Synthesis and thermal reactivity of 2-azido-5-trimethylsilylthiophene and 2-azido-5-methylthiophene. The *para*-like substituent effect on fragmentation of the azido group

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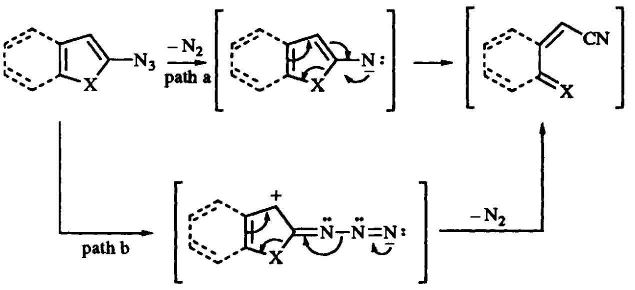
2-Azido-5-trimethylsilylthiophene **1** and 2-azido-5-methylthiophene **2**, prepared by azido group transfer of the corresponding heteroaryllithium derivative with toluene-*p*-sulfonyl azide, show differing chemical reactivity and kinetic behaviour upon 1,3-cycloaddition with the dipolarophile (trimethylsilyl)acetylene and thermal decomposition.

In comparison to the chemistry of aryl azides, whose physical, industrial and biochemical applications are well documented,[1] azides derived from five-membered heteroaryl systems containing one heteroatom have received less attention.[2] The general trend that has emerged from recent studies of the thermal decomposition of the few known heteroaryl azides, suggests that formal nitrene generation at the α-position of five-membered rings generally results in ring opening, whilst normal arylnitrene behaviour is exhibited by compounds having a nitrene function at the β-position.

On the basis of results from our recent studies of the chemical and kinetic behaviour of α-azidobenzo[*b*]thiophene (2-BTA)[3] and α-azido-thiophene[4] and -selenophene[5] we suggest that these azides undergo unimolecular thermal decomposition and ring-opening probably in a concerted manner (path b, Scheme 1). This observation is consistent with the assumption that both ground-state resonance conjugation of the azido group with the attached ring and reorganization of the delocalized π-bond system, in the transition state of the thermal azide decomposition, play an important role in effecting cleavage of the azido $N-N_2$ bond. However, electronic effects are exerted by *para*-like (or *ortho*-) substituents upon unimolecular decomposition and ring cleavage of α-azidoheteroaryls is virtually unknown.†‡

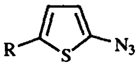


Scheme 1

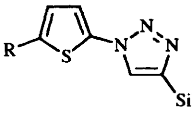
We were, therefore, prompted to extend our study for 5-substituted heteroaryl azides as possible precursors of nitrenes (or otherwise). We now report the synthesis of 2-azido-5-trimethylsilylthiophene **1** and 2-azido-5-methylthiophene **2**, and a preliminary investigation of their thermal decomposition in the absence and in the presence of (trimethylsilyl)acetylene.

The new azides **1** and **2** were prepared (in 69.0 and 52.5% yield, respectively) through azido group transfer of the corresponding 2-heteroaryllithium derivatives with toluene-*p*-sulfonyl azide and subsequent fragmentation of the resulting triazene lithium salts, according to a previously reported procedure.[7] Structural assignments for compounds **1** and **2** were made on the basis of IR, ^1H and ^{13}C NMR and mass spectral results.

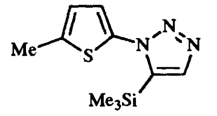
The azide **1** proved to be more thermally stable than the azide **2**, which even in a freezer at −20 °C underwent total decomposition within a few months to give a single solid compound, mp 123–124 °C, whose ^1H, ^{13}C NMR and exact mass spectral data were consistent with the dihydrothiophene structure **3**. This product was possibly formed through initial cyclodimerization of the intermediate ring-opened 4-cyano enethione leading to a 1,5-dithiocine and subsequent rearrangement of this by sulfur extrusion (Scheme 2).



