

$^{13}\text{C}$ -NMR SPECTRA OF SUBSTITUTED THIOPHENECARBOXYLIC ACIDSI. STIBOR<sup>a</sup>, L. RADICS<sup>b</sup>, M. JANDA<sup>a</sup>, J. ŠROGL<sup>a</sup> and M. NĚMEC<sup>a</sup><sup>a</sup> Department of Organic Chemistry,

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$^{13}\text{C}$ -NMR spectra of 4-substituted 2-thiophenecarboxylic acids and 5-substituted 3-thiophenecarboxylic acids have been measured. A significant correlation has been found between  $^{13}\text{C}$ -NMR shifts of 3-carboxyl group and  $\sigma_1$  constants of the substituents.

Our previous report<sup>1</sup> dealt with transmission of inductive effect through thiophene nucleus, and it was found that the transmission is due to  $\sigma$  bonds with significant participation of  $\pi$  electrons. It is known<sup>2</sup> that  $^{13}\text{C}$ -NMR shifts of the individual atoms reflect the overall electron density about the respective nucleus, being little affected by magnetic anisotropy which plays an important part in the case of  $^1\text{H}$ -NMR shifts.

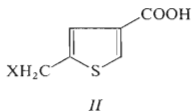
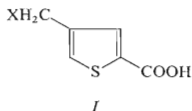
Therefore, it could be presumed that  $^{13}\text{C}$ -NMR shifts of individual atoms of thiophene nucleus or their relative changes would give further information about transmission of inductive effect in the studied system. Results of this investigation are given below.

## EXPERIMENTAL

The  $^{13}\text{C}$ -NMR spectra were measured with a Varian XL-100-15 apparatus at 25.16 MHz equipped with a Varian S 124X Fourier's transformation with 16K 620L computer. For the measurements 10% solutions in deuteriochloroform were used (in the case of  $\text{X} = \text{SO}_2\text{Ph}$  a mixture of deuteriochloroform and dimethyl sulphoxide- $d_6$  1:1 was used). All the samples contained TMS as internal standard. TMS and all the solvents used were of spectrometric purity (Merck, Darmstadt). The chemical shifts are given in ppm with respect to TMS. The measurement accuracy of the shifts was 0.04 ppm. The individual shifts were assigned on the basis of single frequency off-resonance proton decoupling experiments allowing to correlate splitting and broadening of  $^{13}\text{C}$ -NMR signals with  $^1\text{H}$  spectra, the latter being measured for identical samples at 100.1 MHz. Thanks to considerable number of published data about shifts and coupling constants in NMR spectra of thiophene derivatives<sup>3</sup> it was possible to assign unambiguously all the shifts in  $^1\text{H}$ -NMR spectra, which, in turn, enabled a complete interpretation of  $^{13}\text{C}$ -NMR spectra. Synthesis of individual derivatives was described in ref.<sup>1</sup>.

## RESULTS

Thiophenecarboxylic acids of general formulae *I* and *II* were used as model substances as in our previous report<sup>1</sup>. <sup>13</sup>C-NMR shifts of the compounds *I* and *II* are given in Tables I and II, respectively.



At first, the least squares method was used to calculate the correlation characteristics of individual carbon shifts of thiophene nucleus with the corresponding  $\sigma_1$  constants. In most cases the correlations thus obtained were statistically insignificant. However, for some carbon atoms satisfactory dependences were found. Thus for the acids of *I*

TABLE I  
<sup>13</sup>C-NMR Shifts of 2-Thiophenecarboxylic Acids (*I*) and  $\sigma_1$  Constants

X	5	4	3	2	COOH	CH <sub>2</sub>	Others	$\sigma_1$
COOH	130·17	135·76	135·13	135·10	172·94 164·04	35·76	—	0·34
SH	128·73	142·69	133·85	135·63	163·87	23·11	—	0·28
SC <sub>2</sub> H <sub>5</sub>	131·14	140·99	136·23	133·55	168·21	30·26	CH <sub>3</sub> 14·40 CH <sub>2</sub> 25·68	0·22
SO <sub>2</sub> Ph	133·60	138·32	134·89	135·75	163·31	56·79	128·47 129·37 129·18 134·19	0·62
OPh	129·80	139·19	132·98	136·01	163·83	65·25	115·06 121·39 129·78 158·71	0·42
OCH <sub>3</sub>	130·33	140·59	134·05	135·00	165·10	69·61	CH <sub>3</sub> 58·14	0·33
OH	128·23	144·77	133·05	135·19	163·85	59·32	—	0·31
H	128·27	138·66	135·29	134·89	164·05	—	CH <sub>3</sub> 15·41	0·00
Br	131·38	139·19	134·01	136·11	163·29	27·08	—	0·50

series dependence between  $\delta_{C_2}$ ,  $\delta_{C_5}$  and  $\sigma_1$  was found. The former was significant when tested at the 90% significance level, the latter at 95% significance level testing.

