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SKELETAL REARRANGEMENT OF 2,5-DIARYL-1,4-DITHIIN-1-OXIDES INDUCED BY HYDROCHLORIC ACID

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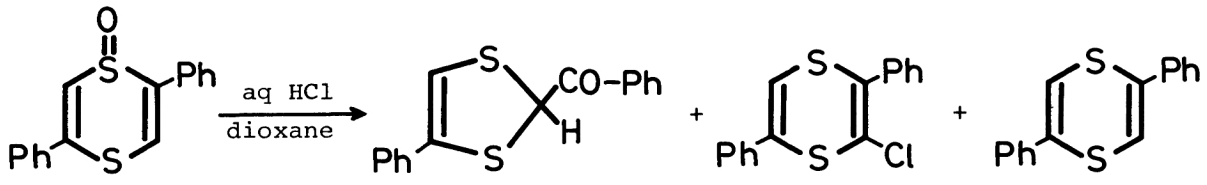
Treatment of 2,5-diphenyl-1,4-dithiin-1-oxide with hydrochloric acid in dioxane caused a novel skeletal rearrangement to give 2-benzoyl-4-phenyl-1,3-dithiole together with the deoxygenation products. The reaction with gaseous hydrogen chloride in methanol afforded the adduct due to the additive Pummerer rearrangement, which was also converted into the 1,3-dithiole.

Sulfoxides can enter into reactions with hydrochloric acid, generally leading to the stereomutation,[1] the carbon-sulfur bond cleavage,[2] or the oxygen exchange.[3] The mechanism of those reactions has been the subject of extensive research.[4] Hydrochloric acid, however, rarely reduces sulfoxides to sulfides in contrast to hydroiodic acid;[5] in quite an earlier work hydrochloric acid has been reported to be available for the deoxygenation of sulfoxide.[6] We now wish to report the unusual skeletal rearrangement of the heterocyclic S-oxides accompanying the facile deoxygenation reaction with hydrochloric acid.

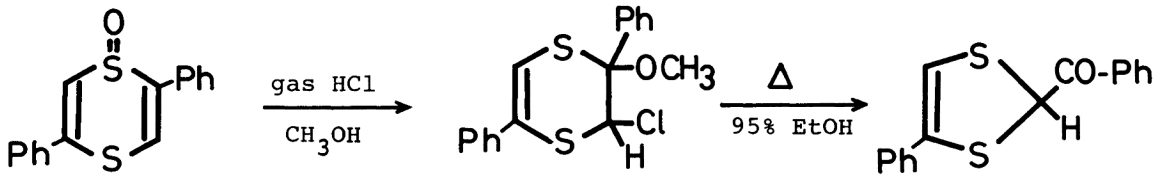
2,5-Diphenyl-1,4-dithiin-1-oxide (1a) was dissolved in a 2:1 V/V mixture of dioxane and 12 M aqueous hydrochloric acid and allowed to stand at room temperature for 1 hour. After basic work-up chromatography on silica gel afforded 2-benzoyl-4-phenyl-1,3-dithiole (2a) (32%), 3-chloro-2,5-diphenyl-1,4-dithiin (3a) (3%), and the dithiin 4a (45%). The spectral data of 2a [mp 144°C; NMR($CDCl_3$) δ 6.15(1H, s), 6.22(1H, s), 7.2-7.7(8H, m), 7.95(2H, bd); IR(nujol) 1688 cm^{-1}; m/e 284(M^+), 179(base peak, M^+-COPh)] and 3a [oil; NMR($CDCl_3$) δ 6.70(1H, s), 7.3-7.8(10H, m); m/e 304 and 302(1:3, M^+), 267(base peak, M^+-Cl)] confirm these structural assignments. The facile isomerization to the 1,3-dithiole ring system is surprising, because the reaction conditions employed here are typical for the stereomutation of non-cleavable sulfoxide.[1] No reaction was induced by a



1a 2a 3a 4a

catalytic amount of hydrochloric acid.