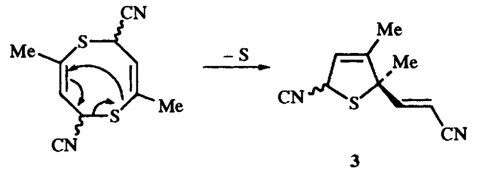
1 R = $SiMe_3$
2 R = Me



1a R = $SiMe_3$
2a R = Me



2b



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Scheme 2

Formation of a dithiocine product was previously observed in the related ring-opening decomposition of 2-azidobenzo[*b*]-thiophene[3] but not in that of the parent 2-azidothiophene (2-ATh) previously studied, which only gave a mixture of isomeric *m*-dithiins.[4]

In inert toluene solvent at 50 °C decomposition rates of the azides **1** and **2** (*ca.* 30 mmol dm^{-3}), determined by measuring the intensity of the IR asymmetric stretching azido band as a function of time, were cleanly first-order with half-life of *ca.* 290 and 12 min, respectively. Under the same conditions 2-ATh was previously shown to exhibit a half-life of *ca.* 46 min.[4]

At room temperature the azide **1** underwent 1,3-dipolar cycloaddition[8] with the neat dipolarophile (trimethylsilyl)-acetylene within 7 days to give exclusively 1-(5-trimethylsilyl-2-

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† Thermally induced ring-cleavage of 2-azido-5-oxo-furans has been postulated to occur *via* a nitrene intermediate.[6]

‡ *Note added in proof.* Thermal ring-cleavage of 5-azidopyrazoles is also believed to occur *via* a nitrene intermediate on the basis of very recent kinetic evidence; see: G. L'abbé, L. K. Dyall, K. Meersman and W. Dehaen, *J. Chem. Soc., Perkin Trans. 2*, 1994, 2401.

thienyl)-4-(trimethylsilyl)-1,2,3-triazole **1a**. Under analogous condition the azide **2** reacted *ca.* twice as fast and led instead to a mixture of regioisomeric triazole cycloadducts **2a** and **2b** accompanied by significant amounts of dihydrothiophene **3** (the observed **2a**:**2b**:**3** ratio was 70:3:27). As might have been expected,[3] a decrease in the reaction temperature favoured 1,3-cycloaddition of the azide **2** with trimethylacetylene at the expense of its unimolecular ring-opening fragmentation. In fact, almost complete suppression of the product **3** in favour of triazoles **2a** and **2b** occurred when the azide **2** was allowed to react with neat (trimethylsilyl)acetylene at 5 °C (7 days) (in such case the observed **2a**:**2b**:**3** ratio was 90:4:6).

In the light of the present experimental evidence, it may be inferred that the thermal stability of 2-ATh is significantly depressed by a 5-methyl substituent, but, conversely, is enhanced by a trimethylsilyl one. The electron-donating methyl group [whose calculated δ_P Hammett constant value and resonance parameter (R) are -0.17, and -0.18, respectively][9] would, therefore, destabilize the *para*-like azido moiety. On the other hand, the trimethylsilyl group, despite its similar (though comparatively weaker) electropositive nature ($\delta_P = -0.07$, $R = -0.08$) appears to confer stabilization. This fact might be ascribed to effective d/π interaction exerted by trimethylsilyl silicon on the heteroaryl π-electron system which would thence result in an electron-withdrawing effect.

Experimental

Preparation of the azides 1 and 2

Following a standard procedure, 2-lithiated 5-trimethylsilyl- or 5-methyl-thiophene (0.16 mol) in dry diethyl ether (100 cm^3) was treated with tosyl azide (0.165 mol) and the resulting triazene salt was then decomposed with aqueous tetrasodium pyrophosphate decahydrate (0.165 mol). Chromatography of the crude reaction mixture on a Florisil column (using hexane as eluent) gave, respectively, (i) 2-azido-5-trimethylsilylthiophene **1** (0.11 mol, 69.0%) as an oil; ν_{max}/cm^{-1} 2140 (N_3) and 850 ($SiMe_3$) (Found: M$^+$, 197.0443. $C_7H_{11}N_3SSi$ requires *M*, 197.0443); *m/z* 197 (M$^+$, 5%), 169 (11, M–N_2), 74 (7.1) and 73 (100); and (ii) 2-azido-5-methylthiophene **2** (0.084 mol, 52.5%) as an oil; ν_{max}/cm^{-1} 2120 (N_3) (Found: M$^+$, 139.020 42. $C_5H_5N_3S$ requires *M*, 139.020 42); *m/z* 139 (M$^+$, 39%), 111 (79, M–N_2) and 96 (100).

