COMMUNICATION

Vacuum–thermal fragmentation and ring cleavage of 1-(*N*-substituted-pyrrol-2-yl)-3-tosyltriazene tetraalkylammonium salts to 4-cyano-1-azabuta-1,3-dienes

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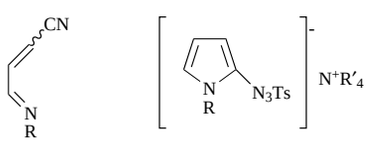
***N*-Methyl- and *N*-phenyl-4-cyano-1-azabuta-1,3-diene (1a and 1b respectively) are produced by vacuum–thermal fragmentation and ring cleavage of 1-(*N*-substituted-pyrrol-2-yl)-3-tosyltriazene tetraalkylammonium salts, prepared by reaction of the corresponding 2-lithiopyrroles with tosyl azide and successive reaction of the resulting lithium triazene salts with tetraalkylammonium bromide.**

The synthesis of nitrogen functionalized five-membered heteroaryl systems is being studied in our laboratories where in the last two decades the application of the azido transfer reaction of lithiated heteroaryls with tosyl azide has been developed.[1] Kinetic and product studies (and synthetic application) of α- and β-azides derived from five-membered heteroaryls, especially azido-thiophene[2] (and -benzothiophene[1]), -indole[3] and -selenophene[4] led us to the conclusion that α-azides easily suffer ring cleavage, leading to the formation of nitrilic 1-hetero-1,3-diene products, in contrast with normal aryl azide behaviour[5] generally exhibited by the isomeric β-azides.

As a continuation of our research in this field, an attempt to prepare 2-azido-*N*-methylpyrrole, by an azido transfer reaction of the appropriate 2-lithio-*N*-methylpyrrole derivative[6] with tosyl azide and fragmentation of the resulting lithium triazene salt, was unsuccessful. In fact, using standard fragmentation conditions on the almost quantitatively formed lithium triazene salt with an aqueous solution of tetrasodium pyrophosphate mainly gave back tosyl azide together with small amounts of the ring cleavage product *N*-methyl-4-cyano-1-azabuta-1,3-diene **1a** and tarry material. In addition, the rate of fragmentation and the product distribution for unsymmetrical 1,3-disubstituted triazenes are controlled by the stability of the two



Ts = *p*-tolylsulfonyl

1a R = Me
1b R = Ph

2a R = Me; R′ = Et
2b R = Ph; R′ = Bu
2c R = Me; R′ = Bu

possible triazenium ions and the population and basicity of the resulting tautomeric forms, which affect the product distributions of the resulting heteroaryl and/or tosyl azide.[7] On these bases we reasoned that a similar method might be suitably applied to the preparation of *N*-substituted 4-cyano-1-azabuta-1,3-dienes (or their azido derivative precursors) using an easily handled triazene salt obtained by converting the original lithium triazene salt into 1-(*N*-methylpyrrol-2-yl)-3-tosyltriazene tetraethylammonium salt **2a** with tetraethylammonium bromide. Since no data were available on thermal decomposition reactions of **2a** we initially performed a brief investigation of the thermolysis of **2a** (2 mmol), in a mineral oil suspension (1:2, w/w) under vacuum at a mild temperature (60–80 °C). The fraction collected in the liquid nitrogen trap during the course of the distillation was characterized as a geometrical *cis*:*trans* (2:1) mixture of **1a** as shown by structural assignments on the basis of IR, ^{1}H and ^{13}C NMR and mass spectral data. Thus these findings were consistent with the thermal behaviour expected upon unimolecular decomposition and ring cleavage of the hitherto unknown 2-azido-*N*-methylpyrrole.†

Hetero-Diels–Alder reactions of azabutadienes have been reported[9] and these particular 4-cyano-1-azabuta-1,3-dienes were also of interest to us as straightforward synthons for heterocyclic synthesis.‡ Consequently, we developed a new route to *N*-substituted 1-azabutadienes extending our reaction to the 1-(*N*-phenylpyrrole-2-yl)-3-tosyltriazene lithium salt, prepared by direct metallation of *N*-phenylpyrrole with butyllithium[11] in a mixture of diethyl ether and tetramethylethylenediamine (TMEDA) followed by reaction with tosyl azide. Final treatment of the resulting lithium triazene salt with tetrabutylammonium bromide afforded the tetrabutylammonium triazene salt **2b**, whose structural assignments were made on the basis of ^{1}H NMR spectroscopy {δ_H(200 MHz; [$^2H_6$]DMSO; *J*/Hz) 7.59 (2 H, d, *J* 7.9, Ts-H), 7.25–7.15 (5 H, m, Ar-H), 7.10 (2 H, d, *J* 7.9, Ts-H), 7.05 (1 H, dd, *J* 1.9 and 3.7, H-3), 6.76 (1 H, dd, *J* 1.9 and 3.0, H-5), 6.10 (1 H, dd, *J* 3.0 and 3.7, H-4), 3.11 (8 H, br m, NCH_2), 2.29 (3 H, s, Me), 1.52 (8 H, br m, CH_2), 1.27 (8 H, m, CH_2) and 0.89 (12 H, m, Me)}.

