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The Substituent Effects in Thiophene Compounds. II.[1] ^{1}H NMR and IR Studies in Methyl (Substituted 3-Thiophenecarboxylate)s

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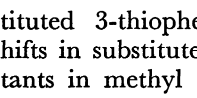
The ^{1}H NMR spectra and the IR carbonyl stretching frequencies of methyl (2-, 4-, and 5-substituted 3-thiophenecarboxylate)s are reported. Good linear correlation between the chemical shifts of the ring protons in methyl (5-substituted 3-thiophenecarboxylate)s and those of the corresponding protons in substituted thiophenes was observed. It was found that in methyl (2- and 4-substituted 3-thiophenecarboxylate)s, which have the carbonyl or nitro group in an *ortho* position, the chemical shifts for the ring protons were considerable affected by the conformation of carbonyl group, the steric hindrance, and the intramolecular hydrogen bonding. Some of methyl (*ortho*-substituted 3-thiophenecarboxylate)s showed the two C=O stretching bands. They were assigned to *anti-s-trans* and *syn-s-trans* forms. The substitutent effects in the C=O frequencies are also discussed. The coupling constants between ring protons of methyl (substituted 3-thiophenecarboxylate)s were correlated very closely with the corresponding ones in substituted thiophenes. The coupling constants in methyl 3-thiophenecarboxylate series were found to vary linearly with the sum of the electronegativities of the substituent on the ring.

In an earlier paper,[1] the ^{1}H NMR spectra have been reported for 2-substituted thiophenes (**1**), 3-substituted thiophenes (**2**), methyl (3-substituted 2-thiophenecarboxylate)s (**3**), methyl (4-substituted 2-thiophenecarboxylate)s (**4**), and methyl (5-substituted 2-thiophenecarboxylate)s (**5**). The effects of the substituents were discussed.

The present study was undertaken to examine the substituent effects in methyl (2-, 4-, and 5-substituted 3-thiophenecarboxylate)s (**6**—**8**). The correlations of the chemical shifts and of the coupling constants between methyl (substituted 3-thiophenecarboxylate)s and substituted thiophenes have been discussed in this paper. Attempts have also been made to compare the IR C=O stretching frequencies in methyl (substituted 3-thiophenecarboxylate)s with the chemical shifts in substituted thiophenes, and the coupling constants in methyl (substituted 3-thiophenecarboxylate)s with the electronegativities of the substituents. The influences of the conformation, steric hindrance, and intramolecular hydrogen bonding upon the chemical shifts of ring protons and C=O stretching frequencies in methyl (2- and 4-substituted 3-thiophenecarboxylate)s have been discussed.



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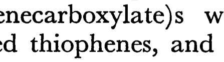

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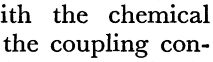

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Results and Discussion

The ^{1}H NMR spectra of methyl (2-, 4-, and 5-substituted 3-thiophenecarboxylate)s (**6**—**8**) were measured in deuteriochloroform at 25 °C. The assignments of the spectra were made on the basis of the chemical shifts and the characteristic ring coupling constants. The refined chemical shifts and coupling constants were obtained iteratively using LAOCN 3.[2] The results are given in Tables 1—3. For convenience, the notation $H_r(\mathbf{N})$ for the rth(position)-proton on thiophene ring of the series of compounds **N**, $\delta_r(\mathbf{N})$ for its chemical shift, and *cc*, *p*, *i*, and *s* for the correlation coefficient, slope, intercept, and standard deviation in the least-squares analysis. For comparison of the effect of substituents on methyl (substituted 3-thiophenecarboxylate)s and substituted thiophenes, the chemical shifts of corresponding protons from the two series of compounds were plotted against each other. The plots of δ_4 (**8**) against $\delta_3(\mathbf{1})$[1] (A, *cc* 0.999, *p* 0.958, *i* 0.069, *s* 0.019) and $\delta_2(\mathbf{8})$ against $\delta_5(\mathbf{1})$(B, *cc* 0.999, *p* 0.847, *i* 1.857, *s* 0.011) gave excellent correlations as shown in Fig. 1. Line A runs almost parallel with B. The

TABLE 1. ^{1}H NMR CHEMICAL SHIFTS AND COUPLING CONSTANTS OF METHYL (2-SUBSTITUTED 3-THIOPHENECARBOXYLATE)S(SERIES **6**)

