Direct Observation of Bicyclic α-Alkoxyoxonium Ions; Reductive Cleavage to Medium-ring Diethers

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1-Oxonia-5-oxabicyclo[4.3.0]nonane and 1-oxonia-6-oxabicyclo[5.3.0]decane ions differ in the extent of charge delocalisation between the two oxygen atoms as shown by ^1H and ^{13}C n.m.r. spectroscopy in SO_2 solution; trapping with triethylsilane leads to medium-ring diethers.
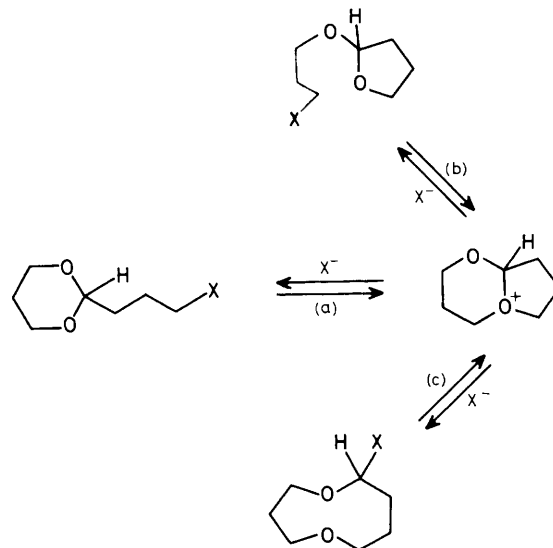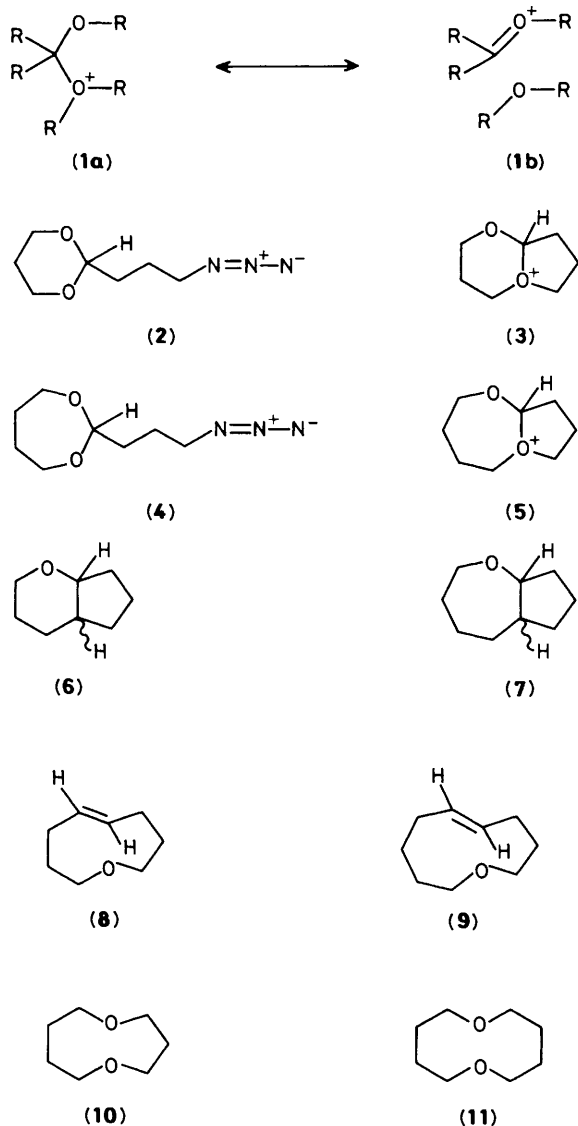
We report the first direct observation in solution of α-alkoxy-oxonium ions, (1); these species are important because of the involvement of analogues in the mechanisms of formation and hydrolysis of acetals.[1] The extent of charge delocalisation and concomitant structural changes, (1a) ⟷ (1b), is of considerable interest. The degree of delocalisation in related neutral species ROCHRX (the generalised anomeric effect)[2] has been studied thoroughly[3] and the importance of stereoelectronic effects on this delocalisation debated extensively.[4,5] In the case of (1a) ⟷ (1b), no charge separation is involved in the resonance, so the contribution of canonical form (1b) is expected to be greater. On the other hand, it might be thought that the reverse anomeric effect[6] could apply to these ions.

