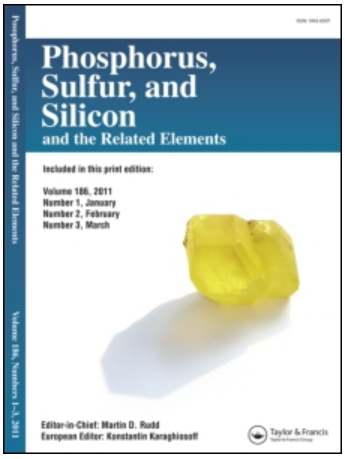

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SULFENAMIDES AND SULFINAMIDES V CONJUGATIVE AFFINITY AND pKa VALUES OF ARYL SULFINAMIDES

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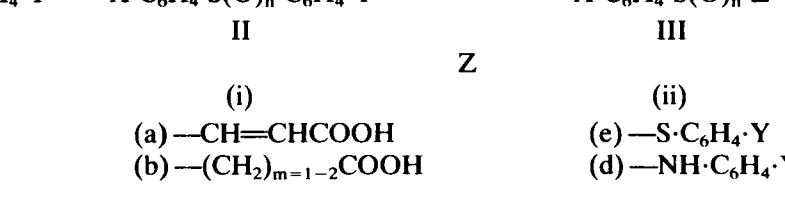
pKa values and NMR properties of aryl sulfinamides are discussed with respect to conjugative affinity in the sulfinamido group.

Key words: Sulfinamides, pKa values, conjugative affinity, NMR, spectrophotometry.

INTRODUCTION

The influence of sulfur atoms at different oxidation levels in compounds of the types I–III (n=0–2) may be classed as indirect or direct according to the manner in which effects are translated to a functional group used as indicator.



In the groups I, II and III (Z = a, b) the $S(O)_n$ group is subject to varying degrees of removal from the functional recording group, Y, so that substituent influence requires transmission through an aromatic ring, a conjugated olefinic group or an interposed alkyl group. By contrast in groups Z = c, d the group is directly attached to the atom or group at stake. With change in the make-up of the central group, —$S(O)_n$·S— or —$S(O)_n$·NH—, influences may extend in a reverse manner to certain properties of the substituent. Irrespective of the class considered the interrelationship between inductive and resonance effects with the conjugative affinity of the $S(O)_n$ group becomes a basis for discussion.

The present report concerns the influence of the SO group on the pKa values of aryl sulfinamides (Z(ii)d) and the equilibrium 1 together with the extents of correlation between NMR properties and conjugative affinities of the —SO·NH— and —SO·S— groups.

$$R{\cdot}SO{\cdot}NH{\cdot}R' + H^+ \rightleftharpoons R{\cdot}SO{\cdot}NH_2^+{\cdot}R' \qquad (1)$$

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RESULTS AND DISCUSSION

Changes in absorption with change in pH of the medium providing the basis for calculation of pKa values are shown in fuller terms for N-(phenyl)-benzenesulfinamide in Table I. Results for methyl substituted derivatives are summarized in Table II.

TABLE I

N-(Phenyl)-benzenesulfinamide (R=R'=C_6H_5) pKa value

pH	Optical density at 235 nm	pKa	Mean pKa
2.0	0.440		
3.03	0.548	3.03	
3.06	0.541	3.11	
3.22	0.562	3.10	
3.26	0.567	3.10	3.19
3.43	0.572	3.23	
3.45	0.571	3.26	
3.58	0.580	3.31	
3.61	0.580	3.34	
5.3	0.635		
7.0	0.655		
9.0	0.655		
12.0	0.616		

TABLE II

Methyl substituted arylsulfinamides. pKa values
p-X·C_6H_4·SO·NH·C_6H_4·Y-*p*

X	Y	pKa	ΔpKa	ΔpKa for R·S·NH·R'[1]
H	H	3.19		
H	CH_3	3.34	0.15	0.39
CH_3	H	3.43	0.24	0.71
CH_3	CH_3	3.49	0.30	1.15

An expectation that conjugation within the —SO·NH— group might lead to lower pKa values for the sulfinamides than has been found for the sulfenamides[1] was not realized. Although the lesser stability of the sulfinamides in aqueous media presented difficulties and the need for repeated determinations, nevertheless results reliably show that the electron withdrawing effect of the phenylthio-group as shown in the sulfenamides is now reduced. Conversion to the sulfinyl group leads to slight but recognizably higher pKa values. Polar features of the sulfinyl group, ($O{=}S \leftrightarrow {}^{-}O{-}S^{+}$) are accepted but present results show limitations in extension of conjugation to the nitrogen atom of the sulfinamides ($-S{=}\overset{+}{N}H$). With its occurrence, protonation of the nitrogen atom would require

$$\begin{array}{l} \\ | \\ O^{-} \end{array}$$

more forcing conditions leading to lower pKa values. Thus it appears that polarities initiated with the sulfinyl group are more closely associated with its attached aromatic system including a potential for electron withdrawal therefrom.

