

SYNTHESIS AND PROPERTIES OF 5-ARYLTHIO- AND 5-ARYLSULPHONYL-2-FURANCARBOXYLIC ACIDS

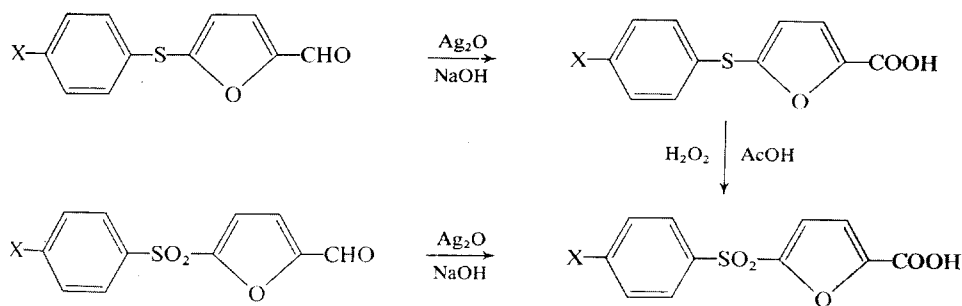
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Oxidation of 5-arylthio- and 5-arylsulphonyl-2-furaldehydes with silver oxide afforded the corresponding 2-furancarboxylic acids. The apparent pK values of the synthesized acids were determined by potentiometric titration and the transfer of electronic substituent effects through —S— or —SO₂— groups is discussed.

Within the framework of our studies on sulphides and sulphones of the furan series we prepared 5-(4-X-phenylthio)- and 5-(4-X-phenylsulphonyl)-2-furancarboxylic acids by oxidation of the corresponding aldehydes the synthesis and physico-chemical properties of which were described previously^{1,2}. Of the compounds of this type, 2-alkylthio-3-furancarboxylic acids³ and 2,5-bis-(dialkylthio-3-furancarboxylic acids)⁴ have hitherto been prepared by silver oxide oxidation. Nazarova and Potemkin⁵ oxidized aldehydes of the furan series with alkali hypochlorites and hypobromites.



X_S = H, CH₃, CH₃O, CH₃CONH, Cl, Br, NO₂
 X_{SO₂} = H, CH₃, CH₃O, CH₃CONH, Cl, Br, NO₂, N(CH₃)₂

SCHEME 1

The 5-arylthio- and 5-arylsulphonyl-2-furancarboxylic acids described in this paper were prepared by oxidation of the corresponding aldehydes with Ag_2O in an alkaline medium; the arylsulphonyl acids were obtained also by oxidation of the corresponding thio acids with hydrogen peroxide in glacial acetic acid.

The physical constants of the prepared furancarboxylic acids, together with their elemental analyses, are given in Table I. The starting 5-(4-X-phenylthio)-2-furaldehydes were prepared by reaction of alkali metal 4-X-substituted thiophenolates with 5-bromo-2-furaldehyde in acetone or ethanol¹. Reaction of this aldehyde with alkali metal salts of the corresponding benzenesulphinic acids in dimethylformamide afforded 5-(4-X-phenylsulphonyl)-2-furaldehydes². Analogous procedure led to the hitherto unknown 5-(4-methoxyphenylsulphonyl)-2-furaldehyde. The aldehydes were oxidized in high yields to the corresponding acids with a freshly prepared silver oxide in an alkaline medium; in the case of the thio acids (compounds I–VII, Table I) at 0–10°C and in the case of the arylsulphonyl acids (compounds VIII–XV, Table I) at room temperature. 5-(4-X-Phenylsulphonyl)-2-furancarboxylic acids were prepared also by oxidation with 30% hydrogen peroxide in glacial acetic acid in 85–90% yields.