$$\delta_{C_2} = 2.64\sigma_1 + 134.36 \quad r = 0.5949$$

$$\delta_{C_5} = 7.33\sigma_1 + 127.73 \quad r = 0.7442$$

Values of critical correlation coefficients and testing procedure were taken from ref.<sup>4</sup>. In the series *II* no dependence was found which would be significant at least at 90% level. In this context it must be, however, pointed at the risk connected with the use of two-parameter equations. *E.g.* all the above mentioned dependences (all carbon atoms of the studied compounds) have their correlation coefficients within 0.99876 to 0.99999, if the equation of Swain and Lupton<sup>5</sup> is used, which would indicate high statistical significance of the dependences. For this reason the poly-parameter equations have been criticised in literature, and empirically it was stated that the critical number of points is about 10 and 20 for one-parameter and two-parameter equations, respectively<sup>6,7</sup>.

TABLE II  
<sup>13</sup>C-NMR Shifts of 3-Thiophenecarboxylic Acids (*II*)

X	5	4	3	2	COOH	CH <sub>2</sub>	Others
COOH	136.73	127.37	133.95	132.20	171.76 164.25	35.28	—
SH	145.99	125.97	134.32	132.08	164.12	22.83	—
SC <sub>2</sub> H <sub>5</sub>	143.75	126.75	134.20	132.55	164.77	30.02	CH <sub>3</sub> 14.23, CH <sub>2</sub> 25.45
SO <sub>2</sub> Ph	137.92	121.15	134.59	134.59	163.76	56.34	128.54; 129.41; 130.67; 134.29
OPh	140.31	127.05	134.20	132.95	163.90	64.29	114.82; 121.22; 129.42; 157.93
OCH <sub>3</sub>	142.69	127.18	132.83	135.39	168.23	68.96	CH <sub>3</sub> 57.99
OH	147.28	124.86	134.21	132.13	164.47	58.84	—
H	140.53	126.17	134.57	131.13	164.83	—	CH <sub>3</sub> 15.03
Br	147.51	124.60	134.14	132.06	164.14	58.52	—

A further significant correlation between  $^{13}\text{C}$ -NMR shifts of the carboxyl group carbon atom in series *II* and  $\sigma_1$  constants was found as it follows:

$$\delta_{3-\text{COOH}} = -1.79\sigma_1 + 164.88 \quad r = 0.8707.$$

This dependence is statistically significant at 99% significance level. No analogous dependence was found in the series *I*. With respect to the fact<sup>1</sup> that  $\sigma_1$  and p*K* values correlate in the both series, only a single explanation can be given for the mentioned finding, *viz.* an interaction of heteroatom with carboxyl group at 2 position.

In conclusion it can be stated that, although several significant dependences between the studied quantities were found, on this basis it is impossible to complete the existing knowledge about the transmission of inductive effect through thiophene nucleus.

#### REFERENCES

1. Janda M., Šrogl J., Němec M., Kalfus K.: This Journal *41*, 1541 (1976).
2. Tribble M. T., Traynham J. G. in the book: *Advances in Linear Free Energy Relationships* (N. B. Chapman, J. Shorter, Eds), p. 163. Plenum Press, London—New York 1972.
3. White R. F. M., Williams H. in the book: *Physical Methods in Heterocyclic Chemistry* (A. R. Katritzky, Ed.), Vol. IV, p. 165. Academic Press, London 1971.
4. Adámek P., Janečková E., Kuthan J., Paleček J., Skála V., Trška P.: *Příklady z fyzikálních metod organické chemie*, p. 315. Prague Institute of Chemical Technology, Prague 1967.
5. Swain C. G., Lupton E. C. jr: *J. Amer. Chem. Soc.* *90*, 4328 (1968).
6. Exner O. in the book: *Advances in Linear Free Energy Relationships* (N. B. Chapman, J. Shorter, Eds), p. 39. Plenum Press, London—New York 1972.
7. Ref. 6, p. 19.

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