Cyclic Sulphones. Part XIV.[1] Ionisation Constants of Substituted Thiopyran 1,1-Dioxides

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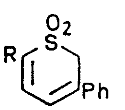
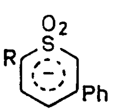
Ionisation constants of 3-phenyl- and 6-methyl-3-phenyl-2*H*-thiopyran 1,1-dioxides have been determined spectrophotometrically in water and in methanol. The data are consistent with the corresponding anions being particularly stable. The results are compared with those for other sulphonyl-substituted carbon acids.

ANIONS of substituted thiopyran 1,1-dioxides and of benzo- and dibenzo-thiopyran 1,1-dioxides have been shown to be particularly stabilised [2] and highly delocalised species.[3,4] Evidence is now presented for the enhanced acidity of the thiopyran 1,1-dioxide system as deduced from the ionisation constants, in water and in methanol, of 3-phenyl- (1) and 6-methyl-3-phenyl-2*H*-thiopyran 1,1-dioxide (2).


(1) R = H
(2) R = Me


(3) R = H
(4) R = Me

EXPERIMENTAL

Materials.—Isomerically pure 3-phenyl-2*H*-thiopyran 1,1-dioxide (1), m.p. 100—101°, was prepared as previously.[5] 6-Methyl-3-phenyl-2*H*-thiopyran 1,1-dioxide (2) was prepared analogously; reaction of ω-bromoacetophenone with 3-mercaptobutan-2-one in the presence of triethylamine gave the *phenacyl sulphide*, b.p. 136° at 0·01 mmHg, $n_D^{22\cdot5}$ 1·5627 (Found: C, 65·0; H, 6·3. $C_{12}H_{14}O_2S$ requires C, 64·8; H, 6·3%). The corresponding crude sulphone, obtained by permanganate oxidation, was cyclised to 6-*methyl*-3-*phenyl*-5,6-*dihydro*-2H-*thiopyran*-5-*one* 1,1-*dioxide*, m.p. 136° (from ethanol) (Found: C, 60·9; H, 5·1. $C_{12}H_{12}O_2S$ requires C, 61·0; H, 5·0%). Reduction with sodium borohydride and dehydration of the corresponding alcohol with phosphoric acid afforded 6-*methyl*-3-*phenyl*-2H-*thiopyran* 1,1-*dioxide* (2), m.p. 107° (from methanol) (Found: C, 65·5; H, 5·5. $C_{12}H_{12}O_2S$ requires C, 65·4; H, 5·5%), for n.m.r. spectrum see ref. 4.

Spectra and pK_α *Determinations.*—U.v. and visible spectra were recorded with a Beckman DB-GT instrument fitted with a thermostatted (25°) cell compartment. N.m.r. spectroscopy had already established [4] that the action of sodium methoxide in methanol on the sulphones (1) and (2) causes deprotonation to give the conjugate anions (3) and (4) respectively. The anions (3) and (4) exhibit strong u.v. absorptions; upon acidification with aqueous mineral acid the original spectra are obtained, thus proving that a reversible proton abstraction–protonation process is involved. Basic solutions of sulphones (1) and (2) are extremely sensitive to oxygen and, contrary to our previous claim,[4,5] titration can be performed provided that great care is taken in avoiding contact with air. Thus distilled water and AnalaR methanol were carefully deoxygenated first by passing in a vigorous flow of purified anhydrous nitrogen and then by slow distillation under reduced pressure and in an atmosphere of purified nitrogen. All operations, except recording of the spectra, were performed in a dry box. Cells, before coming in contact with air, were carefully stoppered with Teflon stoppers. Alkaline methanol solutions were more stable (*ca.* 2—3 h) than water solutions.

Series of spectra were measured, for sulphone (1) in standard carbonate and phosphate buffers,[6] and for sulphone (2) in potassium chloride–sodium hydroxide.[6] Ionisation constants $R = [Ty^-]/[TyH]$ (Ty = thiopyran substrate) were evaluated from extinction coefficients at four wavelengths near the absorption maxima of the anion and of the neutral precursor respectively. Ionic strengths of solution, I, were taken from Bates and Bower [6] and for concentrations <0·1M, values of pK_a were deduced from equation (1).[7]

$$pK_a = pH - \log_{10}R + \{0{\cdot}5115(I^{\frac{1}{2}}/1 + I^{\frac{1}{2}})\} - 0{\cdot}2I \quad (1)$$

The pH values [6] were not corrected for the effect of ionisation of the sulphones (a correction of *ca.* ±0·005 *versus* a given pH accuracy of ±0·02). Since the spectra of the more basic solution did change slightly during the recording period, optical densities were extrapolated to zero time for all solutions at 370 and 380 nm, for anions (3) and (4) respectively. Average values so obtained were not different from those taken without extrapolation (±0·01 pK_a units) except for the range of average deviation (*ca.* 0·02 and 0·04 respectively). No further correction was then made and accuracy is thus believed to be ±0·04.

