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A ONE-STEP RING ENLARGEMENT OF A THIOPHENE TO A THIEPIN

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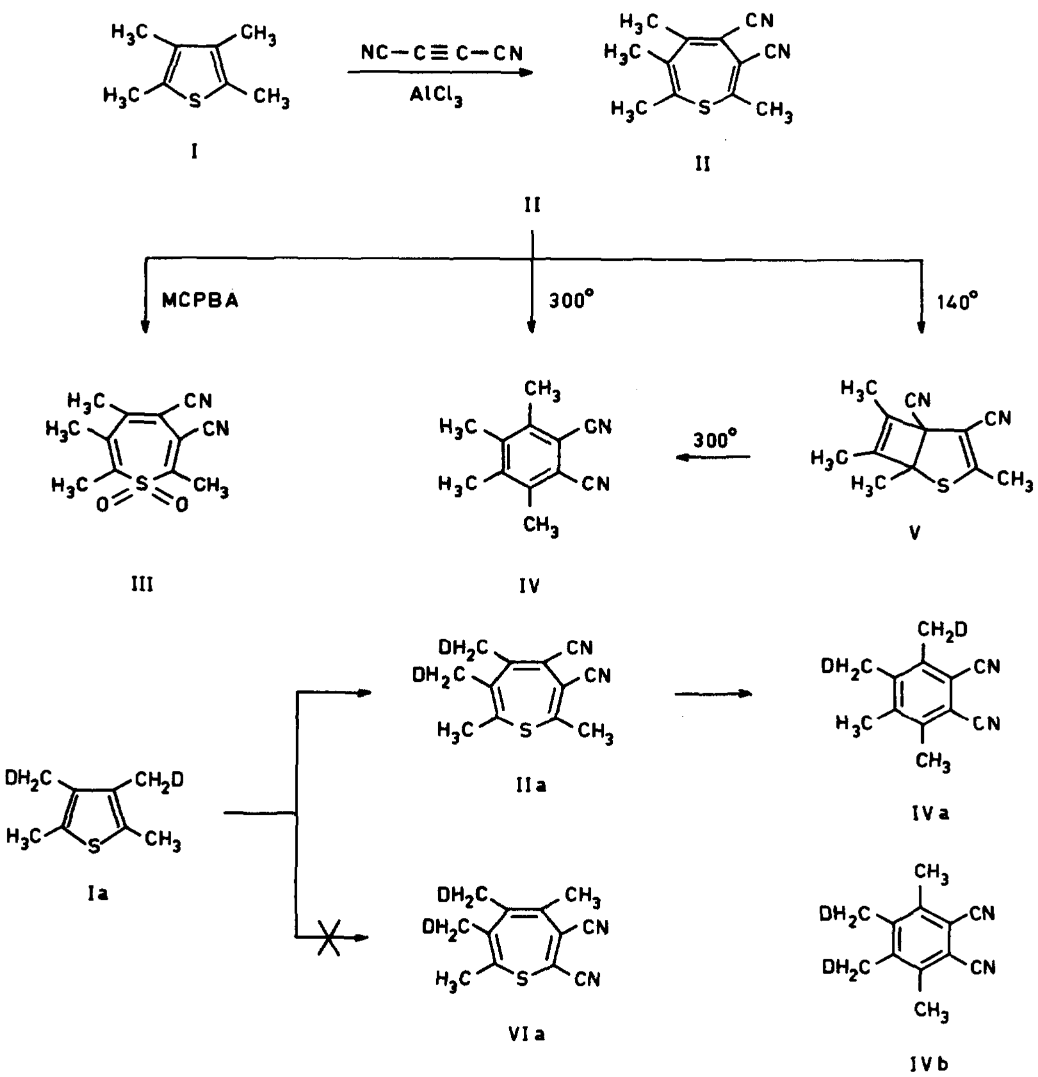
In our previous communication[1] we reported the Diels-Alder reaction of dicyanoacetylene with a number of thiophenes, furnishing the corresponding phthalonitriles in reasonable yields. These reactions were carried out at temperatures ranging from 60-120°. In order to enable the isolation of a sulfur-containing intermediate, it seemed necessary to carry out the reaction at lower temperatures.[2]

The accelerating effect of $AlCl_3$ on a number of Diels-Alder reactions is well known.[3]

We have now found that the course of the reaction between 2,3,4,5-tetramethylthiophene (I) and dicyanoacetylene was dramatically influenced by the presence of $AlCl_3$.

