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FIRST ISOLATION OF MONOCYCLIC THIABENZENES

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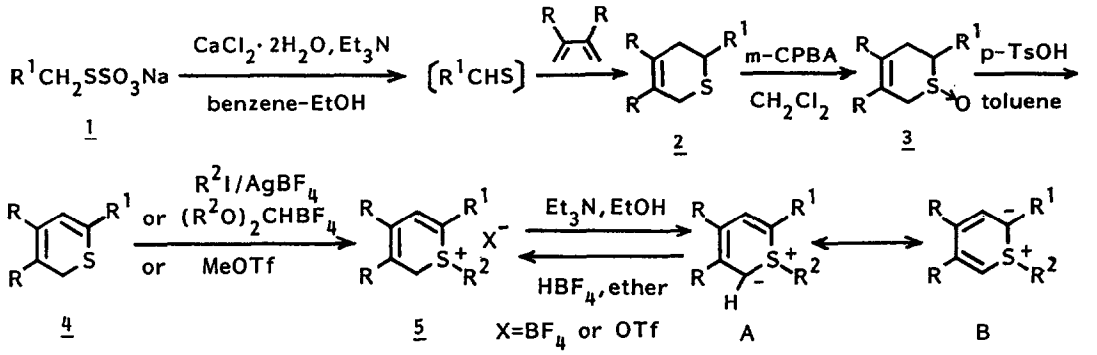
Abstract: Monocyclic thiabenzenes, 1-alkyl-2-aroyl- (or 1-alkyl-2-cyano-) 4,5-dimethylthiabenzenes (**6**) are successfully synthesized by deprotonation of the corresponding thiopyranium salts (**5**) with triethylamine in ethanol. The ylide structures of **6** are elucidated by spectral and chemical evidence. Thermal reaction of **6** in several solvents provides S-alkyl rearranged products and ring-contracted ones, depending upon solvents used.

We have strongly focussed on the chemistry of cyclic sulfur ylides, so-called "Thiabenzenes," in which sulfur-ylide bond forms a part of a cyclic conjugated ring system having with six π-electrons, from the standpoint of their structural interest and moreover of the reactivities promising the construction of novel sulfur-containing heterocycles.

We have succeeded in the preparation of isolable thiabenzene derivatives, 1-,[1a] and 2-thianaphthalenes,[1b] and 9-thiaanthracenes[1c] and 9-thiaphenanthrenes.[1d] We also found a lot of their unexpected interesting reactions so far.[1] However, all of these thiabenzenes are benzo-condensed derivatives. It is of great interest to synthesize monocyclic thiabenzenes as the final target in order to investigate closely the chemistry of thiabenzene skeleton itself. There is no report on the successful isolation of stable monocyclic thiabenzenes,[2,3] although Weber reported the stabilization of thiabenzene as a ligand of a metal complex.[4]

In this communication, we report the first example of isolable monocyclic thiabenzenes (**6**) stabilized with an electron-withdrawing substituent such as cyano or carbonyl group.

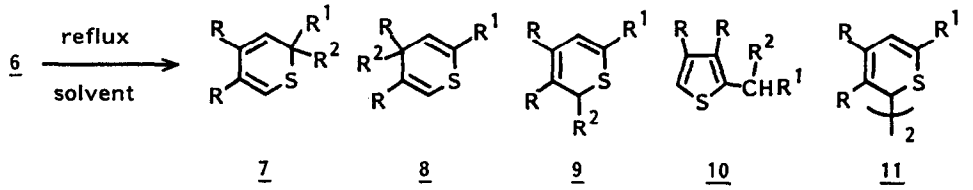
The synthesis of monocyclic thiabenzenes (**6**) was performed as shown in Scheme 1. Starting dihydrothiopyrans (**2**) were prepared by Diels-Alder reaction of 2,3-dimethyl- (or unsubstituted) 1,3-butadiene with thioaldehydes generated from Bunte salts (**1**) and triethylamine, according to the method reported by Kirby et al.[5] The thiopyrans (**2**) were led in high yields to the corresponding sulfoxides (**3**) by oxidation with m-CPBA in dichloromethane. The sulfoxides (**3**) were proved to be mixtures of cis and trans stereoisomers by ^{1}H NMR spectroscopy (1:3 for **3a**, **3b**, and **3c**, and 1:1 for **3d**, respectively). Isomeric mixtures of **3** were submitted to the dehydration conditions,[6] refluxing in toluene in the presence of catalytic amount of p-toluenesulfonic acid, to give the corresponding 6H-thiopyrans (**4**) in 71-78% yields. Alkylation of **4a**, **4b**, and **4c** with alkyl iodide/silver



a: R = H, R^1 = p-BrC_6H_4CO, R^2 = Me
b: R = Me, R^1 = p-BrC_6H_4CO, R^2 = Me
b': R = Me, R^1 = p-BrC_6H_4CO, R^2 = Et
c: R = Me, R^1 = PhCO, R^2 = Me
d: R = Me, R^1 = CN, R^2 = Me