No.	X	δ_{H_4}	δ_{H_5}	δ_{COOCH_3}	Others	J_{45}/Hz	Others	
1	H	7.53	7.30	3.87	8.10(H$_2$)	5.05	1.15(J_{24})	3.05(J_{25})
2	OCH$_3$	7.18	6.48	3.83	4.06(OCH$_3$)	6.00		
3	CH$_3$	7.37	6.97	3.84	2.74(CH$_3$)	5.40	0.35(J_{CH_3-4})	
4	Cl	7.35	7.05	3.88		5.85		
5	Br	7.36	7.21	3.88		5.75		
6	I	7.32	7.40	3.88		5.60		
7	CHO	7.58	7.64	3.96	10.62(CHO)	5.10	1.15(J_{CHO-5})	
8	COCH$_3$	7.35	7.46	3.91	2.61(COCH$_3$)	5.10		
9	COOCH$_3$	7.45	7.28	3.89	3.91(COOCH$_3$)	5.15		
10	NO$_2$	7.18	7.50	3.96		5.45		

TABLE 2. ^{1}H NMR CHEMICAL SHIFTS AND COUPLING CONSTANTS OF METHYL (4-SUBSTITUTED 3-THIOPHENECARBOXYLATE)S (SERIES **7**)

No.	X	δ_{H_2}	δ_{H_5}	δ_{COOCH_3}	Others	J_{25}/Hz	Others	
1	H	8.10	7.30	3.87	7.53(H_4)	3.05	1.15(J_{24})	5.05(J_{45})
2	OCH_3	8.01	6.28	3.85	3.89(OCH_3)	3.60		
3	CH_3	8.06	6.91	3.84	2.46(CH_3)	3.40	0.35(J_{CH_3-2})	1.10(J_{CH_3-5})
4	Cl	8.12	7.18	3.88		3.70		
5	Br	8.11	7.31	3.88		3.60		
6	I	8.07	7.50	3.88		3.45		
7	CHO	8.16	8.18	3.94	10.50(CHO)	3.40	0.35(J_{CHO-2})	
8	$COCH_3$	7.89	7.68	3.88	2.53($COCH_3$)	3.20		
9	$COOCH_3$	7.85	7.85	3.88	3.88($COOCH_3$)	—		

TABLE 3. ^{1}H NMR CHEMICAL SHIFTS AND COUPLING CONSTANTS OF METHYL (5-SUBSTITUTED 3-THIOPHENECARBOXYLATE)S (SERIES **8**)

No.	X	δ_{H_2}	δ_{H_4}	δ_{COOCH_3}	Others	J_{24}/Hz	Others	
1	H	8.10	7.53	3.87	7.30(H_5)	1.15	3.05(J_{25})	5.05(J_{45})
2	OCH_3	7.37	6.59	3.83	3.88(OCH_3)	1.65		
3	CH_3	7.85	7.17	3.83	2.47(CH_3)	1.35	1.15(J_{CH_3-4})	
4	Cl	7.86	7.33	3.85		1.60		
5	Br	7.98	7.47	3.85		1.55		
6	I	8.08	7.65	3.85		1.40		
7	CHO	8.44	8.16	3.91	9.94(CHO)	1.35	1.40(J_{CHO-2})	0.20(J_{CHO-4})
8	$COCH_3$	8.32	8.06	3.89	2.58($COCH_3$)	1.30		
9	$COOCH_3$	8.25	8.16	3.88	3.90($COOCH_3$)	1.40		
10	NO_2	8.24	8.28	3.92		1.80		

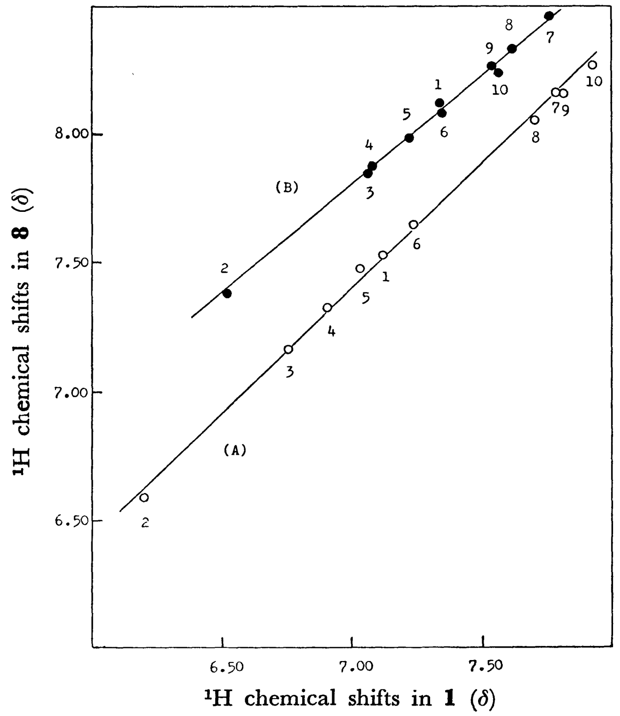


Fig. 1. Correlation between ^{1}H chemical shift in **8** and **1**; numbering as in Table 3. A, δ_4(**8**) *vs.* δ_3(**1**). B, δ_2(**8**) *vs.* δ_5(**1**).

