Pyridine-Substituted Hydroxythiophenes. IV. Preparation of 3- and 4-(2-, 3- and 4-Pyridyl)-2-hydroxythiophenes

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3-(2-, 3- and 4-Pyridyl)-2-methoxythiophenes have been prepared in good yields through the Pd(0)-catalyzed coupling of the three isomeric bromopyridines with 3-trimethylstannyl-2-methoxythiophene. This compound was prepared through halogen-metal exchange of 3-bromo-2-methoxythiophene followed by stannylation. 3-Bromo-2-methoxythiophene was prepared by dibromination and α-debromination of 2-methoxythiophen. Most attempts to demethylate 2-methoxy-3-pyridylthiophenes using a large variety of reagents failed, probably due to the instability and high reactivity of the desired 3-pyridyl-2-hydroxythiophene systems. Only 2-methoxy-3-(3-pyridyl)thiophene reacted with boron tribromide to give 3-(3-pyridyl)-3-thiolene-2-one, which only was stable in ether solution at -20°. The attempted demethylation of 2-methoxy-3-(2-pyridyl)thiophene with trimethylsilane chloride/sodium iodide in refluxing acetonitrile led to a dimer. Demethylation of the 2-methoxy-3-pyridylthiophenes with dibenzyl diselenide and sodium borohydride gave 3-pyridylthiophan-2-ones.

A number of other routes to prepare 3-pyridyl-2-hydroxythiophenes were also explored, but none of them gave the desired compounds. On the other hand, the 4-(2-, 3-, and 4-pyridyl)-2-hydroxythiophene systems could easily be prepared by hydrogen peroxide oxidation of the corresponding 4-pyridyl-2-thiopheneboronic esters, which were obtained from 2-bromo-4-pyridylthiophenes by halogen-metal exchange followed by reaction with ethyl borate. The 2-bromo-4-pyridylthiophenes were prepared by dibromination of the known 3-pyridylthiophenes to the 2,5-dibromo derivatives, and removal of the 2-bromine by halogen-metal exchange at -100°, followed by hydrolysis. The ^1H nmr and ir spectroscopic investigations show that these quite stable 2-hydroxythiophene systems exist exclusively in the 4-pyridyl-3-thiolen-2-one forms.

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Introduction.

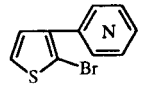
In a recent paper [1], the preparation of *o*-(2-, 3- and 4-pyridyl)-3-hydroxythiophenes was described. Spectroscopic investigations showed that these potentially tautomeric compounds exist solely in the enol forms. It is known that carbonyl-substituted 3-hydroxythiophenes also exist exclusively in the hydroxy aromatic forms independent of the position of carbonyl groups [2]. However, alkyl-substituted 3-hydroxythiophenes were shown to exist as a mixture of the keto- and enol-tautomers [3].

The 2-hydroxythiophenes show interesting tautomeric behavior as most alkyl-, aryl- and halo-substituted 2-hydroxythiophenes that have been prepared exist as α,β- and β,γ- unsaturated γ-thiolactones [4-13]. The only exceptions so far are 3-carbonylsubstituted 2-hydroxythiophenes and 5-carbethoxy-2-hydroxythiophene. The former exists exclusively in the hydroxy form in the pure liquid state and in solution, while the latter exists as a mixture containing 85% of the enol form and 15% of β,γ-unsaturated γ-thiolactone [14,15]. In this paper we present our investigations of the 3- and 4-pyridyl-substituted 2-hydroxythiophene systems.

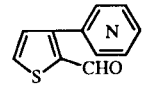
Results and Discussion.

Syntheses.

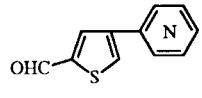
The initial strategy for the preparation of 3-pyridyl-2-hydroxythiophenes was that used for the preparation of *o*-pyridyl-3-hydroxythiophenes. The 3-(2-, 3- and 4-pyridyl)thiophenes were brominated with *N*-bromosuccinimide in acetic acid [16] giving 2-bromo-3-(2-, 3- and 4-pyridyl)thiophenes **1-3** in yields of 42-60%, each of which underwent lithiation by halogen-metal exchange with butyllithium at -100°. However, reaction of the lithium derivatives with ethyl borate followed by oxidation with 30% hydrogen peroxide did not lead to the desired hydroxy systems; only the parent pyridylthio-



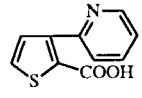
1 2-N
2 3-N
3 4-N



4 2-N
5 3-N
6 4-N



7 3-N
8 4-N



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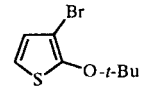

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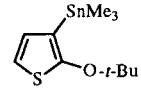

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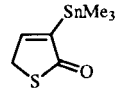

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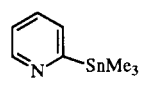

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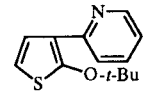

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phenes were obtained. Analyses (glc) used for monitoring the reactions showed that the boronation step was unsuccessful. Elevation of reaction temperature in this step (from -100° to -70° and even 25°) did not improve the results. Replacement of ethyl borate by methyl borate was also unsuccessful.

Acid-catalyzed cleavage of 2-*t*-butoxythiophenes is another important approach introduced by Lawesson and Frisell [17] for the preparation of 2-hydroxythiophenes. Mazaki *et al.* modified the procedure; using benzene as solvent led to a more convenient method for the preparation of the hydroxy derivatives of thieno[3,2-*b*]thiophene and thieno[3,2-*b*]thieno[2',3'-*d*]thiophene [18]. Following this procedure, 2-bromo-3-(4-pyridyl)thiophene was converted to the corresponding lithium compound, which was transformed to the magnesium derivatives with anhydrous magnesium bromide, and then treated with *t*-butyl perbenzoate. However, also in this case, only 3-(4-pyridyl)-thiophene was obtained. The inability to form the *t*-butyl derivative could probably be caused by steric hindrance due to the bulkiness of the *t*-butyl perbenzoate.

It has been reported that reaction of 2-thiophenemagnesium bromide with *bis*[trimethylsilyl]peroxide furnished 2-trimethyl silyloxythiophene, which could be converted to 2-hydroxythiophene [19]. Unfortunately, attempts to prepare 2-trimethylsilyloxy-3-(4-pyridyl)thiophene in this way failed.