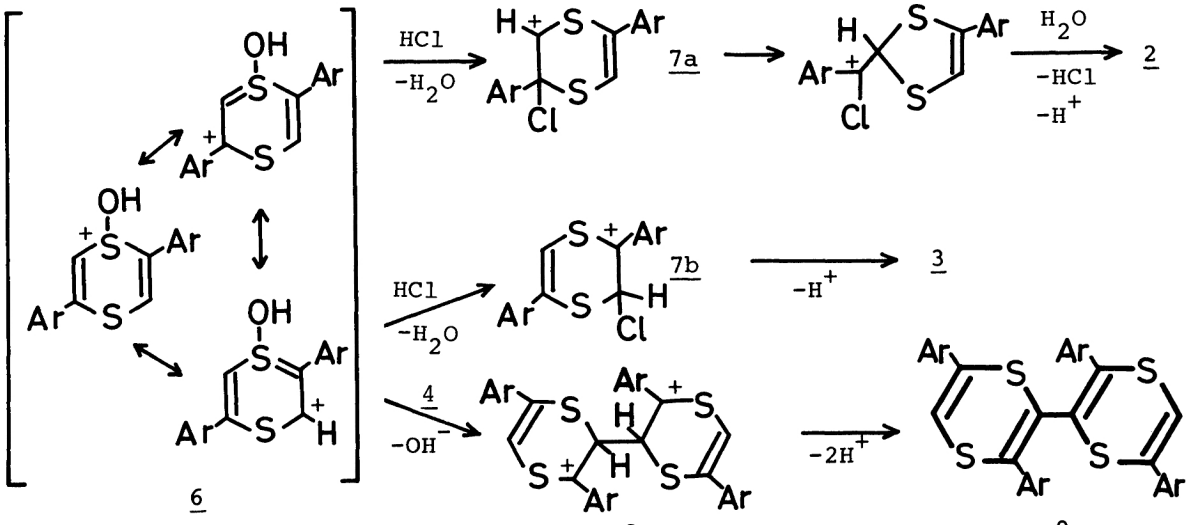
When gaseous hydrogen chloride in place of aqueous HCl was introduced to 1a in dry dioxane, 2a (34%), 3a (22%), and 4a (25%) were again obtained. In methanol, however, gaseous HCl gave rise to the adduct 5 (42%) as well as 2a (26%) and 3a (3%). The structure of 5 [mp 105-107°C decomp.; NMR($CDCl_3$) δ 3.23(3H, s), 5.23(1H, s), 6.47(1H, s), 7.2-7.8(10H, m); m/e 336 and 334(1:3, M^+) 105(base peak, $PhCO^+$)] was deduced from spectral information.[7] The formation of 5 is analogous with the additive Pummerer rearrangement.[8,9] The isolation of the Pummerer adduct, coupled with the findings that 5 was readily converted into 2a by heating in 95% ethanol, provides a clue to a possible mechanism of the skeletal rearrangement of 1a to 2a in HCl-dioxane.



1a 5 2a

The nucleophilic attack of a chloride ion at the carbon atom of the protonated sulfoxide 6 would generate the sulfur-stabilized carbonium ions such as 7a and 7b as illustrated in Scheme 1. Loss of a proton from 7b should lead to 3a.[10] On the other hand, 7a could be responsible for the rearrangement; 1,2-migration of the neighbouring sulfur atom would afford the carbonium ion bearing a 1,3-dithiole ring. The formation of 5 and its rearrangement to 2a appear to be in line with this sequence. The reduction of 1a to afford 4a would involve a chlorosulfonium ion as an intermediate,[11] which could be formed by the attack of a chloride ion at the positively charged sulfur atom in 6.

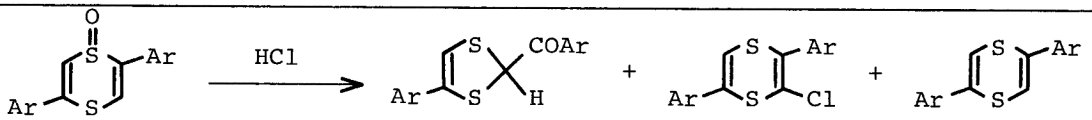
When acetyl chloride, which has been used to induce the additive Pummerer reaction,[9] was reacted with 1a in dichloromethane, 3a (53%) and 4a (21%) were



6 8 9

Scheme 1

Table 1. Product distribution from the reaction of *para*-substituted derivatives of 1a with HCl-dioxane [a)]



Ar = *p*-Cl-C_6H_4	(1b)	68 %	0 %	32 %
C_6H_5	(1a)	39	6	55
p-CH_3-C_6H_4	(1c)[b)]	0	21	79
p-CH_3O-C_6H_4	(1d)[b)]	0	61	39

a) The product ratio was calculated from the relative intensity of their characteristic nmr signals.[12]

b) Normalized yields excluding nmr-detectable minor products less than ca. 5%. See text.

obtained[10] but no rearranged products were detected. Treatment of 1a with 47% hydroiodic acid in dioxane afforded 4a as a sole product. Thus the skeletal rearrangement of the 1,4-dithiin is clearly characteristic of the reaction with HCl.