Scheme 1.

tetrafluoroborate or dialkoxycarbenium tetrafluoroborate afforded the corresponding thiopyranium tetrafluoroborates, **5a**, **5b**, **5b'**, and **5c** in 58-100% yields, respectively. Unfortunately, alkylation of **4d** with the above alkylating agents proceeded only in low yields. However, when treated with methyl trifluoromethanesulfonate, **4d** was nicely methylated to afford 1-methylthiopyranium salt (**5d**) in 95% yield. Deprotonation of **5** with triethylamine in ice-cooled ethanol gave monocyclic thiabenzenes (**6**) in 57-100% yields as orange-yellow compounds. Among these thiabenzenes, **6b'** and **6c** are oily materials (decomp. on distillation), and the others are crystalline ones (mp: **6a** 90-92 °C (decomp.), **6b** 123.0-124.8 °C (decomp.), **6d** 68-69 °C). The structures of these thiabenzenes were established mainly based on the spectral data. Particularly, the spectral data of thiabenzene **6a** as representative are discussed in the following. The strong absorption band of the carbonyl group in the IR spectrum appears at 1540 cm^{-1}, lower wavenumber than that of an ordinary aroyl group (1620-1690 cm^{-1}), which supports considerable delocalization of the ylide carbanion of **6a** to the carbonyl group. The ^1H NMR spectrum ($CDCl_3$) shows a singlet signal at δ 2.17 assignable to S-Me and two doublet ones at δ 5.20 and 6.90 which are attributable to H-6 and H-3, respectively, and two triplet ones at δ 5.58 and 6.98 due to H-4 and H-5, respectively. The ^{13}C NMR spectrum (off-resonance) shows a singlet signal for C-2 at δ 65.7 and a doublet one for C-6 at δ 85.0, suggesting that the resonance form B, in which ylide carbanion is localized on C-2 position, is an important contributor to the electronic distribution in **6a**, in addition to that form A. Thiabenzene **6a** was acidified with tetrafluoroboric acid in ether to reintroduce **5a** as the sole product in 84% yield. This indicated that the resonance form A was less stable and reacted with acid much faster than that form B. The above spectral and chemical observations show the ylidic character of thiabenzene **6a**. Similar spectral and chemical behaviors were also observed for the other thiabenzenes **6b**, **6b'**, **6c**, and **6d**.[7]



Scheme 2.

Table. Thermal Reaction of 6

Entry No.	Compound	Solvent	Time	Products (% yield)				
				7	8	9	10	11
1	6b	Benzene	1.7 h	25	15	20	—	—
2	6b	EtOH	10 h	—	8	4	12	—
3	6b	MeCN	4 h	7	13	14	5	—
4	6b'	Benzene	1 h	24	13	15	—	—
5	6b'	EtOH	8 h	—	17	19	13	—
6	6d	Benzene	45 min	5	5	—	7	3
7	6d	EtOH	1 h	10	4	—	11	18

Since the thiabenzenes 6 were stable in solvents such as benzene, ethanol, and acetonitrile at room temperature even after stirring for several days, we investigated a thermal reaction of thiabenzenes 6 in refluxing solvents. The results are summarized in Scheme 2 and the table.

In general, thermal decomposition of thiabenzenes 6 has proceeded faster in non-polar solvent than in polar one, probably because of the lack of solvent stabilization towards polar ylide resonance structure of thiabenzenes. 2-Aroyl substituted thiabenzenes 6b and 6b' decomposed in non-polar solvent, benzene, to afford three kinds of S-methyl rearranged products, 7, 8, and 9 (entries 1 and 4). But they decomposed in protic solvent, ethanol, to give two S-methyl rearranged products 8 and 9, and instead of 7, ring-contracted products, thiophene derivatives 10 (entries 2 and 5). In polar aprotic solvent, acetonitrile, interestingly 6b afforded all of the above four products after refluxing for 4 h (entry 3). 2-Cyano substituted thiabenzene 6d also underwent a similar thermal decomposition to give two S-methyl rearranged products, 7d and 8d, and instead of 9d, dimerized product (11d). The compound 11d would be produced presumably by self-coupling of demethylated intermediate of 6d. The structures of the products 7-11 were easily elucidated mainly on the basis of their spectral data.[8]

We think that the rearranged products 7 may be the intermediates for the thermal ring contraction of 6 giving thiophene derivatives 10, because the compounds 7 are gradually converted to the compounds 10 on standing at room temperature, and more rapidly decompose on heating in ethanol to give the same ones.