The tetrabutylammonium triazene salt **2c** which was similarly obtained gave the following ^{1}H NMR spectrum; δ_H(200 MHz; {$^2H_6$}DMSO) 7.61 (2 H, d, *J* 7.9, Ar-H), 7.22 (2 H, d, *J* 7.9, Ar-H), 6.83 (1 H, dd, *J* 1.8 and 3.7, H-3), 6.53 (1 H, dd, *J* 1.8 and 2.8, H-5), 5.89 (1 H, dd, *J* 2.8 and 3.7, H-4), 3.69 (3 H, s, Me), 3.06 (8 H, br m, NCH_2), 2.28 (3 H, s, Me), 1.50 (8 H, br m, CH_2), 1.26 (8 H, m, CH_2) and 0.82 (12 H, m, Me).

Thermolysis of compound **2b** (2 mmol) under vacuum at 60–80 °C in mineral oil suspension afforded a light yellow liquid, collected during the course of the distillation, which was characterized as pure *cis*-*N*-phenyl-4-cyano-1-azabuta-1,3-diene **1b**. Structural assignment of **1b** was made on the basis of IR, ^{1}H and ^{13}C NMR and mass spectral data.

Satisfactory yields of 1-azabuta-1,3-dienes **1a** and **1b** were obtained by our present procedure, the yields of the whole process being 90 and 70%, respectively. The lowest yield of compound **1b** could be due to a less-favoured metallation of *N*-phenylpyrrole compared with *N*-methylpyrrole.[11] Standard

† Attempted S_NAr reaction of 5-chloro-4-formylpyrroles with sodium azide in DMSO gave 4-cyano-5-hydroxypyrroles, this reaction has been postulated to occur by ring cleavage and successive cyclization of the related nitrile azabutadiene intermediate.[8]

‡ Reactions of various terminal or 1,2-disubstituted (*E*)/(*Z*) dienophiles with related *o*-quinone cyanomethide methylimine (IUPAC name: 5-cyanomethylene-6-methyliminocyclohexa-1,3-diene) to 4-cyanotetrahydroquinolines[3] as well as of isosteric *N*-phenyl-2-cyano-1-aza-1,3-butadiene have been recently reported.[10]

fragmentation of the triazene salt **2b** with an aqueous solution of tetrasodium pyrophosphate mainly gave back tosyl azide and *N*-phenylpyrrole, together with small amounts of *N*-phenyl-1-azabuta-1,3-diene **1b** and the unexpected *N*-(2-azidophenyl)pyrrole; δ_H(200 MHz; $CDCl_3$) 7.40–7.18 (4 H, br m, Ar-H), 6.92 (2 H, AA′XX′, H-α) and 6.35 (2 H, AA′XX′, H-β); *m/z* 184 (M^+, 71.8%), 156 (M − N_2, 100) 155 (77.3), 129 (40.7), 103 (34.6) and 51 (36.2) (Found: M^+, 184.074 90. $C_{10}H_8N_4$ requires *M*, 184.074 89).

Experimental

Preparation of 1-(*N*-substituted-pyrrol-2-yl)-3-tosyltriazene tetraalkylammonium salts 2a–c

A solution of 1-methylpyrrole (or 1-phenylpyrrole) (16 mmol) and 19 mmol of tetramethylethylenediamine (TMEDA) in dry diethyl ether (30 cm^3) was treated, with stirring under nitrogen at −70 °C, with butyllithium (1.6 M in hexane; 11 cm^3). The reaction mixture was stirred for an additional 1 h (6 h for 1-phenylpyrrole), after which a solution of tosyl azide (17 mmol) in dry diethyl ether (20 cm^3) was added. The pale yellow triazene salt which formed was stirred and allowed to reach 0 °C within 8 h, then rapidly filtered off and suspended in pentane. The suspension was treated at 0 °C for 10 min with tetrabutylammonium (or tetraethylammonium) bromide (16 mmol) in water (1 cm^3), after which the brown precipitate of 1-(pyrrol-2-yl)-3-tosyltriazene tetraalkylammonium salt (**2a–c**) was filtered by suction and dried under vacuum.

Vacuum–thermal fragmentation of triazenes 2a and 2b

A simple apparatus for vacuum distillation (p = 0.5–1 mmHg) was charged with a suspension of the triazene salt (2 mmol) in mineral oil suspension (1:2, w/w), which was then allowed to react carefully in a thermostatic bath at the appropriate temperature (60–80 °C). The fraction collectors were cooled in a liquid nitrogen trap and the fractions collected during the course of the distillation (2–3 h) were then weighed (yields of thermal process *ca*. 90%, based on the starting triazene product) and characterized. The following 1-azabuta-1,3-dienes **1a** and **1b** were obtained.