correlation between δ_4(**8**) and δ_2(**8**) is in good accord with that between δ_3(**1**) and δ_5(**1**). These data seem to show that the introduction of methoxycarbonyl group into position 4 of 2-substituted thiophene is confined to the parallel transfer of the substituent effects on H_3 and H_5. The author further compared the chemical shifts of the ring protons in **8** with those in methyl (4-substituted 2-thiophenecarboxylate)s (**4**). The correlation between δ_4(**8**) and δ_3(**4**) was in agreement with that between δ_3(**1**) and δ_4(**2**). The correlation between δ_2(**8**) and δ_5(**4**) was also in agreement with that between δ_5(**1**) and δ_2(**2**). These correlations also demonstrate that the substituent effects in the series of compounds **8** and **4** follow the same trend.

Figure 2 shows the rough linearities between the effects of the substituents on δ_5(**6**) and those on δ_5(**1**) (A, *cc* 0.934, *p* 0.821, *i* 1.20, *s* 0.108) and between those on δ_4(**6**) and those on δ_4(**1**)(B, *cc* 0.868, *p* 0.590, *i* 3.28, *s* 0.055). The correlation between δ_5(**6**) and δ_4(**6**) is worse than that between δ_5(**1**) and δ_4(**1**). The author has compared the chemical shifts of the ring protons in **6** with those in methyl (3-substituted 2-thiophenecarboxylate)s (**3**), both of which belong to *ortho*-disubstituted thiophenes. The correlation between δ_4(**6**) and δ_4(**3**) was considerably worse than that between δ_4(**1**) and δ_4(**2**). Furthermore, the correlation between δ_5(**6**) and δ_5(**3**) was remarkably worse than that between δ_5(**1**) and δ_5(**2**). These results show that the additivity rule on the substituent effect in substituted thiophenes is not applicable to compounds **6**.

Figure 3 shows the good linearity between the effects of the substituents on δ_5(**7**) and those on δ_2(**2**)(A, *cc* 0.970, *p* 0.853, *i* 1.06, *s* 0.128), and no correlation between those on δ_2(**7**) and those on δ_5(**2**)(B, *cc* 0.085,

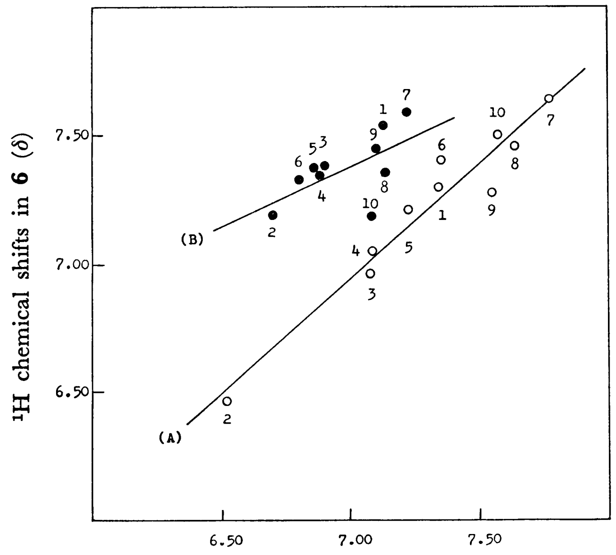


Fig. 2. Correlation between ^{1}H chemical shifts in **6** and **1**; numbering as in Table 1. A, δ_5(**6**) *vs.* δ_5(**1**). B, δ_4(**6**) *vs.* δ_4(**1**).

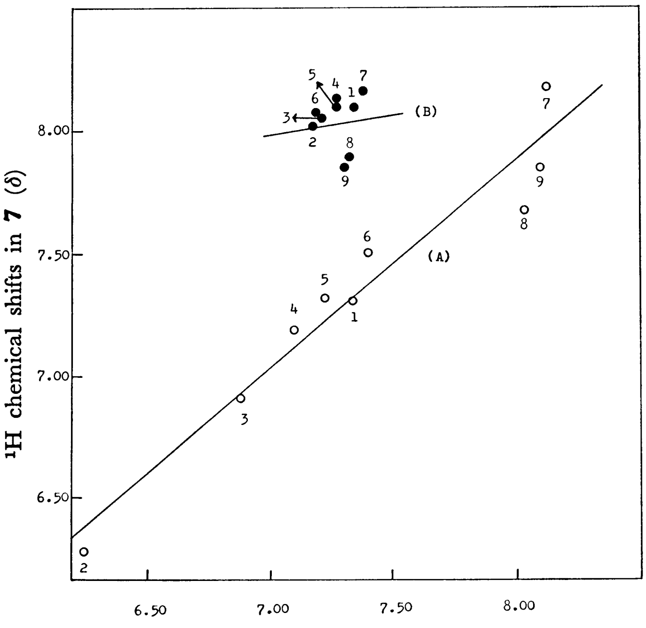
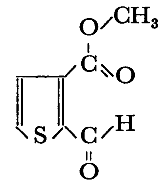


Fig. 3. Correlation between ^{1}H chemical shifts in **7** and **2**; numbering as in Table 2. A, δ_5(**7**) *vs.* δ_2(**2**). B, δ_2(**7**) *vs.* δ_5(**2**).