On the detailed mechanism regarding the ring contraction we are now under investigation, and moreover on the reaction of the newly prepared thiabenzenes with various kinds of electrophiles we are also in progress.

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7. **6b**: ^{1}H NMR ($CDCl_3$) δ 1.90 and 2.08 (each 3 H, br s, Me), 2.05 (3 H, s, SMe), 5.06 (1 H, s, H-6), 6.53 (1 H, br s, H-3), 7,45 and 7.52 (each 2H, d, J = 9.0 Hz, aromatic H); ^{13}C NMR ($CDCl_3$) δ 76.6 (s, C-2), 84.1 (d, C-6). **6b'**: ^{1}H NMR ($CDCl_3$) δ 1.12 (3 H, t, J = 7.3 Hz, CH_2CH_3), 1.87 (3 H, br s, Me), 2.05 (3 H, s, Me), 2.34-2.63 (2 H, m, CH_2CH_3), 5.04 (1 H, s, H-6), 6.55 (1 H, br s, H-3), 7.44 and 7.52 (each 2 H, d, J = 8.5 Hz, aromatic H); ^{13}C NMR ($CDCl_3$) δ 76.0 (s, C-2), 82.5 (d, C-6); IR (KBr) 1535 cm^{-1} (C=O). **6c**: ^{1}H NMR ($CDCl_3$) δ 1.89 and 2.07 (each 3 H, br s, Me), 2.04 (3 H, s, SMe), 5.03 (1 H, s, H-6), 6.59 (1 H, br s, H-3), 7.36-7.58 (5 H, m, aromatic H); ^{13}C NMR ($CDCl_3$) δ 53.3 (s, C-2), 83.5 (d, C-6); IR (KBr) 1535 cm^{-1} (C=O). **6d**: ^{1}H NMR ($CDCl_3$) δ 1.89 and 2.04 (each 3 H, s, Me), 1.98 (3 H, s, SMe), 4.68 (1 H, br s, H-6), 6.54 (1 H, br s, H-3); ^{13}C NMR ($CDCl_3$) δ 31.9 (s, C-2), 74.0 (d, C-6); IR (KBr) 2175 cm^{-1} (CN).
8. All new compounds were fully characterized. The main features of **7b**-**10b** and **11d** as representatives are given below. **7b**: ^{1}H NMR ($CDCl_3$) δ 1.65 (3 H, s, Me), 1.88 (3 H, d, J = 1.7 Hz, Me), 1.89 (3 H, d, J = 1.7 Hz, Me), 5.45 (1 H, br s), 5.92 (1 H, br s), 7.54 and 8.01 (each 2 H, d, J = 8.6 Hz, aromatic H); IR (NaCl) 1680 cm^{-1} (C=O). **8b**: ^{1}H NMR ($CDCl_3$) δ 1.22 (6 H, s, Me), 1.87 (3 H, d, J = 1.3 Hz, Me), 5.91 (1 H, q, J = 1.3 Hz, H-6), 6.15 (1 H, s, H-3), 7.58 and 7.60 (each 2 H, d, J = 9.0 Hz, aromatic H); IR (KBr) 1650 cm^{-1} (C=O). **9b**: ^{1}H NMR ($CDCl_3$) δ 1.28 (3 H, d, J = 6.8 Hz, $CHCH_3$), 1.84 and 1.98 (each 3 H, br s, Me), 3.29 (1 H, q, J = 6.8 Hz, $CHCH_3$), 6.70 (1 H, s, H-3), 7.56 and 7.59 (each 2H, d, J = 9.0 Hz, aromatic H); IR (KBr) 1620 cm^{-1} (C=O). **10b**: ^{1}H NMR ($CDCl_3$) δ 1.53 (3 H, d, J = 6.8 Hz, $CHCH_3$), 2.10 and 2.11 (each 3H, s, Me), 4.83 (1 H, q, J = 6.8Hz, $CHCH_3$), 6.76 (1 H, br s), 7.54 and 7.78 (each 2H, d, J = 8.6 Hz, aromatic H); IR (NaCl) 1690 cm^{-1} (C=O). **11d**: ^{1}H NMR ($CDCl_3$) δ 1.82 and 1.87 (each 6 H, br s, Me), 3.27 (2 H, s, H-6), 6.83 (2 H, br s, H-3); IR (KBr) 2220cm^{-1} (CN).

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