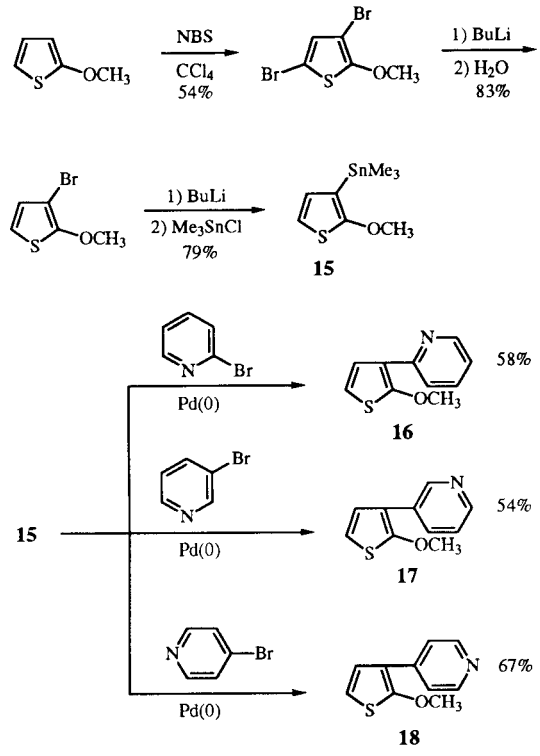
It has been shown that furanone can be synthesized by Baeyer-Villiger reaction of furfural [20-22]. We, therefore, tried to apply this strategy to the preparation of 3-pyridyl-2-hydroxythiophenes from the corresponding aldehydes. Lithiation of 3-(2-pyridyl)thiophene with lithium diisopropylamide followed by formylation with *N,N*-dimethylformamide gave esclusively 3-(2-pyridyl)-2-thiophenecarbaldehyde (**4**) in 69% yield. When the same reaction conditions were applied to 3-(3- and 4-pyridyl)-thiophenes, lithiation was not selective and occurred predominantly in the 5-position. Upon reaction with *N,N*-dimethylformamide, 3-(3-pyridyl)thiophene gave 28% of 4-(3-pyridyl)-2-thiophenecarbaldehyde (**7**) and 21% of 3-(3-pyridyl)-2-thiophenecarbaldehyde (**5**) and 3-(4-pyridyl)thiophene gave as much as 68% of 4-(4-pyridyl)-2-thiophenecarbaldehyde (**8**) and 15% of 3-(4-pyridyl)-2-thiophenecarbaldehyde (**6**). The selectivity in the 2-pyridyl derivative is probably due to intramolecular chelation of the lithium with the pyridine nitrogen, which is not possible in the two other cases. Lithiation in different thiophene positions depending upon the lithiation reagent has been observed by Kauffman *et al*, who found that lithiation of 2-(2-pyridyl)thiophene with butyllithium in ether occurred in the 3-position while lithium diisopropylamide in the same solvent metalated predominantly in the 5-position [23].

Unfortunately, Baeyer-Villiger oxidation of 3-(2-pyridyl)-2-thiophenecarbaldehyde (**4**) with hydrogen peroxide, formic acid and sodium sulphate in dichloromethane resulted in 3-(2-pyridyl)-2-thiophenecarboxylic acid (**9**). When the same substrate was subjected to Dakin oxidation with alkaline hydrogen peroxide in methanol at room temperature, the same acid was obtained, while 3-(3- and 4-pyridyl)-2-thiophenecarbaldehydes **5** and **6** gave decarbonylated products, 3-(3- and 4-pyridyl)thiophenes, under the same reaction conditions. We believe that the reason for the formation of the acid instead of the hydroxy compound is due to the electron-withdrawing effect of the pyridine ring resulting in reduction of electron density of the thiophene ring. Similarly, electron-poor 3-isoquinolinecarbaldehyde was oxidized to the carboxylic acid by 30% hydrogen peroxide [24], and acidic hydrogen peroxide converted electron-withdrawing chloro- or nitro-substituted benzaldehyde to benzoic acid, while those substituted with electron-donating groups such as methoxybenzaldehydes were smoothly converted to phenols under the same reaction conditions [25].

Quite recently, Hollingworth and Sweeney showed that 3- and 4-aryl-substituted 2(5*H*)-furanone could be prepared *via* palladium catalyzed cross-coupling of the corresponding furanone tin derivatives with aryl iodides [26]. Therefore, we tried to prepare 3-(2-pyridyl)-2-hydroxythiophene by palladium catalyzed cross-coupling of 3-trimethylstannyl-3-thiolen-2-one (**12**) with 2-bromopyridine. Synthesis of **12** was accomplished starting from 2,3-dibromothiophene. Halogen-metal exchange with butyllithium followed by reaction with magnesium bromide and then treatment with *t*-butyl perbenzoate furnished 3-bromo-2-*t*-butoxythiophene (**10**), which underwent halogen-metal exchange with butyllithium and stannylation with trimethylstannyl chloride giving 2-*t*-butoxy-3-trimethylstannylthiophene (**11**), subsequent dealkylation with boron tribromide etherate provided **12**. Unfortunately, **12** did not couple with 2-bromopyridine, even when copper(II) oxide was used as a co-reagent [27]. Attempts to couple 3-bromo-3-thiolen-2-one, obtained from dealkylation of 3-bromo-2-*t*-butoxythiophene, with 2-trimethylstannylpyridine (**13**) failed, and no reaction occurred and the starting materials were recovered. However, coupling of **10** with **13** qave a low yield (17%) of 3-(2-pyridyl)-2-*t*-butoxythiophene (**14**). Clevage of the *t*-butyl ether with boron trifluoride etherate in benzene [28] gave a complex mixture (monitored by glc and tlc). On the other hand, 2-*t*-butoxy-3-trimethylstannylthiophene (**11**) did not couple with 2-bromopyridine in the presence of Pd(0) and copper(II) oxide as co-reagent. This might be due to steric hindrance from the bulky *t*-butyl group.

It has previously been observed that the Stille coupling is sensitive to steric hindrance [29]. Therefore, we tried to

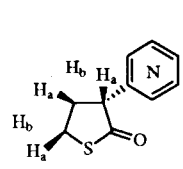
Scheme 1



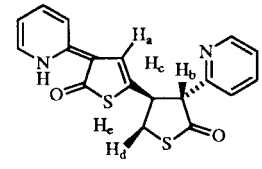
couple bromopyridine with 2-methoxy-3-trimethylstannylthiophene (**15**), prepared from 2-methoxythiophene *via* dibromination and α-debromination, followed by stannylation. This approach was successful and coupling of compound **15** with 2-, 3- and 4-bromopyridines smoothly afforded 2-methoxy-3-(2-, 3- and 4-pyridyl)thiophenes **16-18** in yields of 58%, 54% and 67%, respectively, as shown in Scheme 1.

However, upon attempted demethylation of these methoxy compounds we met some difficulties. It is known that pyridine hydrochloride is a powerful reagent for demethylation of a number of substituted 3-methoxythiophenes [30-34]. Demethylation of compound **18** with pyridine hydrochloride without solvent at 200° for 2 hours only gave tars. With quinoline as solvent at 180° for 2 hours, demethylation resulted in viscous resinous products. Another useful method for demethylation of alkoxythiophenes is treatment with boron tribromide in methylene chloride [35]. The obvious advantage of boron tribromide is that the cleavage is effected under mild conditions.