When 980 mg (7 mmole) of 2,3,4,5-tetramethylthiophene[4] (I) in 40 ml of methylene chloride was treated at room temperature with 836 mg (11 mmole) of freshly prepared dicyanoacetylene[5] and 935 mg (7 mmole) of $AlCl_3$, a rapid reaction ensued. After 30 minutes aqueous HCl was added to the stirred reaction mixture. Work-up furnished 860 mg (57%) of a bright yellow solid, m.p. 93-94°. The combustion analysis[6] and the spectral properties are in accord with a thiepin having the molecular formula $C_{12}H_{12}N_2S$. NMR (CCl_4) δ 1.33 (s, 3H), δ 1.53 (s, 3H), δ 1.80 (3H) and δ 1.90 (3H); the signals at δ 1.80 and δ 1.90 are weakly coupled; IR (KBr) 2225 cm^{-1}, 2235 cm^{-1} (CN). Mass spectrum m/e 216, M^+, 100%; m/e 184, $(M-S)^+$, 33%; m/e 183, $(M- S,H)^+$, 31%; m/e 162, $(M- H_3C-C{\equiv}C-CH_3)^+$, 43%; m/e 140, $(M- NC-C{\equiv}C-CN)^+$, 59%. UV $\lambda_{max}^{96\%\ C_2H_5OH}$ 400 mμ (ε 2018)[7]; for the only non-annulated thiepin described in the literature $\lambda_{max}^{CH_3OH}$ 381 mμ (ε 444) is reported.[8]



Oxidation of the thiepin (structure II, see below) with m-chloroperbenzoic acid gave a sulfone (III), m.p. 122-123° (ether) in 81% yield. IR (KBr) 2235 cm^{-1}, 2240 cm^{-1} (CN) and 1160 cm^{-1}, 1310 cm^{-1} (SO_2, very strong); the UV λ^{ether}_{max} 262 mμ (ε 4581) is in complete agreement with $\lambda^{C_2H_5OH}_{max}$ 262 mμ (ε 4610) reported[9] for the unsubstituted parent system. Mass spectrum m/e 248, M^+, 20%; m/e 184, $(M-SO_2)^+$, 38%; m/e 169, $(M-SO_2, CH_3)^+$, 100%.

Although these data leave little doubt about the thiepin structure of our yellow product, the ring substitution pattern cannot be assigned on the basis of these data alone.

Pyrolysis of the thiepin at 275° in tetraethylene glycol dimethyl ether gave tetramethylphthalonitrile (IV), m.p. 227.5-228.5° in 49% yield. This compound was shown to be identical (m.p., mixture m.p., IR, NMR and TLC) with tetramethylphthalonitrile prepared earlier in our laboratory.[10] When the thiepin was heated for 7 minutes at 300° with triphenylphosphine (no solvent) the phthalonitrile (IV) was formed again, this time in a quantitative yield (NMR). Such a sulfur extrusion[11] with concomitant formation of the corresponding benzene derivative is a general reaction for thiepins.[12]

The isolation of a phthalonitrile (IV) from the pyrolysis of the thiepin in combination with the NMR spectrum of the latter reduces the number of possible isomers to two, namely II and VI (VI is the all-^{1}H analogue of VIa). Unambiguous assignment of the ring substitution pattern was achieved by using the deuterated tetramethylthiophene (Ia) in the entire sequence.[13] The deuterated phthalonitrile which was obtained on pyrolysis of the deuterated thiepin could be identified readily on the basis of its NMR (see ref. 10 for the NMR of the non-deuterated phthalonitrile IV). The NMR of the deuterated phthalonitrile shows two signals in a 5:5 ratio, corresponding to IVa[14,15]; for IVb the expected ratio is 6:4.