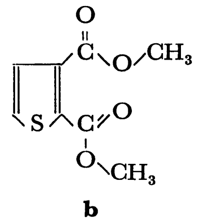
p 0.126, *i* 7.09, *s* 0.104). As given in Table 2, the chemical shifts of H_2 in the series of compounds **7** appear at significantly lower fields than those in the series of compounds **8**. It is noticeable that the H_2 signals of acetyl and methoxycarbonyl derivatives appear at higher fields than those in methoxy and methyl derivatives. These facts seem to account for the very poor correlation between δ_2(**7**) and δ_5(**2**).

Methyl proton chemical shifts of methyl (substituted 3-thiophenecarboxylate)s, which show the narrow range of variation, were found to be correlated with the chemical shifts of the corresponding protons of similarly substituted thiophenes. The result implies that the substituent effect is transmitted to the methyl group in a "through-bond" manner through the –CO–O–π system. The effect is attenuated by a factor of about 10.

The chemical shifts of the ring protons in methyl (2-, 4-, and 5-substituted 3-thiophenecarboxylate)s were calculated by making use of those of 2- and 3-substituted thiophenes. The observed chemical shifts are in good agreement with the calculated ones, within δ 0.1 in the series of compounds **8**. For example, the calculated ring proton chemical shifts were δ 7.83 and 7.16 for methyl 5-methyl-3-thiophenecarboxylate and δ 8.11 and 7.65 for methyl 5-iodo-3-thiophenecarboxylate. These calculated values were in good accord with the observed ones. This agreement suggests that the additivity rule, which is based on substituted thiophenes, is applicable to the chemical shifts of the ring protons in **8**, as well as in **4**.[1] In the series of compounds **6**, large deviations of the observed values from the calculated are seen in the carbonyl derivatives. As mentioned in the preceding paper,[1] methyl 2-formyl-3-thiophenecarboxylate and dimethyl 2,3-thiophenedicarboxylate are considered to take preferably the conformations **a** and **b**, respectively. The calculated chemical shifts of H_4 and H_5

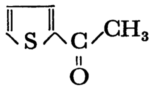


a



b

in methyl 2-acetyl-3-thiophenecarboxylate are δ 7.54 and 7.59 respectively, but the doublets occur at δ 7.35 and 7.46 and produce significant shifts to higher fields than the calculated values. The acetyl ester has a single ester carbonyl stretching band assignable to *anti-s-trans* form at 1731 cm^{-1}, quite analogous to methyl 2-formyl-3-thiophenecarboxylate (1729 cm^{-1}). It is confirmed that 2-acetylthiophene exists in *syn-s-trans* form **c**.[3] However, the C=O stretching band of acetyl group of this acetyl ester appears at 1671 cm^{-1} with a shoulder at 1686 cm^{-1}. Consequently, it is considered that another conformation **e** will exist in addition to the predominant conformation **d** in this compound. It is expected that the difference between the chemical shifts of H_4 and H_5 is enlarged by the presence of the conformation **e**. The signals at δ 7.35 and 7.46 may thus be assignable to those of H_4 and H_5, respectively. The discrepancy between the



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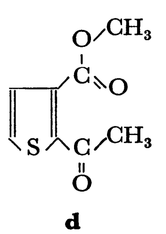

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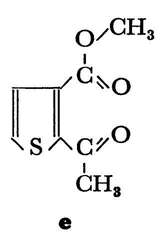
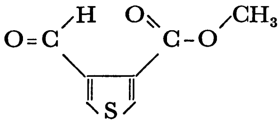


e

observed chemical shifts of H_4 and H_5 and those estimated seems to suggest that the coplanarity of carbonyl functions to the thiophene ring is lost by the steric hindrance. The H_4-chemical shift of methyl 2-nitro-3-thiophenecarboxylate is δ 7.18. This is a considerably higher field than the calculated value. The UV spectrum of nitro ester [λ_{max}: 284 nm(ε 6620)] is more similar to one of 2-nitrothiophene[λ_{max}: 300 nm(ε 6730), 282 nm(ε 5970)] than one of methyl 3-thiophenecarboxylate[λ_{max}: 239 nm(ε 7550)]. Consequently, it is considered that the methoxycarbonyl group at position 3 will exist with the considerable loss of the coplanarity to thiophene ring by the steric hindrance.