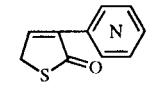
With this reagent the three isomeric 2-methoxy-3-pyridylthiophenes gave different results. Compound **18** gave a complex mixture according to glc and tlc analysis, while **17** afforded the desired 3-(3-pyridyl)-2-hydroxythiophene system as the 3-(3-pyridyl)-3-thiolen-2-one tautomer (**24**), which was stable only in ether solution at -20°. Attempts to purify it further after chromatography by recrystallization from petroleum ether led to tars. The third isomer **16** took a third route in its reaction with boron tribromide, and gave a 47% yield of the dimeric product **22**. Compound **22** was also formed in 52% yield upon attempted demethylation of **16** with trimethylsilane chloride/sodium iodide in refluxing acetonitrile. The reaction leading to **22**, its structure and the possible mechanism for its formation are discussed in a separate publication [36]. In contrast to **16**, compounds **17** and **18** were not demethylated under these conditions.



+/-**19** 2-N
+/-**20** 3-N
+/-**21** 4-N



+/-**22**



23 2-N
24 3-N
25 4-N

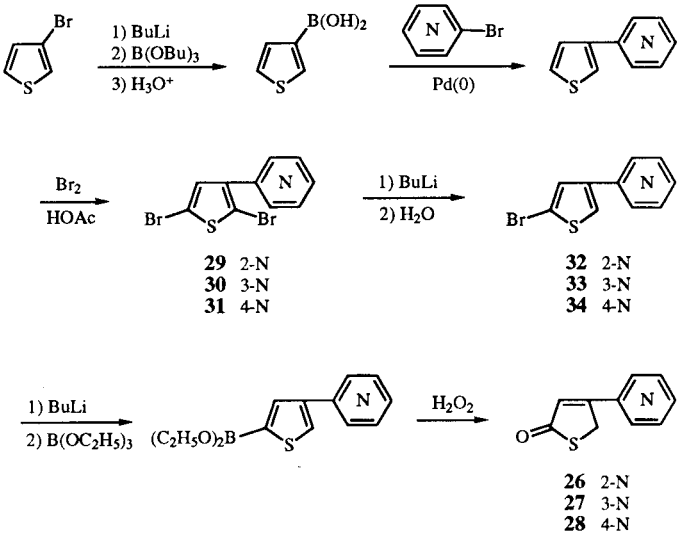
Attempts to demethylate **18** under basic conditions were carried out. Sodium ethanethiolate in aprotic solvents such as *N,N*-dimethylformamide, has been extensively used for the cleavage of aromatic ethers [37,38]. Demethylation of **18** with ethanethiol/sodium hydride in refluxing *N,N*-dimethylformamide also gave a complex mixture. Sodium cyanide in dimethyl sulfoxide is a useful reagent for the conversion of aromatic methyl ethers to phenols [39]. Even this reagent gave upon attempted demethylation of **18** negative result. Sodium phenylmethaneselenolate generated by sodium borohydride and dibenzyl diselenide has been found to be a superior reagent for the demethylation of aryl methyl ethers [40]. Reaction of compound **18** with three equivalents of this reagent in refluxing dimethylformamide was performed. The product formed was 3-(4-pyridyl)thiophan-2-one (**±21**) and not 3-(4-pyridyl)-3-thiolen-2-one (**25**). It seems likely that compound **±21** is formed through reduction of compound **25** by sodium borohydride during the course of demethylation. Using only one equivalent of sodium borohydride did not change the result.

The reaction of 3-(2- and 3-pyridyl)-2-methoxythiophenes **16** and **17** with dibenzyl diselenide, sodium borohydride (1 equivalent) in *N,N*-dimethylformamide at room temperature gave the same results as that obtained for the 4-pyridyl isomer and (±)-3-(2- and 3-pyridyl)thiophan-2-ones **19** and **20** were formed in yields of 14% and 16%, respectively. Attempts to prepare 3-(2-, 3- and 4-pyridyl)-3-thiolen-2-ones **23-25** by dehydrogenation of compounds **±19-21** with dichlorodicyanobenzoquinone [18] failed. Another attempt to avoid the reduction of the double bond was to heat compounds **16-18** and dibenzyl diselenide

with or without copper(I) iodide as a promoter in 1,3-dimethyl-2-imidazolidinone, a highly polar solvent recommended as a replacement for hexamethylphosphoramide [41,42], was unsuccessful.

In sharp contrast to the preparation of the 3-pyridyl-2-hydroxythiophenes, the 4-pyridyl-2-hydroxythiophene systems were smoothly obtained in 57%, 58% and 50% yield, respectively, by hydrogen peroxide oxidation of the esters of the 4-pyridyl-2-thiopheneboronic acids. The known 3-pyridylthiophenes [43], prepared by Pd(0)-catalyzed coupling of 3-thiophenboronic acid [44] with the three isomeric bromopyridines, were brominated with 2.5 equivalents of bromine in acetic acid to give 2,5-dibromo-3-(2-, 3- and 4-pyridyl)thiophenes **29-31** in 70%, 64% and 75% yield, respectively. Debromination of **29-31** by halogen-metal exchange with one equivalent of butyllithium followed by hydrolysis gave 2-bromo-4-(2-, 3- and 4-pyridyl)thiophene **32-34** in 80%, 55% and 57% yield, respectively. Halogen-metal exchange of **32-34** with butyllithium at -100° followed by the reaction with ethyl borate gave the 4-pyridyl-2-thiopheneboronic esters, which were oxidized to the desired hydroxythiophene systems (*cf.* Scheme 2). For these systems three tautomeric forms are possible. In their ^{1}H nmr spectra no signals due to aromatic thiophene protons could be detected, indicating that they exist as unsaturated thiolactones. This is also confirmed by the observations, that there are two bands, at δ 6.77-6.92 and δ 4.44-4.61 with the relative intensities 1:2, attributed to the thiophene moiety. Their splittings gave coupling constants of 1.65-1.80 Hz. Which of the two posibilities, 3-thiolen-2-ones or 4-thiolen-2-ones, to be the thermodynamically more stable cannot be predicted. In the 4-thiolen-2-one case there is conjugation between the pyridine ring and the ring sulfur, while in the 3-thiolen-2-one case there is cross-conjugation between the pyridine ring and the carbonyl group. It has previously been shown that the two types of unsaturated thiolactones

Scheme 2



have characteristic frequencies for their carbonyl absorptions in their ir spectra. The conjugated form shows absorption in the interval 1695-1670 cm^{-1} and the unconjugated form in the interval 1750-1730 cm^{-1} [6]. The 4-pyridyl-2-hydroxythiophene systems have their carbonyl absorptions in the interval 1665-1645 cm^{-1}, consequently they exist as 4-pyridyl-3-thiolen-2-ones **26-28**. Compounds **27** and **28** have previously been obtained as minor components in the synthesis of 3-hydroxy-4-(3- and 4-pyridyl)thiophenes, as rearrangement occurred during halogen-metal exchange of 3-bromo-4-(3- and 4-pyridyl)thiophenes [1]. In the literature only a few examples of this "meta" type substituted hydroxythiophenes have been reported, for instance, 4-bromo- [45], 4-methoxy- [46] and 4-methyl-2-hydroxythiophene [47]. These compounds exist also in their 3-thiolen-2-one forms, in contrast to the 5-substituted 2-hydroxythiophene systems, where both keto forms could be observed.

