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THE COMPARISON OF A THIEPIN, THIEPIN SULFOXIDE AND THIEPIN SULFONE

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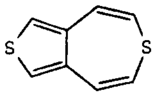
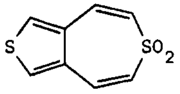
The requirements for aromaticity in heterocyclic compounds containing $4n$-π-electrons are of considerable interest. In this regard numerous studies have been reported for oxepins and azepines.[1] However, virtually nothing is known concerning the possible aromatic character of thiepins.[2] Of particular interest in systems of this type is the relative significance of sulfur *p* and *d*-orbital bonding, thus making the study of a thiepin and its S-oxide analogues highly desirable. The limited availability of these heterocycles has severely restricted efforts along these lines. Indeed, in only one instance has the chemical reactivity of a thiepin and its sulfone analogue been compared.[3] Furthermore, the preparation of a simple thiepin sulfoxide to our knowledge has not been reported. We wish to report the preparation of a thiepin sulfoxide as well as its corresponding sulfone and to describe some preliminary results of comparative spectroscopic and chemical studies carried out on these compounds and the parent thiepin system.

Recently we described the synthesis of thieno[3,4-*d*]thiepin (I).[4] The remarkable stability of I prompted us to attempt its oxidative conversion into the thiepin sulfone and sulfoxide. Treatment of I with *m*-chloroperbenzoic acid in chloroform gave in 95% yield the colorless highly crystalline sulfone II, mp 183°. When the oxidation of I was carried out at 0° under carefully defined conditions there was isolated in 90% yield the unstable crystalline sulfoxide III, mp 75-95° dec.[5] The infrared spectrum of II showed bands at 7.70 and 8.90µ while III exhibited a band characteristic of sulfoxides at 9.50µ.

The mass spectra of compounds I, II and III all gave rise to a base peak at m/e 134, the molecular ion of benzo[c]thiophene (IV), in addition to parent ions at 166, 198 and 182 respectively. In all three cases an increase in the 134 peak accompanied by the disappearance of the parent peak was observed upon raising the source temperature.


I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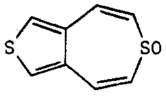
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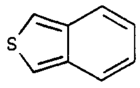
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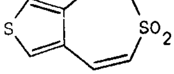
The ultraviolet spectrum of sulfone II gave absorption at λ_{max}^{MeOH} 246mµ (ε 36,800) with tailing to 320mµ. A similar spectrum was also observed for III with a value of λ_{max}^{MeOH} 244mµ (ε 22,400) and tailing to 330mµ. Maxima at λ_{max}^{MeOH} 251mµ (ε 25,700) and 260mµ (ε 25,700) accompanied by well defined absorption as far out as 390mµ have been reported for I.

The nmr values found for I, II and III showed an interesting trend when compared to their dihydro analogues. Sulfone II showed resonance at field values between 0.25 and 0.55ppm lower than sulfone V. Sulfoxides III and VI gave resonance at very similar values. Thiepin I gave resonance at values between 0.25 and 0.70ppm higher than sulfide VII. It is possible that this upfield shift may be due to the presence of a paramagnetic ring current in I.[6] This phenomenon has been observed for a number of hydrocarbons but not for heterocyclic systems.[7] The nmr spectrum of I may be due entirely to other effects.

Sulfide VII along with the sulfoxides III and VI was found to undergo catalytic hydrogenation (palladium on carbon in methanol) with rapid and quantitative uptake of hydrogen to give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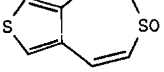
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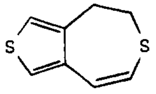
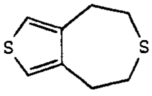

VII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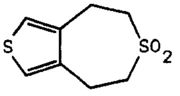
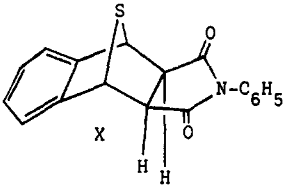
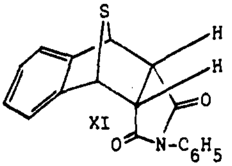

IX

the tetrahydro thiepin VIII in high yield. The tetrahydro sulfone IX was obtained in the same manner from compounds II and V. Thiepin I was found to be completely inert to a variety of catalytic hydrogenation conditions.

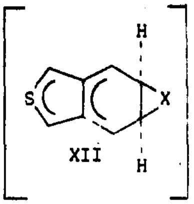
Both II and III undergo the Diels-Alder reaction with N-phenylmaleimide at a rate faster than that found for thiepin I. Using the dienophile as the solvent, at 90° and 150° II gave in 85% yield a 1:1 mixture of the exo and endo adducts X and XI.[8] This ratio changed to 4:1 with the exo adduct predominating at 240°. At 90° III gave both adducts in equal amounts while a 3:1 ratio in favor of the exo adduct was observed at 150°. As previously reported, I gave only the exo isomer at 150°.[4] However, at 90° and 120° I gave rise to a mixture of the adducts, the exo form again predominating in a ratio of 3:1. Thiophene IV has been found to give approximately equal amounts of X and XI at temperatures ranging from 90° to 240°. Prolonged heating of 1:1 mixtures of the adducts at temperatures of 90°, 120°, 150° and 240° did not significantly change their composition. Additionally, I and II but not III have been shown to be thermally stable at temperatures sufficient to effect their combination with dienophile.[5]



X



XI



XII

These results tend to indicate that thiepins I, II and possibly III undergo direct reaction with N-phenylmaleimide. Thus, contrary to previous interpretation, valence isomers such as XII (X=S, SO_2 and SO) do not appear to be intermediates in these reactions.[4] The role that either charge-separated contributors or nonplanar geometry plays in the Diels-Alder behavior of these thiepins is not known with certainty. Hopefully, conclusions on these points may be drawn when the X-ray structures of I and II are complete. It is obvious however, that relative to its sulfoxide and sulfone analogues, thiepin I possesses considerable aromatic like character, which may be the result of sulfur *p*-orbital delocalization.

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5. Elemental analyses of all new compounds are in accord with the assigned structure with the exception of sulfoxide III which decomposed on standing.
6. For a theoretical basis for the presence of a paramagnetic ring current in 4*n* monocyclic systems, see J. A. Pople and K. G. Untch, *J. Am. Chem. Soc.*, **88**, 4811 (1966).
7. For examples, see (a) I. C. Calder and F. Sondheimer, *Chem. Commun*. 904 (1966); (b) G. Schroeder and J. F. M. Oth, *Tetrahedron Letters*, 4083 (1966); (c) B. M. Trost and G. M. Bright, *J. Am. Chem. Soc.*, **89**, 4244 (1967); (d) K. G. Untch and D. C. Wysocki, *J. Am. Chem. Soc.*, **89**, 6386 (1967).
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