Series of spectra were measured for sulphones (1) and (2) in methanol containing known amounts of a solution of sodium methoxide in methanol. Estimation of the alkalinity of the mother solution of sodium methoxide (prepared under nitrogen from clean sodium and methanol) was made by titration with standard aqueous hydrochloric acid. Values of pK_a were deduced by the method of More O'Ferrall and Ridd.[8] Neither sulphone (1) nor (2) showed ideal behaviour, log R − log[NaOMe] being not a constant. Therefore extrapolation to zero concentration of sodium methoxide was necessary to evaluate pK_b. Values of R were calculated for each of the four wavelengths studied and the mean taken. No correction to zero time appeared necessary. The ionic product of methanol was taken as pK_s = 16·91.[9] The accuracy of the pK_a values is believed to be in the range ±0·05.

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Well defined reproducible isosbestic points were observed for methanol solutions. Less precise isosbestic points (±2 nm) were obtained for water: after correction to zero time these became perfectly centred.

RESULTS AND DISCUSSION

Electronic absorption data for sulphones (1) and (2) and for their corresponding anions (3) and (4) are in Table 1. pK_a Values of sulphones (1) and (2) in water and in methanol are in Table 2. Unfortunately no pK_a values are known for open chain or cyclic sulphones whose anions are stabilised by allylic delocalisation of the negative charge. However, comparison with acidities of other sulphonyl-substituted carbon acids shows that the thiopyran 1,1-dioxide ring has unusually high acidity. Acidities in dimethyl sulphoxide of monosulphonyl-substituted carbon acids are in the range [10] benzyl phenyl sulphone pK_a 22, tetrahydrothiopyran 1,1-dioxide p$K_a > 31$. The pK_a values of (1) and (2) in DMSO are difficult to estimate.* It seems safe to conclude, however, that there is an increase in the acidity of the order of 15—20 powers of ten in going from tetrahydrothiopyran 1,1-dioxide to substrate (1). For β-disulphones pK_a values are in the range 12·50—13·90 [$(MeSO_2)_2CH_2$ p$K_a(H_2O)$ 12·50,[14] 12·64;[15] $[CH_2]_n\cdot SO_2\cdot CH_2\cdot SO_2$, $n = 5$—8, p$K_a(H_2O)$ 13·90—10·99[14]] while those for β-keto-sulphones[16] are in the range 9·0—10·4 [$MeCO\cdot CH_2\cdot SO_2Me$ p$K_a(H_2O)$ 9·90; $[CH_2]_3\cdot CO\cdot CH_2\cdot SO_2$, p$K_a(H_2O)$ 9·01].

TABLE 1

U.v. and visible absorptions of thiopyran 1,1-dioxides

Compd.	Solvent	λ/nm (log $\varepsilon_{max.}$)			
(1)	H_2O		311 (3·97)		226 (3·87)
	MeOH		310 (3·98)		226 (3·95)
(2)	H_2O		312 (4·02)		227 (3·71)
	MeOH		312 (4·15)		230 (3·89)
(3)	H_2O [a]	367 (3·81)		256 (4·29)	
	MeOH [b]	371 (3·79)		255 (4·12)	
(4)	H_2O [c]	373 (3·74)		257 (4·16)	
	MeOH [d]	377 (3·88)		259 (4·18)	

[a] 4·1 × 10^{-2}N-NaOH. [b] 3·28 × 10^{-2}N-MeONa. [c] 1·5N-NaOH. [d] 1·6N-MeONa.

TABLE 2

pK_a Values of thiopyran 1,1-dioxides

Compound	p$K_a(H_2O)$	pK_a(MeOH)
(1)	10·79	14·34
(2)	12·36	16·15

pK_a Values of the thiopyran 1,1-dioxide ring system are thus the lowest ever reported not only for carbon acids containing one sulphonyl group as the sole function for conferring acidity but also for disulphonylmethanes and are of comparable magnitude with those of some β-keto-sulphones. The pK_a value of the thiopyran 1,1-dioxide system is evidence that the conjugate anion is remarkably stabilised. In line with previous results [2-4] this effect is intrinsic in the attainment of a certain degree of aromaticity.

The value of ΔpK, [pK(MeOH) − p$K(H_2O)$], 3·60, for sulphones (1) and (2) is intermediate between that observed for aniline (ΔpK 3·13)[8] and phenol indicators (ΔpK 4·13). The acidity decrease due to α-methyl substitution [ΔpK $(H_2O) = 1·57$] is analogous to that observed for α-methylbenzyl sulphones [ΔpK (DMSO) = 1·5].[10]

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* Although Ritchie [11,12] noted that acidities of precursors of large polarisable carbanions are higher in dimethyl sulphoxide than in methanol, the acidity of nitromethane is higher in water [13] than in dimethyl sulphoxide.[11]

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