Table 1

HETCOR Data for some 2-, 3- (R_1-, R_2-)Disubstituted Thiophenes in Deuteriochloroform

			^{1}H NMR			^{13}C NMR					
			δ (ppm)		J (Hz)	δ (ppm)		$^1J_{CH}$ (Hz)		$^2J_{CH}$ (Hz)	
Compound	R_1	R_2	H_4	H_5	J_{45}	C_4	C_5	J_{C4H4}	J_{C5H5}	J_{C4H5}	J_{C5H4}
1	Br	2-Py	7.40	7.33	5.60	129.4	126.0	171.6	188.8	3.42	6.10
2	Br	3-Py	7.05	7.37	5.65	128.6	126.7	169.5	187.3	4.30	7.95
3	Br	4-Py	7.07	7.38	5.70	128.4	126.9	169.2	191.3	4.35	4.05
9	COOH	2-Py	7.91	7.96	5.45	129.5	131.9	176.6	189.5	4.25	5.15
10	OtB [a]	Br	6.54	6.21	6.15	127.8	116.0	173.9	189.2	3.80	5.90
11	OtB [a]	$SnMe_3$	6.72	6.80	5.60	129.0	116.6	166.5	185.8	2.50	6.60
14	OtB [a]	2-Py	7.46	6.75	6.10	125.8	114.7	170.2	188.2	3.25	5.90
15	OCH_3	$SnMe_3$	6.77	6.74	5.45	130.3	113.4	166.6	190.0	2.95	7.30
17	OCH_3	3-Py	7.06	6.68	5.95	125.4	111.5	166.6	190.0	3.50	5.55
18	OCH_3	4-Py	7.13	6.68	6.00	125.2	111.2	166.8	190.3	3.45	5.30

[a] OtB = O-*t*-Bu.

Table 2

^{1}H NMR Chemical Shifts (ppm) for some Pyridyl-substituted Thiophene Derivatives in Deuteriochloroform

Compound	H_3	H_4	H_5	H_2	H_3	H_4	H_5	H_6	O-*t*-Bu	OCH_3	CHO
1		7.40	7.33		7.86	7.70	7.26	8.69			
2		7.05	7.37	8.80		7.89	7.37	8.60			
3		7.07	7.38	8.69	7.50		7.50	8.69			
4		7.45	7.72		7.62	7.82	7.33	8.73			10.48
5		7.25	7.81	8.75		7.80	7.44	8.69			9.86
6		7.26	7.82	8.75	7.40		7.40	8.75			9.91
7	8.05		7.92	8.88		7.89	7.38	8.61			10.00
8	8.09		8.04	8.68	7.50		7.50	8.68			10.00
9 [a]		7.91	7.96		8.27	8.19	7.62	8.72			
14		7.46	6.75		8.03	7.67	7.11	8.60	1.37		
17		7.06	6.68	8.89		7.96	7.29	8.45		3.99	
18		7.13	6.68	8.58	7.58		7.58	8.58		4.04	
29		7.41			7.83	7.77	7.27	8.68			
30		7.04		8.76		7.84	7.37	8.62			
32	7.63		7.78		7.55	7.71	7.19	8.61			
33	7.35		7.41	8.81		7.80	7.33	8.56			

[a] In DMSO-d_6.

Table 3

^{1}H NMR Coupling Constants (Hz) for some Pyridyl-substituted Thiophene Derivatives in Deuteriochloroform

Compound	J_{35}	J_{45}	J_{23}	J_{24}	J_{25}	J_{34}	J_{35}	J_{36}	J_{45}	J_{46}	J_{56}	J_{CHO-H5}
1		5.60				8.00	1.20	1.00	7.50	1.75		
2		5.65		1.60	0.85				7.75	1.80	4.70	
3		5.70	4.55		1.60			1.60			4.55	
4		5.10				7.80	1.10	1.00	7.65	1.85	4.85	1.15
5		5.05		2.10					7.75	1.70	5.00	1.25
6		5.10	4.75		1.60			1.60			4.75	1.15
7	1.20			1.95					7.90	1.70	4.80	1.00
8	1.30		4.85		1.60			1.60			4.85	1.10
9 [a]		5.45				8.15	1.20	0.90	7.50	1.75	5.15	
14		6.10				8.05	1.15	1.05	7.45	1.90	4.90	
17		5.95		2.30	0.85				8.00	1.65	4.80	
18		6.00	4.65		1.65			1.65			4.65	
29						7.95	1.35	1.00	7.35	1.80	4.85	
30				2.30	0.80				7.90	1.65	4.85	
32	1.70					7.95	1.05	0.95	7.45	1.75	4.85	
33	1.75			2.35	0.85				7.95	1.65	4.85	

[a] In DMSO-d_6.

Table 4

^{1}H NMR Chemical Shifts (ppm) for Compounds **±19-21** in Deuteriochloroform

Compound	H_{3a}	H_{4a}	H_{4b}	H_{5a}	H_{5b}	H_2	H_3	H_4	H_5	H_6
±19	3.90	2.69	2.83	3.46	3.58		7.28	7.68	7.21	8.58
±20	3.76	2.76	2.44	3.51	3.44	8.56		7.57	7.31	8.50
±21	3.72	2.75	2.46	3.49	3.43	8.60	7.18		7.18	8.60

^{1}H NMR Studies.

