent a molecular doubling leading to a strongly colored product, mp >365°; ms: *m/z* 498 (100%), 249 (13%).

11-Hydroxybenzo[*b*]naphtho[2,3-*d*]thiophene (13a) and/or (13b).

This compound was obtained as colorless needles (toluene), mp 255-260°.

*Anal.* Calcd. for C<sub>16</sub>H<sub>10</sub>OS: C, 76.8; H, 4.0. Found: C, 76.5; H, 4.1.

After melting the product turned deep green and became solid again, mp >370°; ms: *m/z* 498 (100%).

Oxidation of **12**.

To 500 mg of **12** in solution of 50 ml of acetic acid one adds 500 mg of

chromic anhydride and the resulting solution was refluxed for ½ hour. By cooling, yellow needles of benzo[*b*]naphtho[2,3-*d*]thiophene-6,11-dione (**11**) came out, yield 76%, mp 213°, (lit [19] mp 212-214°).

Benzo[*b*]phenanthro[3,2-*d*]thiophene (15).

This compound was obtained as colorless needles (ethanol), mp 184° (lit [10] mp 143°, lit [21] mp 115°); for nmr see Table 2; uv: 234 (4.55), 244 (4.58), 267 (4.6), 278 (4.75), 288 (4.93), 299 (4.78), 320 (4.07), 338 (4.11), 353 (3.31), 372 (3.19).

*Anal.* Calcd. for C<sub>20</sub>H<sub>12</sub>S: C, 84.5; H, 4.25. Found: C, 84.51; H, 4.00.

Benzo[*b*]phenanthro[2,3-*d*]thiophene (17).

This compound was obtained as pale yellow leaflets (benzene), mp 245° (lit [4c] mp 327°, lit [10] mp 323°, lit [21] mp 328°) [28]; for nmr see Table 2; uv: 220 (4.35), 253 (4.46), 262 (4.55), 271 (4.76), 285 (4.87), 292 (4.91), 317 (4.31), 329 (3.83), 359 (2.82), 378 (3.20).

*Anal.* Calcd. for C<sub>20</sub>H<sub>12</sub>S: C, 84.5; H, 4.25. Found: C, 84.4; H, 4.1.

Benzo[*b*]phenanthro[3,4-*d*]thiophene (14).

This compound was obtained as colorless needles (cyclohexane), mp 127° (lit [4a] mp 120-122°); for nmr see Table 2; uv: 231 (4.73), 248 (4.82), 272 (4.93), 280 (4.89), 295 (4.65), 308 (4.70), 330 (3.86), 348 (3.81), 365 (3.98).

*Anal.* Calcd. for C<sub>20</sub>H<sub>12</sub>S: C, 84.5; H, 4.25. Found: C, 84.4; H, 4.1.

Benzo[*b*]phenanthro[3,4-*d*]thiophene-5,6- or 7,8-dione.

This compound was obtained as red needles (acetic acid), mp 270°.

*Anal.* Calcd. for C<sub>20</sub>H<sub>10</sub>O<sub>2</sub>S: C, 76.4; H, 3.2; S, 10.2. Found: C, 76.1; H, 3.1; S, 10.1.

This compound underwent easy condensation with *ortho*-phenylenediamine to form a phenazine as short yellow needles (dioxane), mp 295°.

*Anal.* Calcd. for C<sub>26</sub>H<sub>14</sub>N<sub>2</sub>S: C, 80.8; H, 3.7; N, 7.2. Found: C, 80.3; H, 3.9; N, 7.15.

Benzo[*b*]phenanthro[2,1-*d*]thiophene (16).

This compound was obtained as colorless leaflets (benzene) mp 331°, (lit [22] mp 331°, lit [4a] mp 230°, lit [4c] mp 330°); for nmr see Table 2; uv: 220 (4.43), 253 (4.73), 2.60 (4.68), 270 (4.67), 277 (4.69), 287 (4.7), 305 (4.57), 310 (4.44), 320 (3.72), 330 (3.59), 346 (3.59), 362 (3.64).