Protonation of the nitrogen might also lead to greater electron withdrawal by the sulfinyl group from the aromatic system as deduced from a study of the sulfoxides.[2] Resonance stabilization of this kind would tend to be base strengthening.

In the event it could be anticipated that electron donating effects of methyl substitution would also be affected. Table II shows that extents of change in pKa values induced by methyl substitution in the sulfinamides are of a different order from those produced in the sulfenamides.[1]

Substitution on the amine side produces an expected increase in pKa value but less than that with the sulfenamides. More marked differences occur with substitution on the sulfur side. Here the increase is only about one-third that obtained with the sulfenamides, a trend supported in the doubly substituted derivative. It is thus confirmed that inductive effects from substitution on the sulfur side are largely lost and it is tempting to suggest that this is the result of superposing on a system where the mesomeric effect is already operating in the same direction. The inductive effect of methyl substitution is thus absorbed by the sulfinyl group. Potentiometric measurements of the pKa values in the acrylic acid series, Z(i)a, also showed that substituent effects were better transmitted by a divalent atom than by sulfinyl and sulfonyl groups.[3] Comparison of mean values indicated that electronic effects of a substituent pass a divalent sulfur atom 1.7 times as effectively as they pass a sulfinyl or sulfonyl bridge. A similar result from the mercaptoacetic acid based series, ((Z(i)b), led to the conclusion that inductive effects instead of being directed through the methylene group may be partially "shunted into the highly polar sulfur-oxygen bond".[4]

An alternative approach lies in determination of NMR shifts resulting from methyl substitution, first by examining shifts for the N—H proton and then conversely shifts for the methyl protons themselves. Table III shows the marked effect on the N—H proton response of substitution on the amine side in contrast with the minimal effect of substitution on the sulfinyl side. On the amine side the NMR shifts uphold the influence of the methyl group (X = H; Y = CH_3), which is dampened by the sulfinyl group with the alternate substitution (K = CH_3; Y = H). The shift in the doubly substituted derivative (X = CH_3; Y = CH_3) is therefore almost completely due to the substitution on the amine side.

To the extent that resonance in the —SO·NY— group is impeded differences in the NMR shifts of methyl protons should occur. To test this proposal comparisons were made with methyl substituted disulfides, thiosulfinates and thiosulfonates in which the divalent sulfur atom is replacing the —NH— group. From an

TABLE III

Effect of methyl substitution on N—H shift in sulfinamides
p-X—C_6H_4·SO·NH·C_6H_4—Y-*p*

X	Y	N—H Shift Hz	ΔN—H Shift, Hz
H	H	380	
H	CH_3	363.5	16.5
CH_3	H	376	4
CH_3	CH_3	360	20

TABLE IV

NMR shifts (Hz) of methyl protons in sulfenamides, sulfinamides and sulfonamides
p-X—C_6H_4·$S(O)_n$·NH·C_6H_4—Y-p

n =		0		1		2	
X	Y	X	Y	X	Y	X	Y
H	CH_3	—	136	—	137	—	136
CH_3	H	137.5	—	145.2	—	142.2	—
CH_3	CH_3	137.5	136	144.7	137.7	142.2	136

established capacity of divalent sulfur to relay electronic effects the differences in response of methyl protons appearing in the progression from the sulfenamides to the sulfonamides should disappear in the progression from disulfides to the thiosulfinates and thiosulfonates.

Tables IV and V support this view. Irrespective of the oxidation level of the sulfur atom in the sulfenamides, sulfinamides and sulfonamides there is practically no change in the responses of the methyl protons on the amine side of the molecule.

By contrast shifts occur in the resonances of groups directly influenced by the sulfinyl and sulfonyl groups, and to a slightly greater extent in those influenced by the sulfinyl group. Convincing evidence of differences according to whether a sulfur atom or the —NH— group is involved is thus provided.

TABLE V

NMR shifts (Hz) of methyl protons in Di-p-tolyl sulfide and disulfide derivatives at various oxidation levels

Derivative	n = 0	1	2
CH_3·C_6H_4·$S(O)_n$·C_6H_4·CH_3	138	141	143
CH_3·C_6H_4·$S(O)_n$·S·C_6H_4·CH_3	135	144* 142	144.4* 141.8

* Refers to protons closer to oxidized sulfur.

In the disulfides the shift is about the level common for the series but in the oxidized derivatives the equivalences of shifts of the methyl protons means that in contrast with the sulfinamides and sulfonamides interaction in the —SO·S— group occurs whereby the influence of the sulfinyl group is transmitted to the methyl protons through the sulfur atom. Other differences are that the effect of the sulfinyl group in the sulfinamides is greater than that of the sulfonyl group in the sulfonamides and is only slightly lower in the thiosulfinates compared to the thiosulfonates. The closer affinity with the methylene protons in the benzyl series is reflected in the greater shifts (Table VI), which also confirms the stronger effect of the sulfinyl group and the interplay in the —SO·S— groups. In the aliphatic series the shifts for the thiosulfinates (177.6 Hz, 174.6 Hz) are between those of the disulfide (134.2 Hz) and thiosulfonate (192.6 Hz, 185.6 Hz),[5] which must be related to removal of the levelling influence of the aromatic ring.