For the new 2,3-disubstituted thiophenes, **1-3**, **9**, **11**, **14**, **15**, **17**, and **18**, the ^{1}H nmr spectra show too small shift differences between H_4 and H_5 to allow significant interpretation. Therefore HETCOR experiments were carried out and the results are given in Table 1. The ^{13}C parameters are in accordance with those previously obtained for mono substituted thiophenes [48], with the exception that the shift difference for the α- and β-carbons are more pronounced. For the known compound **10** Jakobsen and Lawesson observed that the AB-spectrum in deuteriochloroform was reduced to a singlet, while it is in deuteriobenzene showed doublets at δ 6.57 and 6.30 [15]. This

Table 5

^{1}H NMR Coupling Constants (Hz) for the Thiophan-2-one Moieties in Compounds **±19-21** in Deuteriochloroform

Compound	J_{3a-4a}	J_{3a-4b}	J_{4a-4b}	J_{4a-5a}	J_{4a-5b}	J_{4b-5a}	J_{4b-5b}	J_{5a-5b}
±19	6.80	8.55	12.95	6.75	8.90	9.65	5.40	10.40
±20	6.65	11.15	12.15	4.25	9.85	10.90	6.75	11.25
±21	6.65	10.80	12.25	4.80	8.52	10.25	6.51	10.90

Table 6

^{1}H Coupling Constants (Hz) for the Pyridyl Moieties in Compounds **±19-21** in Deuteriochloroform

Compound	J_{23}	J_{24}	J_{25}	J_{34}	J_{35}	J_{36}	J_{45}	J_{46}	J_{56}
±19				7.75	1.15	0.95	6.85	1.85	4.85
±20		2.20					7.90	1.75	4.70
±21	4.45		1.55			1.55			4.45

experiment was repeated with the same results and with HETCOR investigation the definite assignments for the two protons were achieved (*cf.* Table 1).

Concerning the unknown 2,3-disubstituted compounds **4-6**, there is a coupling between the formyl group and the proton in the 5-position [49], consequently the resonance due to this proton is split into four lines. We, therefore, could safely assign the protons in the 4- and 5-positions (Table 2 and 3).

The thiophan-2-one moiety in compounds **±19-21** is structurally similar to that in compound **±22**. In the preceding paper in this series [36], we determined the stereochemistry of the latter compound by X-ray crystallographic investigation. It is shown that in compound **±22**, H_b is *trans* to H_c while H_c is *trans* to H_d and *cis* to H_e. The ^{1}H nmr spectrum showed that the coupling constant J_{bc} is 11.55 Hz, J_{cd} = 10.95 Hz and J_{ce} = 6.5 Hz, respectively. In view of that the sum of $J_{cis} + J_{trans}$ between two vicinal protons in dihydrothiophene equals 17.5 Hz [50], it is reasonable that the *trans* coupling constants are larger than the *cis* coupling constants in this type of 3-pyridylthiophan-2-one. Based on this assumption and by decoupling techniques we successfully made assignments of all protons in compounds **±19-21**, the results are given in Tables 4, 5 and 6.

EXPERIMENTAL

Melting points were uncorrected. Infrared spectra were recorded on a Perkin Elmer 298 spectrophotometer. The nmr spectra (^{1}H, ^{13}C, HETCOR) were recorded on a Varian XL 300 spectrometer. The mass spectra were recorded on a Finnigen 4021 (Date System Incos 2100). High resolution mass spectra were recorded on a JEOL JMS-SX 102 spectrometer. The glc analyses were carried out on a Varian 1400 gas chromatography using an OV-17 (3%, 2 m) column. Elemental microanalyses were performed at Dornis und Kolbe, Mikroanalytisches Laboratorium, Mülheim a. d. Ruhr, Germany.

General Procedure for the Preparation of 2-Bromo-3-pyridylthiophenes.

A solution of 267 mg (1.50 mmoles) *N*-bromosuccinimide in 10 ml of acetic acid was added dropwise to a stirred solution of 161 mg (1.00 mmole) of 3-(2- or 3- or 4-pyridyl)thiophene [43] in 5 ml of acetic acid. After the addition was complete, the mixture was stirred for 5-10 minutes and then poured into cold water, neutralized with sodium bicarbonate to *p*H 7-8, and extracted with dichloromethane. The combined dichloromethane phases were washed with water and dried over anhydrous sodium sulphate. After evaporation, the residue was purified by column chromatography using silica gel 60.

2-Bromo-3-(2-pyridyl)thiophene (**1**).

This compound was obtained as an oil by using petroleum ether/ethyl acetate (4:1) as eluent to yield 100.8 mg (42%); for ^{1}H nmr data see Tables 2 and 3.

Anal. Calcd. for C_9H_6BrNS: C, 45.02; H, 2.52. Found: C, 45.10; H, 2.57.

2-Bromo-3-(3-pyridyl)thiophene (**2**).

This compound was obtained as an oil by using hexane/ethyl acetate (3:2) as eluent to yield 168.0 mg (70%); for ^{1}H nmr data see Tables 2 and 3.

Anal. Calcd. for C_9H_6BrNS: C, 45.02; H, 2.52. Found: C, 45.01; H, 2.61.

2-Bromo-3-(4-pyridyl)thiophene (**3**).

This compound was obtained by using ethyl acetate/cyclohexane (4:1) as eluent followed by recrystallization from petroleum ether to yield 144.0 mg (60%), mp 56.5-58.5°; for ^{1}H nmr data see Tables 2 and 3.

Anal. Calcd. for C_9H_6BrNS: C, 45.02; H, 2.52. Found: C, 45.07; H, 2.58.

General Procedure for the Preparation of 3-Pyridyl-2-thiophenecarbaldehydes.

A solution prepared from 1.11 g (11.0 mmoles) of diisopropylamine and 2.50 ml of anhydrous diethyl ether was added under nitrogen to 5.42 ml (11.0 mmoles) of 2.03 *N* butyllithium in cyclohexane with stirring. After the addition was complete, the mixture was cooled to -70°, whereupon a solution of 1.61 g (10.0 mmoles) of 3-(2- or 3- or 4-pyridyl)thiophene in 5 ml of anhydrous diethyl ether was added dropwise at the same temper-

ature. The mixture was stirred at -70° for 2 hours; 5 ml of anhydrous dimethylformamide was added dropwise. The mixture was then allowed to warm to room temperature and stirred for 30 minutes. The mixture was quenched with saturated aqueous ammonium chloride and extracted with ethyl acetate. The combined extracts were washed with water to *p*H 7-8 and dried over anhydrous sodium sulphate. After evaporation, the residue was purified by column chromatography using silica gel 60.

3-(2-Pyridyl)-2-thiophenecarbaldehyde (**4**).

This compound was obtained by using cyclohexane/ethyl acetate (3:2) as eluent to give 1.31 g (69%) of the title compound, mp 72-74°; ir (potassium bromide): ν 1650 cm^{-1} (C=O); for ^1H nmr data see Tables 2 and 3.

Anal. Calcd. for $C_{10}H_7NOS$: C, 63.47; H, 3.73. Found: C, 63.56; H, 3.79.

3-(3-Pyridyl)-2-thiophenecarbaldehyde (**5**).

This compound was obtained by using ethyl acetate/heptane (9:1) as eluent followed by purification by hplc using chloroform as eluent and finally sublimation to give 0.40 g (21%), mp 128.0-129.5°; ir (potassium bromide): ν 1650 cm^{-1} (C=O); for ^1H nmr data see Tables 2 and 3.

Anal. Calcd. for $C_{10}H_7NOS$: C, 63.47; H, 3.73. Found: C, 63.26; H, 3.79.

