

2*H*-Thiopyrans as Intermediates in the Rearrangement of Thiophenium Bisalkoxycarbonylmethylides to Thiophene-2-malonates: the Crystal and Molecular Structures of 2,2-Bis-*t*-butoxycarbonyl-5-bromo-2*H*-thiopyran and 2,2-Bis-*t*-butoxycarbonyl-6-bromo-2*H*-thiopyran

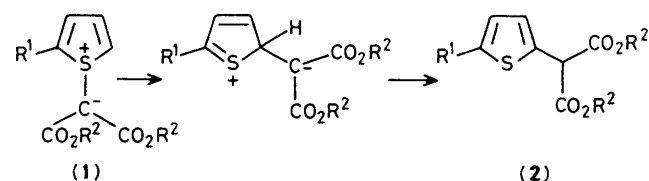
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2*H*-Thiopyrans have been observed as intermediates in the rearrangement of thiophenium bisalkoxycarbonylmethylides to thiophene-2-malonates.

We have previously demonstrated¹ that thiophenium bisalkoxycarbonylmethylides (1) undergo a facile thermal rearrangement to produce thiophene-2-malonates (2). Cross-over experiments² indicated that this rearrangement was intramolecular in nature and a mechanism involving a 'walk' of the ylide carbon atom (Scheme 1) to position 2 of the thiophene ring was proposed.



Scheme 1

In our continued study of this system we have examined the rearrangement of the ylides in detail, to ascertain the scope and limitations of the reaction. During a kinetic study of the decomposition of the ylide (1; R¹ = H, R² = Me) monitored by ¹H n.m.r. spectroscopy, it was noted that an intermediate was formed during the reaction, but all attempts to isolate a pure sample of the intermediate were frustrated owing to its similar chromatographic behaviour to that of the malonate (2; R¹ = H, R² = Me). In contrast however, the di-*t*-butyl ylide (1; R¹ = H, R² = Bu^t) on heating for 2 min in refluxing xylene was smoothly converted into the intermediate in 84% yield.[†] Elemental analyses confirmed that the intermediate was isomeric with the ylide and on the basis of the ¹H n.m.r.

[†] All new compounds exhibited satisfactory elemental analyses and spectroscopic properties.

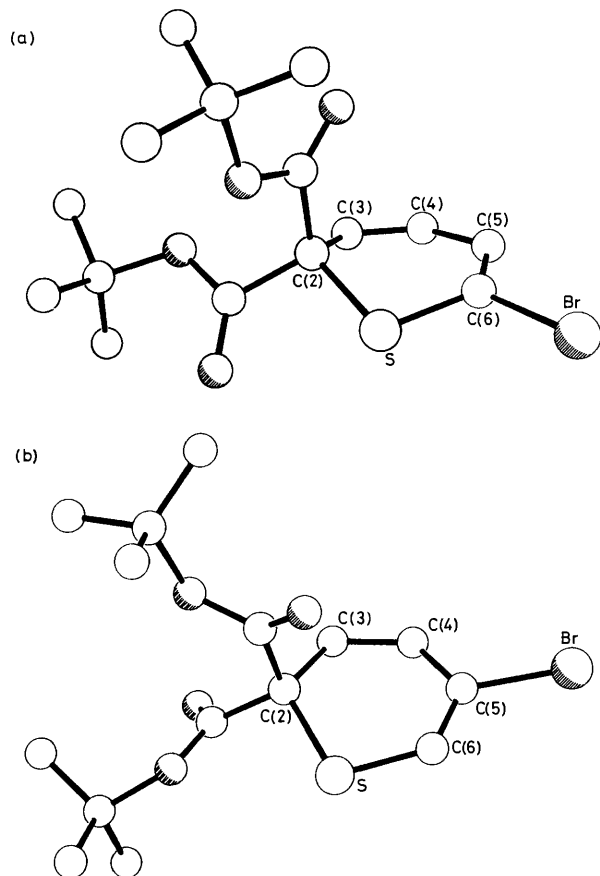
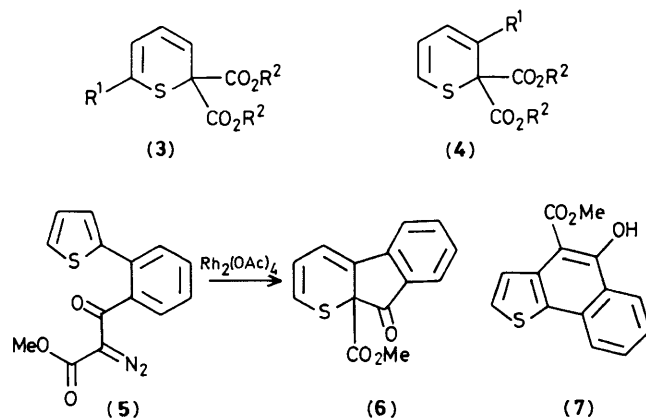


Figure 1. Molecular structures of (a) (3; $R^1 = \text{Br}$, $R^2 = \text{Bu}^t$); (b) (8).