The measured pK values of 5-(4-X-phenylthio)- and 5-(4-X-phenylsulphonyl)-2-furancarboxylic acids are listed in Table I. The pK values for the thio derivatives range between 4.31–4.73, the lowest and highest value corresponding to the compounds with NO_2 and CH_3O group, respectively. The interval $\Delta\text{pK} = 0.42$ indicates that the substituent X in the position 4 of the benzene nucleus affects the acidity of the carboxyl group across the sulphidic bridge and the furan ring. This fact is confirmed also by the linear plot of pK values against the Hammett σ_p constants ($r = 0.99$ and $\rho = 0.40$) as depicted in Fig. 1. For the arylsulphonyl acids VIII–XV the dissociation constant values are by an order of magnitude lower which shows

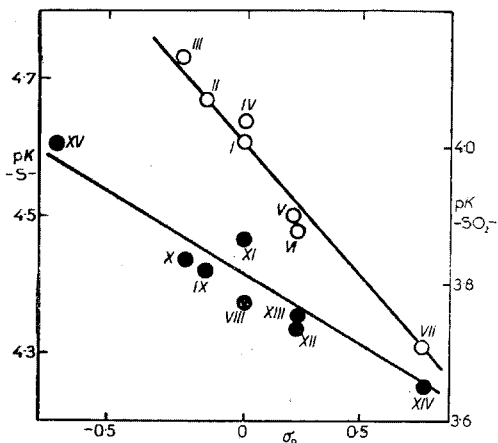
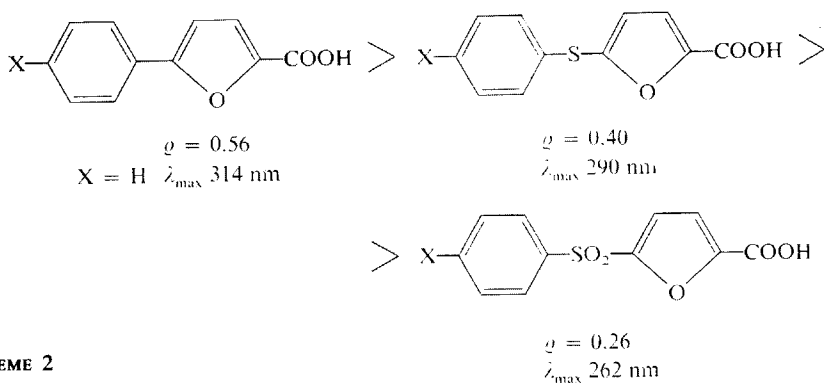


FIG. 1
Plot of pK-Values against σ_p Constants for 5-(4-X-Phenylthio)-2-furancarboxylic Acids I–VII (left scale) and for 5-(4-X-Phenylsulphonyl)-2-furancarboxylic Acids VIII–XV (right scale)

TABLE I
The Synthesized 5-(4-X-Phenyl-Y)-2-furancarboxylic Acids

Acid	X Y	Formula (mol.w.)	M.p., °C yield, %	Calculated/Found			pK
				% C	% H	% S	
<i>I</i>	H S	C ₁₁ H ₈ O ₃ S (220.2)	139–141 86.3	60.00 59.81	3.68 3.47	14.56 34.46	4.61
<i>II</i>	CH ₃ S	C ₁₂ H ₁₀ O ₃ S (234.3)	148–149 91.2	61.54 61.32	4.27 4.23	13.69 13.60	4.67
<i>III</i>	CH ₃ O S	C ₁₂ H ₁₀ O ₄ S (250.3)	154–155 92.7	57.60 57.37	3.99 3.90	12.81 12.72	4.73
<i>IV</i>	CH ₃ CONH S	C ₁₃ H ₁₁ NO ₄ S (277.1)	216–218 87.3	56.33 56.02	3.97 3.67	11.57 11.24	4.64
<i>V</i>	Cl S	C ₁₁ H ₇ ClO ₃ S (254.7)	159–160 93.5	51.88 51.51	2.75 2.67	12.59 12.56	4.50
<i>VI</i>	Br S	C ₁₁ H ₇ BrO ₃ S (299.1)	157–158 95.2	44.17 43.95	2.34 2.11	10.72 10.56	4.48
<i>VII</i>	NO ₂ S	C ₁₁ H ₇ NO ₅ S (265.2)	189–190 87.5	49.80 49.81	2.61 2.35	12.10 11.95	4.31
<i>VIII</i>	H SO ₂	C ₁₁ H ₈ O ₅ S (252.1)	177–179 83	52.40 52.41	3.17 2.99	12.41 12.70	3.77
<i>IX</i>	CH ₃ SO ₂	C ₁₂ H ₁₀ O ₅ S (266.2)	201–202 87.5	54.14 53.81	3.76 3.54	12.04 11.78	3.82
<i>X</i>	CH ₃ O SO ₂	C ₁₂ H ₁₀ O ₆ S (282.3)	187–188 85.5	51.10 51.02	3.54 3.33	11.35 11.28	3.84
<i>XI</i>	CH ₃ CONH SO ₂	C ₁₃ H ₁₁ NO ₆ S (309.2)	278–249 82.4	50.51 50.18	3.56 3.32	10.37 9.98	3.87
<i>XII</i>	Cl SO ₂	C ₁₁ H ₇ ClO ₅ S (286.6)	219–220 92.4	51.90 51.49	2.75 2.03	12.60 12.46	3.74
<i>XIII</i>	Br SO ₂	C ₁₁ H ₇ BrO ₅ S (336.1)	235–236 88.5	39.90 39.48	2.11 2.03	9.68 9.56	3.76
<i>XIV</i>	NO ₂ SO ₂	C ₁₁ H ₇ NO ₇ S (297.2)	214–215 79.5	44.45 44.37	2.36 2.19	10.79 10.35	3.65
<i>XV</i>	(CH ₃) ₂ N SO ₂	C ₁₃ H ₁₃ NO ₆ S (309.3)	261–273 82.7	55.52 55.37	4.62 4.31	11.40 11.32	4.09