3-(4-Pyridyl)-2-thiophenecarbaldehyde (**6**).

This compound was obtained by using dichloromethane/acetone (7:3) as eluent to give 0.17 g (15%), mp 77-80°; ir (potassium bromide): ν 1650 cm^{-1} (C=O); for ^1H nmr data see Tables 2 and 3.

Anal. Calcd. for $C_{10}H_7NOS$: C, 63.47; H, 3.73. Found: C, 63.40; H, 3.70.

4-(3-Pyridyl)-2-thiophenecarbaldehyde (**7**).

This compound was obtained in the preparation of **5** by using the same method for the separation and purification to give 0.52 g (28%), mp 107-109°; ir (potassium bromide): ν 1670 cm^{-1} (C=O); for ^1H nmr data see Tables 2 and 3.

Anal. Calcd. for $C_{10}H_7NOS$: C, 63.47; H, 3.73. Found: C, 63.53; H, 3.83.

4-(4-Pyridyl)-2-thiophenecarbaldehyde (**8**).

This compound was obtained in the preparation of **6** by using the same method for the separation and purification to give 0.80 g (68%), mp 98.5-101.5°; ir (potassium bromide): ν 1665 cm^{-1} (C=O); for ^1H nmr data see Tables 2 and 3.

Anal. Calcd. for $C_{10}H_7NOS$: C, 63.47; H, 3.73. Found: C, 63.57; H, 3.71.

3-(2-Pyridyl)-2-thiophenecarboxylic Acid (**9**).

Method A.

To a stirred solution of 189.0 mg (1.00 mmole) of **4** in 1.0 ml of dichloromethane was added 100.0 mg of sodium sulphate followed by addition of a solution of 50.6 mg (1.1 mmoles) of formic acid and 0.2 ml of 30% hydrogen peroxide. The mixture was stirred at room temperature for 28 hours and the reaction followed by glc and tlc. Water was added. The mixture was neutralized with 1 *M* sodium bicarbonate solution to *p*H 6-7. The phases were separated. The aqueous phase was extracted with dichloromethane. The combined dichloromethane phases were washed with water and dried over anhydrous sodium sulfate. After evaporation, the residue was chromatographed on a silica gel 60 column using dichloromethane/acetone (7:3) as eluent yielding 150 mg (73%), mp 179-181°; ir (potassium bromide): ν 1670 cm^{-1} (C=O), 3400 cm^{-1} (OH); for ^1H nmr data see Tables 2 and 3.

Anal. Calcd. for $C_{10}H_7NO_2S$: C, 58.52; H, 3.44. Found: C, 58.48; H, 3.50.

Method B.

To a stirred solution of 189.0 mg (1.00 mmole) of **4** in methanol was added 0.2 ml of 30% hydrogen peroxide followed by 0.5 ml of 2 *M* sodium hydroxide solution. The mixture was stirred at room temperature for 3 hours. Water was added. The mixture was neutralized with 1 *M* of hydrochloric acid to *p*H 6-7 and extracted with dichloromethane, the combined organic phases were dried over anhydrous sodium sulphate. After evaporation, the residue was chromatographed on a silica gel 60 column using dichloromethane/acetone (7:3) as eluent yielding 140.0 mg (68%) (having the same physical data as discussed above).

2-*t*-Butoxy-3-trimethylstannylthiophene (**11**).

To a stirred solution of 9.40 g (0.04 mole) of 3-bromo-2-*t*-butoxythiophene [15] in 40.0 ml of anhydrous diethyl ether at -70° under nitrogen 21.4 ml (0.044 mole) of 2.06 *N* butyllithium in cyclohexane was added dropwise. The solution was stirred for 30 minutes, after which 8.80 g (0.044 mole) of trimethylstannyl chloride dissolved in 15 ml of anhydrous tetrahydrofuran was added at -70°. After stirring for 4 hours, the mixture was allowed to warm to room temperature. Water was added and the phases were separated. The aqueous phase was extracted with diethyl ether. The combined organic phases were dried over anhydrous sodium sulphate. The residue was distilled at reduced pressure to give 9.19 g (72%), bp 78-79°/0.6 mm Hg; ^1H nmr (deuteriochloroform): δ 0.28 [s, 9H, $Sn(CH_3)_3$], 1.42 [s, 9H, O-*t*-Bu], 6.72 (d, 1H, H_4, J = 5.60 Hz), 6.80 (d, 1H, H_5, J = 5.60 Hz).

Anal. Calcd. for $C_{11}H_{20}OSSn$: C, 41.41; H, 6.32. Found: C, 41.49; H, 6.26.

3-Trimethylstannylthiolen-2-one (**12**).

Dropwise addition of 0.56 g (3.95 mmoles) of boron tribromide etherate was performed with syringe at 0° under nitrogen to a solution of 1.00 g (3.13 mmoles) of **11** in 5 ml of benzene. After stirring for 6.5 hours (monitored by glc and tlc), the mixture was poured into water and neutralized with sodium bicarbonate to *p*H 7-8, and extracted with dichloromethane. The combined organic phases were washed with water and then a saturated sodium chloride solution. After evaparation, the residue was flash column chromatographed over silica gel 60 using pentane/ethyl acetate (95:5) as eluent to afford 40.0 mg (4.9%) as an oil; ir (film): ν 1680 cm^{-1} (C=O); ^1H nmr (deuteriochloroform): δ 1.25 (s, 9H, $Sn(CH_3)_3$], 3.89 (d, 2H, CH_2, J = 3.00 Hz), 7.16 (t, 1H, C=CH, J = 3.00 Hz).

Anal. Calcd. for $C_7H_{12}OSSn$: C, 31.97; H, 4.60. Found: C, 31.92; H, 4.55.

2-Trimethylstannylpyridine (**13**).

To a stirred solution of 10.0 g (0.063 mole) of 2-bromopyridine in 100 ml of anhydrous diethyl ether at -70° 31.6 ml (0.065 mole) of 2.06 *N* butyllithium in cyclohexane added dropwise. The mixture was stirred for 30 minutes and 12.6 g (0.063 mole) of trimethylstannyl chloride dissolved in 30.0 ml of anhydrous

tetrahydrofuran was added dropwise at -70°. The mixture was stirred at -70° for 4 hours and then allowed to warm to room temperature. Water was added, the phases were separated and the aqueous phase was extracted with diethyl ether. The combined organic phases were dried over anhydrous sodium sulfate. After evaporation followed by distillation under reduced pressure, 9.15 g (60%) of the title compound was obtained, bp 52-53°/1.2 mm Hg (lit [51] 81-83°/10 Torr); ^{1}H nmr (deuteriochloroform): δ 0.35 (s, 9H, $Sn(CH_3)_3$), 7.15 (ddd, 1H, H_5, J = 7.45, 4.90, and 1.60 Hz), 7.44 (ddd, 1H, H_3, J = 7.40, 1.55 amd 1.10 Hz), 7.53 (td, 1H, H_4, J = 7.45, 7.45 and 1.85 Hz), 8.74 (ddd, 1H, H_6, J = 4.90, 1.80 and 1.05 Hz).