The discrepancy is largest in the series of compounds **7**, which is the *ortho*(3,4)-disubstituted derivative. It is considered that the contribution of the rotational isomer **f** involving a weak intramolecular hydrogen bond affects the chemical shifts of the ring and formyl protons in methyl 4-formyl-3-thiophenecarboxylate, as in methyl 3-formyl-2-thiophenecarboxylate[1] and methyl 2-formyl-3-thiophenecarboxylate. The H_2- and H_5-signals of this compound shift to significantly lower fields than the corresponding signals of acetyl derivative and dimethyl 3,4-thiophenedicarboxylate. The formyl proton chemical shift of methyl 4-formyl-3-thiophenecarboxylate is δ 10.50, and absorbs at δ *ca.* 0.6 lower field than that of methyl 4-formyl-2-thiophenecarboxylate(δ 9.91). The strong carbonyl band in IR spectrum appears at 1729 cm^{-1}, and is assignable to *syn-s-trans* form. Methyl 4-acetyl-3-thiophenecarboxylate has a single ester carbonyl band at 1730 cm^{-1} and a single acetyl carbonyl band at 1695 cm^{-1}. The observed chemical shifts of the ring protons in this ester are to significantly higher fields than the calculated values. This discrepancy suggests the loss of the coplanarity of carbonyl functions to thiophene ring by the steric hindrance, although this compound seems to exist in the preferred conformation **g**. The chemical shifts of H_2 and H_5 in dimethyl 3,4-thiophenedicarboxylate are equivalent and δ 8.07 in the calculations, but appear at δ 7.85 in the experiment. This discrepancy suggests the participation of the repulsion by the lone pair electrons and the steric hindrance. The IR carbonyl band, which appears as a broad peak centered at 1735 cm^{-1}, also suggests coexistence of several conformations. The additional feature in this series is the discrepancy between the observed and the calculated values in halogen derivatives. Two carbonyl stretching vibrations, which are assignable to *syn-s-trans* and *anti-s-trans* forms, are observed in these compounds. The chemical shifts, which are calculated on the basis of the *syn-s-trans* form in methyl 3-thiophenecarboxylate, are considered to change largely due to the presence of the *anti-s-trans* form.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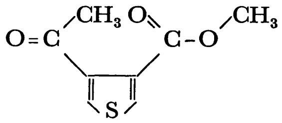
g

In summary, the discrepancy between the observed and estimated values in methyl (2-substituted 3-thiophenecarboxylate)s (**6**) and methyl (4-substituted 3-thiophenecarboxylate)s (**7**), which belong to *ortho*-substituted thiophenes, may be caused by (i) the change of the conformation in methoxycarbonyl, formyl, and acetyl groups, (ii) the loss of coplanarity of carbonyl functions to the thiophene ring by the steric hindrance and the repulsion of the lone pair electrons, and (iii) the electric field effect and the conformational effect by the weak intramolecular hydrogen bond.

The ester carbonyl stretching frequencies of methyl (substituted 3-thiophenecarboxylate)s, which were measured in CCl_4, are listed in Table 4. The correlations between the wavenumber of the C=O band (*syn-s-trans* form) and the proton chemical shift of the corresponding substituted thiophene were examined. A good correlation is obtained between $\nu_{C=O}(\mathbf{8})$[4] and $\delta_4(\mathbf{1})$. However, the C=O frequency data in other two series gave no correlation with ^1H chemical shifts of the corresponding substituted thiophenes. The correlation between the C=O frequencies of methyl (substituted 3-thiophenecarboxylate)s and methyl (substituted 2-thiophenecarboxylate)s was also examined. Reasonably good correlations were obtained between $\nu_{C=O}(\mathbf{6})$ and $\nu_{C=O}(\mathbf{3})$, and between $\nu_{C=O}(\mathbf{8})$ and $\nu_{C=O}(\mathbf{4})$, as well as $\nu_{C=O}(\mathbf{8})$ and $\nu_{C=O}(\mathbf{5})$. The correlation between $\nu_{C=O}(\mathbf{7})$ and $\nu_{C=O}(\mathbf{3})$ was excellent, and better than that between $\nu_{C=O}(\mathbf{6})$ and $\nu_{C=O}(\mathbf{3})$. It is interesting that these correlations are in good agreement with those between the chemical shifts of the ring protons in the three series of compounds **7**, **6**, and **3**, as mentioned above.