that an arylsulphonyl group in the position 5 of a 2-furancarboxylic acid has a stronger acidity-enhancing effect than an arylthio group. Nevertheless, also in this case the substituents X influence the strength of the acids VIII–XV, as shown by the obtained linear relationship $pK = f(\sigma p)$ ($r = 0.94$ and $\rho = 0.26$). Krutošiková and collaborators⁶ studied the pK values of the series of 5-(3-X-phenyl)-2-furancarboxylic acids and from the obtained linear plot they determined the value $\rho = 0.56$. The comparison of this value with the ρ values for the series of thio and sulphonyl 2-furancarboxylic acids shows that the transfer of electronic effects of the substituents X decreases in the order 5-aryl, 5-arylthio, 5-arylsulphonyl derivatives (Scheme 2).



SCHEME 2

The UV-spectral data of the acids I–XV are given in Table II. The spectra of 5-(4-X-phenylthio)-2-furancarboxylic acids exhibit absorption maxima in the region 204–208 nm, 239–268 nm and 290–317 nm. The first two maxima can be assigned to the respective $\pi \rightarrow \pi^*$ and $n \rightarrow \pi^*$ electron transitions in the furan and the arylthio part of the molecule. The third absorption maximum corresponds to the electron oscillation across the whole conjugated system of the molecule (K-band). The spectra of phenylsulphonyl acids VIII–XV display also three absorption maxima at 205 to 206 nm, 221–250 nm and 262–317 nm. The UV spectra of the compounds with nitrogen-containing functional groups (XI–XIV) exhibit a splitting of the second absorption band. The third maxima (at 262–317 nm) in the spectra of 5-(4-X-phenylsulphonyl)-2-furancarboxylic acids have a marked hypsochromic shift (about 20 to 30 nm) in comparison with the corresponding 5-(4-X-phenylthio) acids. The corresponding bands for 5-aryl-2-furancarboxylic acids⁶ are all situated above 300 nm and exhibit a bathochromic shift as compared with the studied compounds.

Also these facts indicate that the transfer of electronic substituent effects through the SO_2 group does exist (the position of the K-band is affected by the substituent X) however, it is substantially weaker than the transfer in the thio compounds.

TABLE II
Spectral Data of the Acids I–XV

Acid	$\tilde{\nu}(\text{C}=\text{O})$ m^{-1}	$\lambda_{\text{max}}, \text{nm}^a$ (log ϵ)	$\lambda_{\text{max}}, \text{nm}$ (log ϵ)	$\lambda_{\text{max}}, \text{nm}$ (log ϵ)
I	1 682	207 (4.23)	250 (4.29)	290 sh (3.93)
II	1 670	207 (4.17)	251 (4.19)	294 (3.95)
III	1 670	204 (4.22)	253 (4.25)	297 sh (3.98)
IV	1 710	207 (4.30)	268 (4.39)	305 i (3.78)
V	1 680	206 (4.09)	254 (4.25)	293 sh (3.96)
VI	1 680	208 (3.84)	256 (4.25)	—
VII	1 710	206 (4.16)	239 (4.23)	317 (4.17)
VIII	1 710	205 sh (3.98)	221 (4.08)	262 (4.26)
IX	1 720	205 (4.02)	229 (4.10)	263 (4.24)
X	1 726	206 (4.16)	239 (4.21)	273 (4.28)
XI	1 735	206 (4.23)	244 sh, 250 (4.24) (4.28)	284 (4.41)
XII	1 700	205 (4.05)	230 (4.17)	266 (4.22)
XIII	1 700	205 (4.16)	235 (4.22)	266 (4.30)
XIV	1 700	206 (4.14)	250, 256 (4.17) (4.15)	317 (4.34)
XV	1 710	206 (4.09)	243 (4.30)	280 (4.16)

^a i Inflex; sh shoulder.