3-(2-Pyridyl)-2-*t*-butoxythiophene (**14**).

A mixture of 470 mg (2.00 mmoles) of 3-bromo-2-*t*-butoxythiophene (**10**), 70.2 mg (0.10 mmole) of tetrakistriphenylphosphinepalladium(0) [52], 726 mg (3.00 mmoles) of **13** and 0.15 ml of dimethylformamide was stirred at 100° under nitrogen for 24 hours. The mixture was cooled to room temperature and 20 ml of diethyl ether was added with stirring. The precipitate was filtered off and the filtrate was evaporated. The residue was chromatographed on silica gel 60 using pentane/ethyl acetate (87:13) as eluent to give 79.2 mg (17%), mp 48-49°; for ^{1}H nmr data see Tables 2 and 3.

Anal. Calcd. for $C_{13}H_{15}NOS$: C, 66.92; 6.48. Found: C, 66.97; H, 6.44.

2-Methoxy-3-(3-pyridyl)thiophene (**17**).

A mixture of 0.79 g (5.00 mmoles) of 3-bromopyridine, 1.53 g (5.50 mmoles) of 2-methoxy-3-trimethylstannylthiophene (**15**) [53], 0.48 g (0.25 mmole) of tetrakistriphenylphosphinepalladium(0) and 35 ml of dimethylformamide was stirred at 100° under nitrogen for 15 hours and monitored by glc. The mixture was allowed to warm to room temperature and evaporated, after which 50 ml of diethyl ether was added to the residue. The precipitate was filtered off. The filtrate was washed with water and dried over anhydrous sodium sulphate. After evaporation, the residue was purified by column chromatography over silica gel 60 using ethyl acetate/cyclohexane (1:1) as eluent. After distillation under reduced pressure 0.52 g (54%) of **17** was obtained, bp 121-122°/0.65 mm Hg; for ^{1}H nmr data see Tables 2 and 3.

Anal. Calcd. for $C_{10}H_9NOS$: C, 62.80; H, 4.74. Found: C, 62.65; H, 4.76.

2-Methoxy-3-(4-pyridyl)thiophene (**18**).

This compound was prepared by using the same procedure as described for **17** from 4-bromopyridine and 2-methoxy-3-trimethylstannylthiophene (**15**) [53] and purified by column chromatography over silica gel 60 and using ethyl acetate/cyclohexane (3:2) as eluent. After recrystallization from petroleum ether 0.64 g (67%) of **18** was obtained, mp 64-65°; for ^{1}H nmr data see Tables 4-6.

Anal. Calcd. for $C_{10}H_9NOS$: C, 62.80; H, 4.74. Found: C, 62.86; H, 4.90.

General Procedure for the Preparation of 3-Pyridylthiophan-2-ones.

To a stirred solution of 222 mg (0.65 mmole) of dibenzyl diselenide in 6 ml of dimethylformamide, 38.0 mg (1.00 mmole) of sodium borohydride was added under nitrogen. After stirring for 30 minutes, 191 mg (1.00 mmole) of 2-methyoxy-3-(2- or 3- or 4-pyridyl)thiophene in 6 ml of dimethylformamide was added dropwise. The mixture was stirred at room temperature for 2-4 days and then evaporated. To the residue, 5 ml of water was added. The *p*H of the mixture was adjusted with 2 *M* hydrochloric acid to 2-3. The mixture was extracted with benzene. The aqueous solution was made alkaline to *p*H 7-8 with sodium bicarbonate and extracted with dichloromethane. The combined dichloromethane phases were washed with water, dried over anhydrous sodium sulphate. After evaporation, the residue was chromatographed over silica gel 60.

3-(2-Pyridyl)thiophan-2-one (**±19**).

This compound was prepared from **16** [53] by using dichloromethane/methanol (99:1) as eluent. After further purification by hplc using dichloromethane/2-propanol (98:2) as eluent 25.0 mg (14%) of **±19** was obtained, mp 80.5-81.5°; ir (potassium bromide): ν 1685 cm^{-1} (C=O); ms: m/z 179 (M^+); for ^{1}H nmr data see Tables 4-6.

Anal. Calcd. for C_9H_9NOS: C, 60.31; H, 5.06. Found: C, 60.28; H, 5.16.

3-(3-Pyridyl)thiophen-2-one (**±20**).

This compound was prepared from **17** and dichloromethane/methanol (99:1) was used as eluent, yield 28.0 mg (16%), mp 54-57°; ir (potassium bromide): ν 1675 cm^{-1} (C=O); ms: m/z 179 (M^+); for ^{1}H nmr data see Tables 4-6.

Anal. Calcd. for C_9H_9NOS: C, 60.31; H, 5.06. Found: C, 60.33; H, 5.11.

3-(4-Pyridyl)thiophan-2-one (**±21**).

This compound was prepared from **18** and dichloromethane/methanol (99:1) was used as eluent, yield 53.7 mg (30%), mp 58-61°; ir (potassium bromide): ν 1680 cm^{-1} (C=O); ms: m/z 179 (M^+); for ^{1}H nmr data see Tables 4-6.

Anal. Calcd. for C_9H_9NOS: C, 60.31; H, 5.06. Found: C, 60.39; H, 5.19.

3-(3-Pyridyl)-3-thiolen-2-one (**24**).

To a stirred solution of 191 mg (1.00 mmole) of **17** in 4 ml of benzene, 0.25 ml (2.5 mmoles) of boron tribromide was added dropwise with syringe under nitrogen. The mixture was refluxed for 2 hours and then cooled to room temperature. Ice-water was added, and the *p*H was adjusted to 7-8. The mixture was extracted with dichloromethane. The combined organic phases were washed with water and then saturated with sodium chloride solution and dried over anhydrous sodium sulphate. After evaporation, the residue was immediately flash chromatographed over silica gel 60 using dichloromethane/methanol (99:1) as eluent giving 150.0 mg (28%); ir (potassium bromide): ν 1690 cm^{-1} (C=O); ^{1}H nmr (deuteriochloroform): δ 4.12 (d, 2H, CH_2, J = 3.05 Hz), 7.31 (ddd, 1H, H_5, J = 8.00, 4.85 and 0.85 Hz), 7.71 (t, 1H, C=CH, J = 3.05 Hz), 7.96 (ddd, 1H, H_4, J = 8.00, 2.10 and 1.85 Hz), 8.57 (dd, 1H, H_6, J = 4.85 and 1.85 Hz), 8.74 (dd, 1H, H_2, J = 2.10 and 0.85 Hz); ms: m/z 177 (M^+), 148, 104. The isolated compound decomposed rapidly.