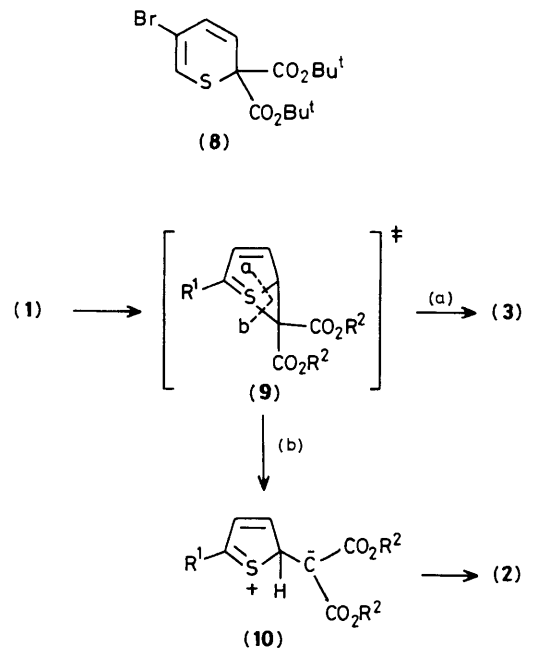


Scheme 2

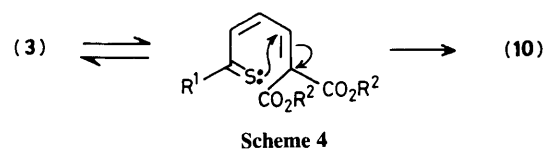
spectrum \ddagger the intermediate was assigned the thiopyran structure (3; $R^1 = \text{H}$, $R^2 = \text{Bu}^t$).

Reaction of 2-bromothiophene with di-*t*-butyl diazomalonate under conditions previously described gave the ylide (1; $R^1 = \text{Br}$, $R^2 = \text{Bu}^t$), 87%, m.p. 135 °C. On heating at 140 °C

\ddagger N.m.r. data (250 MHz, CDCl_3): (3; $R^1 = \text{H}$, $R^2 = \text{Bu}^t$), δ 5.81 (1H, m, J 9.94, 1.20, and 0.53 Hz), 6.62 (1H, m, J 9.94, 7.04, and -0.37 Hz), 6.23 (1H, m, J 9.86, 7.04, and 0.53 Hz), and 6.26 (1H, m, J 9.86, 1.20, and -0.37 Hz); (3; $R^1 = \text{Br}$, $R^2 = \text{Bu}^t$), δ 5.854 (1H, d, J 10.07 Hz), 6.088 (1H, dd, J 10.07 and 6.53 Hz), and 6.476 (1H, d, J 6.53 Hz); (8), δ 5.775 (1H, dd, J 10.42 and 0.90 Hz), 6.168 (1H, dd, J 10.42 and 1.09 Hz), and 6.399 (1H, dd, J 1.09 and 0.90 Hz).



Scheme 3



Scheme 4

in refluxing xylene for 5 min followed by rapid quenching, a partial conversion of this ylide into a less polar product was observed. Chromatographic separation followed by recrystallisation from ethanol gave a colourless crystalline product in 75% yield, m.p. 75 °C, which on the basis of its n.m.r. spectrum \ddagger was assigned one of the two possible thiopyran structures (3 or 4; $R^1 = \text{Br}$, $R^2 = \text{Bu}^t$). To distinguish between these two possible structures an X-ray structure determination \S was carried out (Figure 1a), which established (3) as the correct structure.

The involvement of 2*H*-thiopyrans in the rearrangement of thiophenium ylides to the malonates poses a number of

\S Crystal data: (3; $R^1 = \text{Br}$, $R^2 = \text{Bu}^t$), $\text{C}_{15}\text{H}_{21}\text{BrO}_4\text{S}$, monoclinic, $a = 10.013(7)$, $b = 10.969(5)$, $c = 16.633(13)$ Å, $\beta = 100.43(6)^\circ$, $U = 1797$ Å³, space group $P2_1/n$, $Z = 4$, $M = 377.3$, $D_c = 1.40$ g cm⁻³, $\mu(\text{Cu-K}\alpha) = 43$ cm⁻¹. (8), $\text{C}_{15}\text{H}_{21}\text{BrO}_4\text{S}$, monoclinic, $a = 8.833(2)$, $b = 17.375(6)$, $c = 12.034(2)$ Å, $\beta = 108.20(2)^\circ$, $U = 1755$ Å³, space group $P2_1/c$, $Z = 4$, $M = 377.3$, $D_c = 1.43$ g cm⁻³, $\mu(\text{Cu-K}\alpha) = 44$ cm⁻¹. Data for both compounds were measured on a Nicolet R3m diffractometer with graphite-monochromated Cu-K α radiation using ω -scans. Structure (3) was solved by the heavy-atom method and structure (8) by direct methods. Both structures were refined anisotropically using absorption-corrected data to give for (3) $R = 0.053$, $R_w = 0.069$ for 2273 independent observed reflections [$|F_o| > 3\sigma(|F_o|)$, $\theta \leq 58^\circ$] and for (8) $R = 0.049$, $R_w = 0.059$ for 1730 unique observed reflections ($\theta \leq 50^\circ$). In (8) the analysis revealed the coexistence in the crystal of a rotameric form of (8) with the positions of C(3) and S reversed. The relative occupancy of these two forms was estimated at 80% and 20% respectively which has been allowed for in the refinement of the structure. The atomic co-ordinates for this work are available on request from the Director of the Cambridge Crystallographic Data Centre, University Chemical Laboratory, Lensfield Road, Cambridge CB2 1EW. Any request should be accompanied by the full literature citation for this communication.