The product distribution was found to be also very dependent on the substituent on the phenyl groups, as shown in Table 1. The electron donating substituents give no rearranged product and increase the formation of the chlorodithiin 3. This trend is consistent with the mechanism outlined in Scheme 1. Since the electron withdrawing aryl group makes the carbonium ion 7b labile, it should enhance the relative fraction of the competing reaction leading to the cation 7a, hence 2.

The reaction of 2,5-di-*p*-tolyl-1,4-dithiin-1-oxide (1c) with 12 M aqueous HCl in dioxane led to the isolation of a minor product 9 (2%) in addition to 3c (16%) and 4c (60%). The structure of 9 [mp 185-187°C; NMR($CDCl_3$) δ 2.24(6H, s), 2.35(6H, s), 6.50(2H, s), 6.72(8H, s), 7.21(8H, AA'XX'); m/e 526(base peak, M^+-2S), 263(M^+/2-S)], which arises from the reductive coupling, was elucidated on the basis of the spectral data. It is obvious that the sulfoxide group is essential for the coupling to occur, as no reaction took place by treatment of the dithiin 4c with HCl-dioxane. Intervention of the dithiin in the coupling processes, however, is evident from the observation that the addition of 4c to the reaction mixture increased the formation of 9. Thus the coupling product[13] would be interpreted in terms of the nucleophilic attack of the dithiin, one of the products, at the carbon atom of the protonated sulfoxide 6 as shown in Scheme 1.

Further studies on the application of the skeletal rearrangements[14] for synthesis of five-membered heterocycles are currently in progress.

References

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6. I. A. Smyth, *J. Chem. Soc.*, 95, 349 (1909); see also J. P. A. Castrillon and H. H. Szmant, *J. Org. Chem.*, 32, 976 (1967).
7. The abundant ions, $PhCO^+$, in the mass spectrum of 5 indicate that the methoxy group is bonded to a carbon atom bearing a phenyl substituent. The absence of the fragmentation ions ascribable to the 1,3-dithiolium ion, which should appear abundantly in 1,3-dithiole ring system as observed in 2a, suggests that the 1,4-dithiin ring is still retained in this adduct.
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9. H. Kosugi, H. Uda, and S. Yamagiwa, *J. Chem. Soc., Chem. Commun.*, 1976, 71.
10. As to the formation of the chlorodithiin another pathway may be also involved. Chlorine should be liberated in the reduction process to give 4a. The addition of chlorine thus generated to the dithiin followed by the spontaneous elimination of HCl would give rise to the chlorodithiin.
11. D. Landini, G. Modena, F. Montanari, and G. Scorrano, *J. Am. Chem. Soc.*, 92, 7168 (1970).
12. 2b: yellow oil; NMR($CDCl_3$) δ 6.08(1H, s), 6.17(1H, s), 7.12-7.45(6H, m), 7.76 and 7.85(2H, AA' part of AA'XX'); IR(nujol) 1690 cm^{-1}.
    3c: mp 126°C; NMR($CDCl_3$) δ 2.39(6H, s), 6.66(1H, s), 7.1-7.6(8H, two AA'XX') m/e 332 and 330(1:3, M^+), 295(base peak, M^+-Cl).
    3d: mp 123-125°C; NMR($CDCl_3$) δ 3.83(6H, s), 6.54(1H, s), 6.84 and 6.93 (4H, two AA' parts of AA'XX's), 7.3-7.7(4H, m).
13. In the nmr spectrum of the reaction mixture from 1d, very weak signals reminiscent of the coupling product were observed, although this minor product could not be isolated.
14. A similar skeletal rearrangement initiated by the additive Pummerer reaction has very recently been reported. See R. R. King, *J. Org. Chem.*, 45, 5347 (1980).
15. Satisfactory elemental analyses were obtained for all new compounds.

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