General Procedure for the Preparation of 2,5-Dibromo-3-pyridylthiophenes.

A solution of 5.40 g (30.0 mmoles) of bromine in 20 ml of acetic acid was added dropwise to a stirred solution of 1.61 g (10.0 mmoles) of 3-(2-, or 3-, or 4-pyridyl)thiophene [43] and 3.30 g of sodium acetate in 30 ml of acetic acid. The mixture was refluxed for 4 hours and monitored by glc. After being cooled to room temperature, the mixture was poured into water and neu-

tralized with sodium carbonate to *p*H 7-8, after which it was extracted with tetrahydrofuran and diethyl ether successively. The combined organic phases were washed with water, dried over anhydrous sodium sulphate and evaporated. The residue was chromatographed over silica 60 and/or recrystallized.

2,5-Dibromo-3-(2-pyridyl)thiophene (**29**).

This compound was prepared from 3-(2-pyridyl)thiophene and petroleum ether/ethyl acetate (9:1) was used as eluent. After recrystallization from petroleum ether, 2.23 g (70%) of **29** was obtained, mp 49.5-50.5°; for ^{1}H nmr data see Tables 2 and 3.

Anal. Calcd. for $C_9H_5Br_2NS$: C, 33.88; H, 1.58. Found: C, 33.88; H, 1.52.

2,5-Dibromo-3-(3-pyridyl)thiophene (**30**).

This compound was prepared from 3-(3-pyridyl)thiophene and petroleum ether/ethyl acetate (3:2) was used as eluent. After further purification by hplc using heptane/ethyl acetate (4:1) as eluent, 2.04 g (64%) of **30** was obtained, mp 82-84°; for ^{1}H nmr data see Tables 2 and 3.

Anal. Calcd. for $C_9H_5Br_2NS$: C, 33.88; H, 1.58. Found: C, 33.94; H, 1.61.

2,5-Dibromo-3-(4-pyridyl)thiophene (**31**).

This compound was prepared from 3-(4-pyridyl)thiophene. After recrystallization from petroleum ether, 2.39 g (75%) of **31** was obtained, 113-114° (lit [1] 74%, mp 113-113.5°).

General Procedure for the Preparation of 2-Bromo-4-pyridyl-thiophenes.

To a stirred solution of 3.19 g (10.0 mmoles) of 2,5-dibromo-3-(2- or 3- or 4-pyridyl)thiophene in 60 ml of anhydrous tetrahydrofuran, 4.93 ml (10.0 mmoles) of 2.03 *N* butyllithum in cyclohexane was added dropwise at -100° under nitrogen. After stirring for 30 minutes, the solution was poured into water. The phases were separated and the aqueous phase was extracted with diethyl ether. The combined organic phases were washed with saturated sodium chloride solution, dried over anhydrous sodium sulphate and evaporated. The residue was chromatographed using silica gel 60.

2-Bromo-4-(2-pyridyl)thiophene (**32**).

This compound was prepared from **29** and petroleum ether/ethyl acetate (7:3) followed by dichloromethane/ethyl acetate (9:1) was used as eluent; yield 1.92 g (80%), mp 36-37°; for ^{1}H nmr data see Tables 2 and 3.

Anal. Calcd. for C_9H_6BrNS: C, 45.02; H, 2.52. Found: C, 45.19; H, 2.58.

2-Bromo-4-(3-pyridyl)thiophene (**33**).

This compound was prepared from **30** and petroleum ether/ethyl acetate (3:2) was used as eluent. After recrystallization from hexane, 1.32 g (55%) of **33** was obtained, mp 52-54°; for ^{1}H nmr data see Tables 2 and 3.

Anal. Calcd. for C_9H_6BrNS: C, 45.02; H, 2.52. Found: C, 45.13; H, 2.60.

2-Bromo-4-(4-pyridyl)thiophene (**34**).

This compound was prepared from **31**. After sublimation and recrystallization from petroleum ether, 1.39 g (58%) of **34** was obtained, mp 62-64° (lit [1] 57%, mp 62-64°).

General Procedure for the Preparation of 4-Pyridyl-3-thiolen-2-ones.

A solution of 1.0 g (4.17 mmoles) of 2-bromo-4-(2- or 3- or 4-pyridyl)thiophene in 20 ml of anhydrous tetrahydrofuran was added dropwise at -100° under nitrogen to a stirred solution of 2.46 ml (5.00 mmoles) of 2.03 *M* butyllithium in cyclohexane. The mixture was stirred for 30 minutes and monitored by glc. A cooled solution of 0.8 g (5.5 mmoles) of ethyl borate in 10 ml of anhydrous tetrahydrofuran, was pressed into the reaction mixture at -100°. The mixture was stirred at -100° for 4 hours and then allowed to warm to 0°, after which 1.5 ml of 30% hydrogen peroxide solution was added. The mixture was gently refluxed for 2.5 hours and cooled to room temperature, whereupon 20 ml of water was added. The organic phase was separated and the aqueous phase was extracted with ether. The combined organic phases were washed with cooled water and dried over anhydrous sodium sulphate. After evaporation, the residue was chromatographed over silica gel 60.

4-(2-Pyridyl)-3-thiolen-2-one (**26**).

This compound was prepared from **32** by using petroleum ether/ethyl acetate (3:2) as eluent giving 0.42 g (57%) of **26**, mp 143-145°; ir (potassium bromide): ν 1645 cm^{-1} (C=O); ^{1}H nmr (deuteriochloroform): δ 4.61 (d, 2H, CH_2, J = 1.80 Hz), 6.92 (t, 1H, 3-H, J = 1.80 Hz), 7.35 (ddd, 1H, 5-H, J = 7.55, 4.85 and 1.20 Hz), 7.69 (dt, 1H, 3-H, J = 7.90, 1.10 and 1.10 Hz), 7.80 (ddd, 1H, 4-H, J = 7.90, 7.55 and 1.80 Hz), 8.70 (ddd, 1H, 6-H, J = 4.85, 1.80 and 1.00 Hz); ms: m/z 177 (M^+), 149, 104.

Anal. Calcd. for C_9H_7NOS: C, 60.99; H, 3.98. Found: C, 61.11; H, 4.08.

4-(3-Pyridyl)-3-thiolen-2-one (**27**).

This compound was prepared from **33** and ethyl acetate was used as eluent. After evaporation, 0.43 g (58%) of **27** was obtained, mp 151-152° (lit [1] 151.0-151.5°).

4-(4-Pyridyl)-3-thiolen-2-one (**28**).

This compound was prepared from **34** and ethyl acetate was used as eluent. After evaporation, 0.37 g (50%) of **28** was obtained, mp 156-157.5° (lit [1] 41%, 156-158°).

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