Reduction of Ketones **1-4**.

The diarylmethanes corresponding to ketones **1-4** were obtained by reduction with refluxing formic acid and zinc dust for 24 hours. After dilution with water and extraction with dichloromethane the organic phase was washed with water, dried over calcium chloride and concentrated under reduced pressure. The residual oil was distilled under vacuum to afford the expected benzylic compounds in a yield of about 45%.

3-[2-Methylbenzyl]benzo[*b*]thiophene.

This compound was obtained as a colorless oil, bp<sub>15</sub> 185-190°; nmr: (60 MHz) 2.26 (s, 3H, CH<sub>3</sub>), 4.06 (d, 2H, CH<sub>2</sub>, J<sub>CH<sub>2</sub>,H<sub>2</sub></sub> = 1.5 Hz), 6.66 (m, 1H, H<sub>2</sub>), 7.2 (s, 4H, H<sub>3</sub>, 4', 5', 6'), 6.96-7.56 (env, 4H, H<sub>4</sub>, 5, 6, 7).

*Anal.* Calcd. for C<sub>16</sub>H<sub>14</sub>S: C, 80.6; H, 5.9. Found: C, 80.6; H, 6.0.

2-Benzyl-3-methylbenzo[*b*]thiophene.

This compound was obtained as a colorless oil bp<sub>20</sub> 190-195°; nmr: (60 MHz) 2.16 (5s, 3H, CH<sub>3</sub>), 3.98 (s, 2H, CH<sub>2</sub>), 7.06 (s, 5H, H<sub>2</sub>, 3', 4', 5', 6'), 6.83-7.76 (env, 4H, H<sub>4</sub>, 5, 6, 7).

*Anal.* Calcd. for C<sub>16</sub>H<sub>14</sub>S: C, 80.6; H, 5.9. Found: C, 80.7; H, 5.85.

2-[2-Methylbenzyl]benzo[*b*]thiophene.

This compound was obtained as colorless leaflets (methanol), mp 57°; nmr: (60 MHz) 2.33 (s, 3H, CH<sub>3</sub>), 4.21 (d, 2H, CH<sub>2</sub>, J<sub>CH<sub>2</sub>,H<sub>3</sub></sub> = 1.5 Hz), 6.88 (m, 1H, H<sub>3</sub>), 7.2 (s, 4H, H<sub>3</sub>, 4', 5', 6'), 7.13-7.86 (env, 4H, H<sub>4</sub>, 5, 6, 7).

*Anal.* Calcd. for C<sub>16</sub>H<sub>14</sub>S: C, 80.6; H, 5.9. Found: C, 80.75; H, 5.9.

3-Benzyl-2-methylbenzo[*b*]thiophene.

This compound was obtained as a colorless oil, bp<sub>12</sub> 180-185°; nmr:

(60 MHz) 2.4 (s, 3H, CH<sub>3</sub>), 4 (s, 2H, CH<sub>2</sub>), 6.98 (s, 5H, H<sub>2',3',4',5',6'</sub>), 6.71-7.75 (env, 4H, H<sub>4,5,6,7</sub>).

Anal. Calcd. for C<sub>16</sub>H<sub>14</sub>S: C, 80.6; H, 5.9. Found: C, 80.5; H, 5.9.

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- [26] F. Zajdela, *et al.*, to be published. (Mice of the XVII nc/Z strain received subcutaneous injections, at 4 week intervals, of 0.6 mg of the test compound dissolved in 0.2 ml of neutral olive oil. Animals were killed when they had developed large tumors or at the end of the experiment, at an age of 700-800 days).
- [27] Abbreviations are s, singlet; d, doublet; m, multiplet; env, envelope.
- [28] In spite of numerous purifications and crystallizations, we never reached the mp described by Lee, Castle and coworkers for this compound which they synthesized unambiguously [4c], however, analytical and spectroscopical data are consistent with the proposed structure.