The plots of the proton-proton coupling constants in methyl (substituted 3-thiophenecarboxylate)s against those of the corresponding thiophenes gave good correlations, as shown in Fig. 4. The correlation of $J_{45}(\mathbf{3})$[5] against $J_{45}(\mathbf{1})$ was found to be excellent, in contrast to that of the chemical shifts between both series. Furthermore, the correlations between the coupling constants of methyl (substituted 3-thiophenecarboxylate)s and those of methyl (substituted 2-thiophenecarboxylate)s were examined. Fair correlations were obtained between $J_{45}(\mathbf{6})$ and $J_{45}(\mathbf{3})$, and be-

TABLE 4. FREQUENCIES OF C=O STRETCHING VIBRATION FOR METHYL (SUBSTITUTED 3-THIOPHENECARBOXYLATE)S

No.	X	$\nu_{C=O}/cm^{-1}$					
		Series **6**		Series **7**		Series **8**	
		anti[a)]	*syn*[b)]	*anti*	*syn*	*anti*	*syn*
1	H		1726		1726		1726
2	OCH_3	1712	1725	1713	1734		1722
3	CH_3	1718	1731*	1720*	1725		1723
4	Cl	1718	1735	1720	1740		1729
5	Br	1716	1735	1718	1739		1727
6	I	1718*	1731	1724*	1735		1728
7	CHO	1729			1729		1731
8	$COCH_3$	1731			1730		1729
9	NO_2		1746				1735

a) *anti-s-trans* Form. b) *syn-s-trans* Form. * Shoulder.

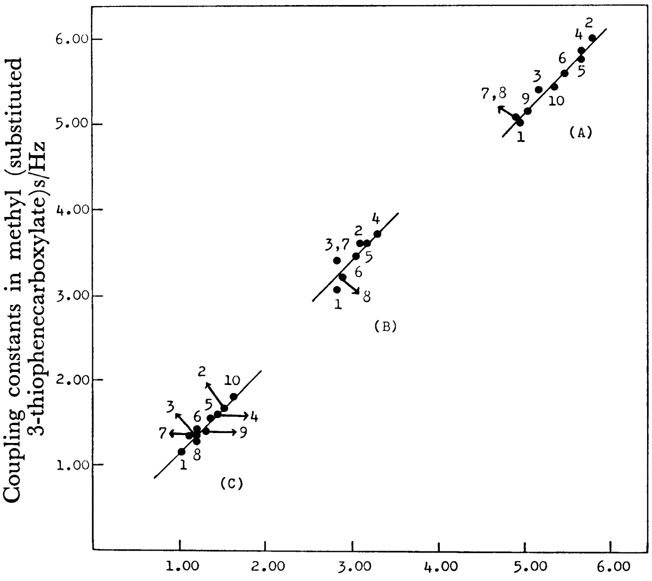

Fig. 4. Correlation between coupling constants in methyl (substituted 3-thiophenecarboxylate)s and substituted thiophenes, numbering as in Table 1. A, J_{45}(**6**) *vs.* J_{45}(**1**). B, J_{25}(**7**) *vs.* J_{25}(**2**). C, J_{24}(**8**) *vs.* J_{35}(**1**).

tween J_{24}(**8**) and J_{35}(**4**). For methyl (substituted 3-thiophenecarboxylate)s as well as for methyl (substituted 2-thiophenecarboxylate)s, the relationship of the coupling constants against the sum of the electronegativities of substituents including methoxycarbonyl group were examined. The individual coupling constants in the series of compounds **6**, **7**, and **8** gave good correlations with the electronegativities. The slope of the correlation for the series of compounds **6** is twice as large as those in the series of compounds **3**, **4**, **5**, **7**, and **8**. This fact shows that the electronegativity effect of the substituent on position 2 is more sensitive to J_{45} than those in all other cases, and is transmitted by a factor of about 2.

Experimental

The ^{1}H NMR spectra of the compounds were obtained at 100 MHz on a JEOL PS-100 spectrometer. The chemical shifts were determined with an accuracy of δ ±0.005 relative to TMS as an internal standard and the coupling constants were determined with an accuracy of ±0.02 Hz. The concentrations of solutions were adjusted approximately at 0.3 mol dm^{-3} with respect to substrates. The IR spectra were recorded on a Perkin-Elmer 257 spectrometer. The UV spectra were recorded on a Shimadzu MPS 5000 spectrometer in hexane.

Methyl 3-thiophenecarboxylate, methyl 2-bromo-3-thiophenecarboxylate, methyl 2-formyl-3-thiophenecarboxylate, methyl 4-methoxy-3-thiophenecarboxylate, methyl 4-bromo-3-thiophenecarboxylate, methyl 4-formyl-3-thiophenecarboxylate, dimethyl 3,4-thiophenedicarboxylate, methyl 5-chloro-3-thiophenecarboxylate, methyl 5-formyl-3-thiophenecarboxylate, and methyl 5-nitro-3-thiophenecarboxylate were prepared according to the reported procedures.[6–12]

Methyl 5-Methoxy-3-thiophenecarboxylate. This material was prepared by the oxidation of 5-methoxy-3-thiophenecarbaldehyde[13] followed by the esterification, bp 101.5—103 °C/4 mmHg (1 mmHg≈133.322 Pa). Found: C, 48.68; H, 4.37; S, 18.88%. Calcd for $C_7H_8O_3S$: C, 48.82; H, 4.68; S, 18.62%. IR (neat, cm^{-1}): 3120(=C–H), 1720(C=O), 1552, 1438, 727(thiophene ring).