***N*-Methyl-4-cyano-1-azabuta-1,3-diene 1a.** (1.8 mmol, 90%), an oil; ν_{max}/cm^{-1} 3060, 2210 (CN); δ_H(200 MHz; $CDCl_3$) *cis*: 8.26 (1 H, dd, *J* 9.2 and 0.9,§ H-2), 6.85 (1 H, dd, *J* 9.2 and 11.1, H-3), 5.78 (1 H, dd, *J* 11.1 and 0.9, H-4) and 3.55 (3 H, s, Me); *trans*: 7.87 (1 H, d, *J* 8.8, H-2), 6.96 (1 H, dd, *J* 8.8 and 16.4, H-3), 5.71 (1 H, d, *J* 16.4, H-4) and 3.51 (3 H, s, Me); δ_C(50 MHz; $CDCl_3$) *cis*: 159.7 (d), 147.9 (d), 114.9 (s), 105.9 (d) and 48.8 (q); *trans*: 160.7 (d), 148.6 (d), 116.6 (s), 107.8 (d) and 48.8 (q); *m/z* 94 (M^+, 5.1%), 93 (M − N_2, 14.8), 72 (34.7), 71 (30.0), 43 (31.8), 42 (100), 41 (57.3) and 39 (23.6) (Found: M^+, 94.053 10. $C_5H_6N_2$ requires *M*, 94.053 10).

***N*-Phenyl-4-cyano-1-azabuta-1,3-diene 1b.** (1.4 mmol, 60%), an oil; ν_{max}/cm^{-1} 3060, 2920, 2220 (CN), 755 and 695; δ_H(200 MHz; $CDCl_3$) 8.61 (1 H, dd, *J* 11.0 and 0.9, H-2), 7.42 (5 H, br s, Ar-H), 7.16 (1 H, dd, *J* 9.3 and 11.0, H-3) and 5.96 (1 H, dd, *J* 9.3 and 0.9, H-4); δ_C(50 MHz; $CDCl_3$) 176.2 (s), 156.2 (d), 148.2 (d), 129.8 (d), 128.6 (d), 115.3 (s), 121.7 (d) and 107.7 (d); *m/z* 156 (M^+, 7.9%), 155 (M − N_2, 35.5), 91 (100), 65 (21.5) and 39 (9.7) (Found: M^+, 156.068 75. $C_{10}H_8N_2$ requires *M*, 156.068 75).

§ *J* Values given in Hz.

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References

1 P. Spagnolo and P. Zanirato, *J. Org. Chem.*, 1978, **43**, 3539; M. Funicello, P. Spagnolo and P. Zanirato, *Acta Chem. Scand.*, 1993, **47**, 231 and references cited therein.
2 D. Spinelli and P. Zanirato, *J. Chem. Soc., Perkin Trans. 2*, 1993, 1129.
3 M. T. Di Gioia, E. Foresti, D. Nanni and P. Zanirato, *Gazz. Chim. Ital.*, 1995, **125**, 151.
4 S. Gronowitz and P. Zanirato, *J. Chem. Soc., Perkin Trans. 2*, 1994, 1815.
5 For information about the chemistry of organic azides (and nitrenes) the reader is referred to the following useful books and reviews; E. F. V. Scriven and K. Turnbull, *Chem. Rev.*, 1988, **88**, 297; E. F. V. Scriven, *Azides and Nitrenes: Reactivity and Utility*, Academic Press, New York, 1984; S. Patai, *The Chemistry of the Azido Group*, Interscience Publishers, London, 1971.
6 N. Gjøs and S. Gronowitz, *Acta Chem. Scand.*, 1971, **25**, 2526.
7 R. H. Smith Jr., B. D. Wladkowski, J. A. Herling, T. D. Pfaltzgraff, B. Pruski, J. R. Klose and C. J. Michejda, *J. Org. Chem.*, 1992, **57**, 654; R. H. Smith Jr., B. D. Wladkowski, J. A. Herling, T. D. Pfaltzgraff, J. E. Taylor, E. J. Thompson, B. Pruski, J. R. Klose and C. J. Michejda, *J. Org. Chem.*, 1992, **57**, 6448; D. W. Farnsworth, D. A. Wink, N. M. Roscher, C. J. Michejda and R. H. Smith Jr., *J. Org. Chem.*, 1994, **59**, 5942.
8 J. Becher and W. Dehaen, *Acta Chem. Scand., Ser. B*, 1993, **47**, 244 and references cited therein.
9 D. L. Boger and S. N. Weinreb, 'Azabutadienes', in *Hetero Diels–Alder Methodology in Organic Synthesis*, ed. H. H. Wasserman, Academic Press, San Diego, 1987, vol. 47, p. 239.
10 N. J. Sisti, A. I. Motorina, M.-E. T. H. Dau, C. Riche, F. W. Fowler and D. S. Grierson, *J. Org. Chem.*, 1996, **61**, 3715.
11 D. A. Shirley, B. H. Gross and P. A. Roussel, *J. Org. Chem.*, 1955, **20**, 225.

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