When, instead of pyrolysis at 275-300°, the thiepin (II) was refluxed for 18 hours in xylene in the dark, a colourless isomer of II (m.p. 97.5-99°, mixture m.p. with II 63-80°) was isolated in 82% yield. UV $\lambda_{max}^{96\%\ C_2H_5OH}$ 288 mμ (ε 8145); IR (KBr) 2210 cm^{-1}, 2245 cm^{-1} (CN) and 1585 cm^{-1} (C=C); NMR ($CDCl_3$) δ 1.70, δ 1.73 (together 6H), δ 1.85 (3H) and δ 2.20 (s, 3H); the signals at δ 1.70 and δ 1.85 are weakly coupled. Mass spectrum m/e 216, M^+, 100%; m/e 184, $(M-S)^+$, 11%; m/e 183, $(M-S,H)^+$, 34%; m/e 162, $(M-H_3C-C{\equiv}C-CH_3)^+$, 88%; m/e 140, $(M-NC-C{\equiv}C-CN)^+$, 17%. Oxidation with m-chloroperbenzoic acid afforded the sulfone, m.p. 106.5-108° (hexane) in 70% yield. IR (KBr) 2235 cm^{-1}, 2250 cm^{-1} (CN) and 1160 cm^{-1}, 1320 cm^{-1} (SO_2, strong); UV $\lambda_{max}^{C_6H_{12}}$ 222 mμ (ε 6116). Mass spectrum: m/e 248, M^+, 11%; m/e 184, $(M-SO_2)^+$, 17%; m/e 169, $(M-SO_2,CH_3)^+$, 100%.

The spectral properties of this sulfide and its sulfone make structure V for the former the most probable. Pyrolysis at 300° of V afforded tetramethylphthalonitrile (IV) in quantitative yield. Although these data show V to be an intermediate in the conversion of the thiepin (II) to the benzene derivative (IV), they neither support nor exclude the generally proposed and accepted intermediacy of the thianorcaradiene system in the sulfur extrusion reaction of thiepins.[11,12]

REFERENCES AND NOTES.

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7. Solutions of II are light-sensitive; initial irradiation experiments look promising.
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10. Uncatalyzed addition of dicyanoacetylene to tetramethylthiophene at 60° afforded tetramethylphthalonitrile, m.p. 228.9-229.2°, NMR ($CDCl_3$) δ 2.33 (s, 6H) and δ 2.53 (s, 6H); E.J. Kwak, unpublished results.
11. (a) B.P. Stark and A.J. Duke, "Extrusion Reactions", Pergamon Press, Oxford, 1967, p. 91;
    (b) J.D. Loudon in "Organic Sulfur Compounds", Vol. I, N. Kharasch Ed., Pergamon Press, Oxford, 1961, p. 299.
12. U. Eisner and T. Krishnamurthy, *Int. J. Sulfur Chem.*, B, 6, 267 (1971).
13. A sample of 3,4-bis-(chloromethyl)-2,5-dimethylthiophene was supplied by Mr. E.P. Schudde.
14. We assume that no methyl-deuterated methyl group rearrangements have occurred, thus eliminating one isomeric phthalonitrile (and 6 isomeric thiepin precursors) from our considerations.
15. If, but only if, the NMR evidence - namely the 5:5 ratio of the proton signals in compound IVa is taken at its face value, we are forced to the conclusion that a 2 + 2 addition involving the C_2-C_3 bond of the thiophene ring has occurred instead of either a 2 + 4 Diels-Alder addition or a 2 + 2 addition to the S-C_2 bond.[16]
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