Reactions of the azides 1 and 2 with (trimethylsilyl)acetylene

A solution of the azides **1** and **2** (0.5 mol dm^{-3}; 20 cm^3) in neat (trimethylsilyl)acetylene was allowed to react in a sealed tube at room temperature and in the dark, until TLC showed the absence of the starting azide (after 7 and 3 days, respectively). The residue, obtained after careful elimination of the excess of silylated alkyne under reduced pressure, was chromatographed on a silica gel column using hexane with increasing amounts of diethyl ether (up to 50%) as eluent. The following new triazoles **1a** and **2a**, **2b** were isolated and characterized.

1-(5-Trimethylsilyl-2-thienyl)-4-(trimethylsilyl)-1,2,3-(triazole **1a** (> 95%), mp 66–68 °C; δ_H(200 MHz; $CDCl_3$) 7.97 (1 H, s), 7.29 (1 H, d, *J* 3.6), 7.10 (1 H, d, *J* 3.6), 0.36 (9 H, s) and 0.33 (9 H, s); δ_C(200 MHz; $CDCl_3$) 147.60 (s), 143.20 (s), 138.13 (s), 133.44 (d, *J* 201.0), 128.83 (d, *J* 205.4), 119.57 (d, *J* 170.2), -0.20 (q, *J* 120.8) and -1.08 (q, *J* 118.9); *m/z* 267 (40, M–N_2), 252 (100), 143 (8), 119 (6), 83 (18), 73 (76), 45 (16) and 43 (11) (Found: C, 48.9; H, 7.1; N, 14.2. Calc. for $C_{12}H_{21}N_3SSi_2$: C, 48.80; H, 7.15; N, 14.25%).

1-(5-Methyl-2-thienyl)-4-(trimethylsilyl)-1,2,3-triazole **2a** (63.0%), mp 65–66 °C; δ_H(200 MHz; $CDCl_3$) 7.78 (1 H, s), 6.97 (1 H, d, *J* 3.7, 3-H), 6.64 (1 H, d, *J* 3.7, 4-H), 2.47 (3 H, s) and 0.34 (9 H, s); δ_C(200 MHz; $CDCl_3$) 153.72 (s), 137.98 (C-2, s), 128.85 (d, *J* 193.8), 124.42 (d, *J* 169.0), 118.59 (d, *J* 165.0), 15.52 (q, *J* 127.0) and 1.08 (q, *J* 120.0); *m/z* 237 (M$^+$, 2%), 209 (37, M–N_2), 194 (100), 83 (35), 73 (35) and 43 (13) (Found: C, 50.5; H, 6.4; N, 17.5. Calc. for $C_{10}H_{15}N_3SSi$: C, 50.60; H, 6.50; N, 17.70%).

1-(5-Methyl-2-thienyl)-5-(trimethylsilyl)-1,2,3-triazole **2b** (2.5%), as an oil; ν_{max}/cm^{-1} 2960, 1255 and 845 ($SiMe_3$); δ_H(200 MHz; $CDCl_3$) 7.74 (1 H, s), 6.95 (1 H, d, *J* 3.6), 6.72 (1 H, d, *J* 3.6), 2.54 (3 H, s) and 0.22 (9 H, s); *m/z* 237 (M$^+$, 2.5%), 209 (42%, M–N_2), 194 (100), 150 (13), 83 (35), 73 (49), 45 (19) and 43 (15) (Found: C, 50.55; H, 6.4; N, 17.6%).

Acknowledgements

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