The following esters were prepared by the esterification of the corresponding carboxylic acids.[14–23]

Methyl 2-Methoxy-3-thiophenecarboxylate. Bp 146—147 °C/21 mmHg. Found: C, 48.96; H, 4.60; S, 18.53%. Calcd for $C_7H_8O_3S$: C, 48.82; H, 4.68; S, 18.62%. IR (neat, cm^{-1}): 3120(=C–H); 1716(C=O); 1542, 1438, 754 (thiophene ring).

Methyl 2-Methyl-3-thiophenecarboxylate. Bp 99—101 °C/16 mmHg. Found: C, 53.92; H, 5.04; S, 20.75%. Calcd for $C_7H_8O_2S$: C, 53.83; H, 5.16; S, 20.53%. IR (neat, cm^{-1}): 3110, 3090 (=C–H); 1712 (C=O); 1537, 1438, 708 (thiophene ring).

Methyl 2-Chloro-3-thiophenecarboxylate. Bp 124—125 °C/30 mmHg. Found: C, 40.68; H, 2.82; Cl, 20.33; S, 17.98%. Calcd for $C_6H_5ClO_2S$: C, 40.80; H, 2.85; Cl, 20.07; S, 18.15%. IR(neat, cm^{-1}); 3120, 3090(=C–H); 1712(C=O); 1529, 1440, 702(thiophene ring).

Methyl 2-Iodo-3-thiophenecarboxylate. Bp 127.5—128 °C/5 mmHg. Found: C, 26.90; H, 1.70; I, 47.50; S, 12.02%. Calcd for $C_6H_5IO_2S$: C, 26.88; I, 1.88; I, 47.34; S, 12.06%. IR(neat, cm^{-1}): 3100, 3090(=C–H); 1710(C=O); 1515, 1436, 707(thiophene ring).

Methyl 2-Acetyl-3-thiophenecarboxylate. Bp 118—119 °C/4.5 mmHg. Found: C, 52.08; H, 4.52; S, 17.35%. Calcd for $C_8H_8O_3S$: C, 52.16; H, 4.38; S, 17.41%. IR(neat, cm^{-1}): 3100(=C–H); 1728, 1672(C=O); 1527, 1438, 737 (thiophene ring).

Methyl 2-Nitro-3-thiophenecarboxylate. Bp 132—133.5 °C/3 mmHg. Found: C, 38.37; H, 2.58; N, 7.30; S, 17.25%. Calcd for $C_6H_5NO_4S$: C, 38.50; H, 2.69; N, 7.48; S, 17.13%. IR(neat, cm^{-1}): 3100(=C–H); 1737(C=O); 1515, 1345(NO_2); 1548, 1437, 742(thiophene ring).

Methyl 4-Methyl-3-thiophenecarboxylate. Bp 110—111 °C/21 mmHg. Found: C, 53.97; H, 5.29; S, 20.38%. Calcd for $C_7H_8O_2S$: C, 53.92; H, 5.16; S, 20.53%. IR (neat, cm^{-1}): 3120(=C–H); 1718(C=O); 1538, 1450, 777 (thiophene ring).

Methyl 4-Chloro-3-thiophenecarboxylate. Mp 51.5 °C. Found: C, 40.98; H, 2.92; Cl, 20.00; S, 18.01%. Calcd for $C_6H_5ClO_2S$: C, 40.80; H, 2.85; Cl, 20.07; S, 18.15%. IR(KBr, cm^{-1}): 3120(=C–H); 1715(C=O); 1507, 1440, 781 (thiophene ring).

Methyl 4-Iodo-3-thiophenecarboxylate. Mp 32 °C. Found: C, 26.92; H, 1.70; I, 47.15; S, 11.82%. Calcd for $C_6H_5IO_2S$: C, 26.88; H, 1.88; I, 47.34; S, 11.96%. IR (KBr, cm^{-1}): 3110(-C–H); 1710(C–O); 1488, 1438, 777 (thiophene ring).

Methyl 4-Acetyl-3-thiophenecarboxylate. Bp 108.5—110 °C/2.5 mmHg. Found: C, 52.08; H, 4.52; S, 17.30%. Calcd for $C_8H_8O_3S$: C, 52.16; H, 4.38; S, 17.41%. IR (neat, cm^{-1}): 3110(=C–H); 1712, 1683(C=O); 1512, 1453, 798(thiophene ring).