questions. First, how do the thiopyrans arise? Skramstad and co-workers³ observed the fused thiopyran (6) and the fused thiophene (7) during the rhodium(II) acetate-catalysed (Scheme 2) decomposition of the diazoester (5) and suggested that (6) was formed by way of a Stevens rearrangement of an unstable ylidic intermediate. We considered that the 2*H*-thiopyran was a kinetic product with the naphthenothiophene (7) being the thermodynamic product, but in our hands no evidence[¶] for the rearrangement (6) → (7) was observed, even on heating for protracted periods at elevated temperatures.

The second question centres on the regiochemistry of such a Stevens rearrangement. In the case of the 2-bromo ylide (1; R¹ = Br, R² = Bu^t) two modes of rearrangement are possible leading to the 6-bromo-2*H*-thiopyran (3; R¹ = Br, R² = Bu^t) or the isomeric 3-bromo-derivative (4; R¹ = Br, R² = Bu^t); however, only (3) was observed and the failure to form (4) is probably a consequence of steric hindrance.

We considered that a suitable 3-substituted thiophene might provide evidence of the two alternative thiopyrans in a Stevens rearrangement of the corresponding ylides. Reaction of 3-bromothiophene with di-*t*-butyl diazomalonate under standard conditions failed to yield the ylide and the only identifiable product,[‡] formed in low yield, was 2,2-bis-*t*-butoxycarbonyl-5-bromo-2*H*-thiopyran (8), m.p. 92–94 °C. The structure of (8) was established unequivocally (Figure 1b) by *X*-ray crystallography.[§]

The remaining problem in the transformation of the ylides (1) to the malonates (2) is the intermediacy of the 2*H*-thiopyrans, since although precedent^{4,5} for this rearrangement exists, the mechanism remains obscure. The formation of the two products could be rationalised if the reaction proceeds through a transition state (9) (Scheme 3), since cleavage 'a' would result in the direct formation of the 2*H*-thiopyrans,⁶

whereas cleavage 'b' would yield (10). Proton transfer in (10) would then in turn lead to the malonates (2).

An alternative mechanism involving the electrocyclic ring opening of the thiopyran to the thiocarbonyl derivative (Scheme 4) followed by Michael addition of the sulphur to the alkylidene malonate to generate (10) can be ruled out. In the case of (3; R¹ = Br, R² = Bu^t) such a ring opening would result in the formation of a thioacid bromide and all attempts to trap such an intermediate in alcoholic media have failed.

Preliminary MNDO and *ab initio* SCF–MO calculations on the potential energy surface of this system have shown it to be highly complex. We are investigating whether (9) is a transition state, as implied in Scheme 3, leading either to a 2*H*-thiopyran (Stevens rearrangement) or to (10), or an intermediate in which the sulphur has a formal oxidation state of +IV, and which requires cleavage at either a or b to form the products. The essential difference between Stevens rearrangement and the latter mechanism rests in the timing of the bond formation and bond cleavage steps.

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References

- 1 R. J. Gillespie, J. Murray-Rust, P. Murray-Rust, and A. E. A. Porter, *J. Chem. Soc., Chem. Commun.*, 1978, 83.
- 2 R. J. Gillespie, A. E. A. Porter, and W. E. Willmott, *J. Chem. Soc., Chem. Commun.*, 1978, 85.
- 3 H. Storflor, J. Skramstad, and S. Nordenson, *J. Chem. Soc., Chem. Commun.*, 1984, 208.
- 4 P. J. W. Schuijl, H. J. T. Bos, and L. Brandsma, *Rec. Trav. Chim. Pays-Bas*, 1969, **88**, 597.
- 5 K. Praefcke and C. Wiechsel, *Liebigs Ann. Chem.*, 1980, 1604.
- 6 We are indebted to a referee for drawing to our attention closely related work on phosphorus ylides; see D. C. Gilheany, J. F. Malone, and B. J. Walker, *J. Chem. Soc., Chem. Commun.*, 1984, 1217. Our own preliminary studies on the rearrangement described in this communication have failed to provide any evidence of radical intermediates.

[¶] We are indebted to Professors J. Skramstad and H. Storflor for samples of (6) and (7).