EXPERIMENTAL

The IR spectra were measured on a double-beam UR-20 (Zeiss) spectrophotometer in KBr pellets (0.2 mg compound/1 g KBr). The instrument was calibrated with a polystyrene foil; accuracy of the wavenumber scale $\pm 1 \text{ cm}^{-1}$. The UV spectra were taken on a recording Specord UV VIS (Zeiss) spectrophotometer in the region 200–400 nm; accuracy $\pm 1 \text{ mn}$. The compounds were measured in $4 \cdot 10^{-4} \text{ M}$ ethanolic solutions in 1 cm cells. The apparent pK values of the synthesized acids were determined in 50% ethanol at 25°C, using a Radiometer 26 (Copenhagen) pH meter equipped with a Radiometer G 202 C electrode and a Radiometer K 4112 reference calomel electrode. The electrodes were standardized using aqueous buffer solutions. The obtained pK values were corrected by a correction factor $F = 1.007$, calculated from the published pK values of benzoic acid and the value determined in our Laboratory.

5-(4-X-Phenylthio)- and 5-(4-X-Phenylsulphonyl)-2-furancarboxylic Acids

5-(4-X-Phenylthio)-2-furaldehyde (0.005 mol) was added under stirring at 0–10°C in the course of 20 minutes to Ag_2O , prepared by addition of silver nitrate (3.38 g; 0.02 mol) to a solution of sodium hydroxide (1.4 g; 0.04 mol) in water. In the case of 5-(4-X-phenylsulphonyl)-2-furaldehydes the reaction was carried out at room temperature. At the end of the reaction the reaction mixture turned black or a silver mirror was formed on the walls of the reaction flask. The reduced silver was filtered off and washed several times with cold water which was combined with the filtrate. The filtrate was acidified and, after standing for 1 h, the liberated acid was filtered and washed with water. The crude product was purified by precipitation of its sodium salt, by crystallisation from dilute ethanol or by sublimation *in vacuo* (for spectral measurements, except the compounds VII and XIV).

Oxidation of 5-(4-X-Phenylthio)-2-furancarboxylic Acids with Hydrogen Peroxide

Hydrogen peroxide (30%; 3 ml) was added to a solution of 5-(4-X-phenylthio)-2-furancarboxylic acid (0.005 mol) in glacial acetic acid (15 ml). The mixture was stirred for 30 minutes at room temperature and set aside for 5 days. The solution was concentrated to half of its original volume and diluted with 4 parts of water. The separated crude product was filtered and purified by the methods mentioned above.

5-(4-Methoxyphenylsulphonyl)-2-furaldehyde

This compound was prepared in 65% yield, analogously as the other 5-arylsulphonyl-2-furaldehydes²; m.p. 154–155°C (ethanol). For $\text{C}_{12}\text{H}_{10}\text{O}_5\text{S}$ (266.3) calculated: 54.92% C, 3.72% H, 12.10% S; found: 54.65% C, 3.56% H, 11.93% S.

REFERENCES

1. Kada R., Kováč J.: Chem. Zvesti 29, 402 (1975).
2. Kada R., Kováč J.: Chem. Zvesti, in press.
3. Goldbarb Yu. L., Danjushevskii J. L., Vinogradova M. A.: Dokl. Akad. Nauk SSSR 15, 332 (1963)
4. Danjushevskii Yu. L., Marakatkina M. A., Goldbarb Yu. L.: Izv. Akad. Nauk SSSR, Ser. Khim. 1968, 2532.
5. Nazarova Z. N., Potemkin G. F.: Zh. Org. Kim. 1, 1079 (1965).
6. Krutošiková A., Surá J., Kováč J., Kalfus K.: This Journal 40, 3357 (1975).

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