Methyl 5-Methyl-3-thiophenecarboxylate. Bp 118—120 °C/26 mmHg. Found: C, 53.97; H, 5.31; S, 20.38%. Calcd for $C_7H_8O_2S$: C, 53.83; H, 5.16; S, 20.53%. IR (neat, cm^{-1}): 3110(=C–H); 1718(C=O); 1550, 1468, 738 (thiophene ring).

Methyl 5-Bromo-3-thiophenecarboxylate. Mp 43 °C. Found: C, 32.47; H, 2.09; Br, 36.03; S, 14.63%. Calcd for $C_6H_5BrO_2S$: C, 32.60; H, 2.28; Br, 36.14; S, 14.50%. IR(KBr, cm^{-1}): 3100(=C–H); 1718(C=O); 1527, 1442, 738 (thiophene ring).

Methyl 5-Iodo-3-thiophenecarboxylate. Mp 72 °C. Found:

C, 26.98; H, 1.70; I, 47.23; S, 11.82%. Calcd for $C_6H_5IO_2S$: C, 26.88; H, 1.88; I, 47.34; S, 11.96%. IR (KBr, cm^{-1}): 3090(=C–H); 1700(C=O); 1520, 1439, 736 (thiophene ring).

Methyl 5-Acetyl-3-thiophenecarboxylate. Mp 114 °C. Found: C, 52.31; H, 4.53; S, 14.28%. Calcd for $C_8H_8O_3S$: C, 52.16; H, 4.38; S, 17.41%. IR(KBr, cm^{-1}): 3120, 3100 (=C–H); 1712, 1663 (C=O); 1534, 1428, 759 (thiophene ring).

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References

1) Part I: H. Satonaka, *Bull. Chem. Soc. Jpn.*, **56**, 2463 (1983).

2) S. M. Castellano and A. A. Bothner-By, *J. Chem. Phys.*, **41**, 3863 (1964).

3) C. L. Cheng, I. G. John, and G. L. D. Ritchie, *J. Chem. Soc., Perkin Trans. 2*, **1975**, 744.

4) The notation $\nu_{C=O}$(**N**) in hereafter used for the carbonyl stretching frequency of the series of compounds **N**.

5) The notation J_{rs}(**N**) is hereafter used for the spin-spin coupling constant between r- and s-protons on thiophen ring of the series of compounds **N**.

6) R. H. Hoffman and S. Gronowitz, *Ark. Kemi*, **16**, 515 (1960).

7) L. S. Owen and F. F. Nord, *J. Org. Chem.*, **16**, 1864 (1951).

8) S. Gronowitz, A. Biezais, and B. Mathiasson, *Ark. Kemi*, **21**, 265 (1963).

9) J. B. Press, C. M. Hofmann, and S. R. Safir, *J. Org. Chem.*, **44**, 3292 (1979).

10) S. Gronowitz, P. Moes, A. Hornfeldt, and R. Hakansson, *Ark. Kemi*, **17**, 165 (1961).

11) C. Sone, Y. Abe, and T. Oikawa, *Nippon Kagaku Zasshi*, **92**, 1193 (1971).

12) I. J. Rinkes, *Recl. Trav. Chim. Pays-Bas*, **53**, 643 (1934).

13) Ya. L. Gol'dfarb, M. A. Kalik, and V. K. Zav'yalova, *Khim. Geterotsikl. Soedin.*, **1981**, 182.

14) A. Hallberg and S. Gronowitz, *Chem. Scr.*, **16**, 38 (1980).

15) G. Cousiglio, S. Gronowitz, A. B. Hornfeldt, R. Noto, K. Pettersson, and D. Spinell, *Chem. Scr.*, **13**, 20 (1979).

16) E. Campaigne and W. M. LeSuer, *J. Am. Chem. Soc.*, **71**, 333 (1949).

17) R. Guilard, P. Fournari, and M. Person, *Bull. Soc. Chim. Fr.*, **1967**, 4121.

18) M. Griffe, F. Durant, and A. F. Pieret, *Bull. Soc. Chim. Belg.*, **81**, 319 (1972).

19) W. Steinkopf and W. Hanske, *Ann.*, **532**, 236 (1937).

20) O. Hromatka, D. Binder, R. Pfister, and P. Zeller, Ger. Patent 2537070 (1975); *Chem. Abstr.*, **85**, 63077f (1976).

21) W. Steinkopf and W. Hanske, *Ann.*, **527**, 264 (1937).

22) E. Campaigne and R. C. Bourgeois, *J. Am. Chem. Soc.*, **76**, 2445 (1954).

23) I. B. Karmanova, Yu. B. Vol'ensktein, and L. I. Bolen'kii, *Khim. Geterotsikl. Soedin.*, **1973**, 490.