Transmission of electronic effects through T in aryl families of the form R·C_6H_4·T—H have been studied in the form of the Hammett equation.

$$\Delta\upsilon = \rho\sigma + \Delta\upsilon_0$$

TABLE VI

NMR shifts of methylene protons in benzyl disulfide derivative
$C_6H_5{\cdot}CH_2{\cdot}S(O)_n{\cdot}S{\cdot}CH_2{\cdot}C_6H_5$

n	CH_2	
0	216.5	
1	256*	254
2	253.5*	242

* Refers to protons closer to oxidized sulfur.

If Δv_0 for R = H or $\sigma = 0$ is the fundamental quantity of the equation then when H is replaced by R, $\rho\sigma$ becomes an increment to Δv_0 assuming ρ and σ are independent.[6] Comparisons of the influences of R on chemical shifts of methyl protons of toluene are in accord with those of the present series.

An earlier discussion[7] concluded that the aryl sulfinamides received an insignificant contribution from double bond structure between the sulfur and nitrogen atoms. Rather there was some contribution from double bond structure between the sulfur atom and the aromatic ring.[7]

In summation reference must be made to the structurally induced variations between the sulfenamides and sulfinamides in responses to the two types of measurement. In the former very little correlation was found between the pKa values and NMR shifts of N—H protons. Major changes appeared in the pKa values. By contrast relatively slight changes occurred in the sulfinamide pKa values but good correlations were possible with the NMR shifts of the N—H and methyl protons in substituted derivatives.

EXPERIMENTAL

Sulfinamides were prepared by condensation of a sulfinyl chloride with the required amine. Products were recrystallized to satisfactory elemental analysis and melting point,[8] generally by dissolving in the minimum amount of ethanol at room temperature followed by addition of water to produce a slight turbidity. Cooling to 5° and standing gave nacreous crystals. Thiosulfinates,[9] thiosulfonates[10,11] and other derivatives were prepared by standard methods.

TABLE VII

Sulphinamides ($X{\cdot}C_6H_4{\cdot}SO{\cdot}NH{\cdot}C_6H_4{\cdot}Y$)

X	Y	Yield %	M.P.°	Found C	H	N	Calc. C	H	N
H	H	60	113	66.41	5.04	6.45	66.36	5.07	6.45
CH_3	H	60	137	66.96	5.52	6.40	67.51	5.62	6.06
H	CH_3	65	134	67.39	5.58	5.99	67.51	5.62	6.06
CH_3	CH_3	70	133	68.37	6.14	5.71	68.52	6.14	5.11

pKa Values were determined spectrophotometrically as previously described for the sulfenamides.[12] Determinations of approximate pKa values were obtained by plotting optical density of solutions over

a range of pH values. The sulfinamide (0.02 g) in spectroscopic ethanol was diluted with water to volume (500 ml). An aliquot (10 ml) of this solution was then diluted with the appropriate buffer solution to volume (50 ml). Absorptions (1 cm silica cells, Beckman spectrophotometer) were measured at the analytical wave length. The pH of solutions was checked before and after the determination. pKa Values were calculated using the conventional procedure for spectrophotometric determinations.[12] N.M.R. spectra of equimolar solutions in deuterochloroform were determined (by Mr. V. Pickles) on a Varian A60 spectrometer operating at 60 MHz. Values correct to ±0.2 Hz are reported in Hz to give a bigger dimension to differences. Tetramethylsilane was used as internal standard.

REFERENCES

1. R. F. Bayfield and E. R. Cole, *Phosphorus and Sulfur*, **45,** 237 (1989).
2. K. K. Andersen, W. H. Edmonds, J. B. Basiotti and R. A. Strecker, *J. Org. Chem.*, **31,** 2859 (1966).
3. H. Hogeveen, *Rec. Trav. Chim.*, **83,** 823 (1964).
4. D. J. Pasto, D. McMillan and T. Murphy, *J. Org. Chem.*, **30,** 2638 (1965).
5. P. Allen, P. J. Benner and E. R. Malinowski, *Chem. and Ind. (London)* 1164 (1964).
6. S. H. Marcus, W. P. Reynolds and S. I. Miller, *J. Org. Chem.*, **31,** 1872 (1966).
7. K. Mon and Y. Ueda, Yakugaku Zasshi, **91,** 940 (1970); *Chem. Abstr.*, **75,** 150938z (1971).
8. J. v. Braun and W. Kaiser, *Ber.*, **56,** 549 (1923).
9. H. J. Backer and H. Kloosterziel, *Rec. Trav. Chim.*, **73,** 129 (1954).
10. C. Pauly and R. Otto, *Ber.*, **9,** 1639 (1876).
11. O. Hinsberg, *Ber.*, **41,** 2836 (1908).
12. A. Albert and E. P. Serjeant, "*Ionization Constants of Acids and Bases*", Methuen, London, 1962).