Reaction of 2-(3-azidopropyl)-1,3-dioxolane† (2) with nitrosonium tetrafluoroborate in sulphur dioxide solution produces a solution which gives a ^{13}C n.m.r. spectrum with lines at δ 121.7 (C-6), 80.9, and 79.9 (C-2 and C-9), 67.0 (C-4), and 28.5, 21.6, and 20.0 (C-3, C-7, and C-8) which may be assigned to the 1-oxonia-5-oxabicyclo[4.3.0]nonane ion, (3). Similar reaction of 2-(3-azidopropyl)-1,3-dioxepane† (4) leads to the 1-oxonia-6-oxabicyclo[5.3.0]decane ion, (5), with ^{13}C n.m.r. lines at δ 145.5 (C-7), 80.1, 79.5, and 79.2 (C-2, C-5, C-10), and 30.4, 29.9, 25.4, and 25.2 (C-3, C-4, C-8, and C-9). Additional proof that these species are responsible for the spectra observed comes from the hydride-trapping experiments described later. It is remarkable that the chemical shift of the methine carbon in (5) is 23.8 p.p.m. downfield of that in (3). We ascribe the difference to a larger contribution from canonical form (1b) to the structure of (5) compared to (3).‡

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† Azides were prepared from the corresponding chlorides by heating with sodium azide for 2 h at 100 °C in DMF.

‡ The experimental evidence doe not exclude that both (3) and (5) are different equilibrium mixtures of discrete chemical structures corresponding to (1a) and (1b); we consider this possibility unlikely.

(1a) ⟷ (1b)

(2)

(3)

(4)

(5)

(6)

(7)

(8)

(9)

(10)

(11)

Scheme 1

The chemical shift of the methylene group next to the dico-ordinate oxygen atom also indicates that there is less positive charge on this oxygen atom in (3) than in (5). If the ions had structures which were entirely of the (1b) type, the chemical shift of the methine carbon would be expected to be about δ 250.[7] Estimation of the chemical shift to be expected from a non-delocalised (1a) structure is not easy. The chemical shifts of the methine carbon in the starting acetals (2) and (4) are δ 101.3 and 102.2 respectively, while triethyloxonium ion has a chemical shift which is about 20 p.p.m. downfield of that of diethyl ether.[8] Thus (1a) might have a chemical shift of about δ 120. Clearly these ions are more 'shut' than 'open' and this is in accord with calculations on the HOCH(OH₂)⁺ ion.[9] In the ¹H n.m.r. spectra of (3) and (5), the methine hydrogen absorptions occur at δ 6.56 and 7.22 respectively; this is also in accord with a more 'open' structure for (5).

Why is (5) more 'open' than (3)? Kirby et al.[3] have correlated the extent of C–X bond breaking in a series of compounds ROCHRX with the electronegativity of X but this is not a variable here. Strain differences between the 'open' and 'shut' forms might be important in our case. We have tried to assess these by doing MM2[10] calculations on (6) and (7) as

models for the closed forms of (3) and (5), and on (8) and (9) in conformations derived by least-motion ring-opening of the best conformations of (6) and (7) as models for the opened forms. The best conformation of (6) (both cis and trans ring junctions were considered; four conformations were calculated) is 26 kJ mol⁻¹ less strained than (8) in the same conformation, but (7) (eighteen conformations calculated) is 19 kJ mol⁻¹ more strained than (9). The preferred conformations of (6) and (7) lead to trans-isomers of (8) and (9) on ring opening, and it is the strain in the trans-alkene bond which is largely responsible for the differences between the two cases, with (8) having a calculated C–C=C–C torsion angle of 152° compared with 168° for (9). This suggests that unstrained α-alkoxyoxonium ions would resemble (5) rather than (3) in their properties.

The reaction of azides with nitrosonium salts to generate carbonium ions which we have used for generating (3) and (5) has been in the literature for some time[11] but has attracted little attention. In order to generate (3) and (5) it is imperative that their precursors are activated in a chemoselective way so that initial reaction occurs at the end-of-chain functionality and not directly at the acetal. Protic acids are clearly useless and many Lewis acids are likely to be little better; our first attempts to generate (5) used the reaction of 2-(3-chloropropyl)-1,3-dioxepane with silver tetrafluoroborate, but this gave, at best, only partial conversion to (5). We believe that the azide/nitrosonium ion reaction has wider application for the cycloalkylation of weakly nucleophilic centres.

In principle, ions such as (3) may be derived from three precursors, and give any of three products on trapping with nucleophiles, as shown in Scheme 1. We have attempted the generation of (3) by route (b) from 1-tetrahydrofuranyloxy-3-azidopropane, but without success. We have also tried without success to apply route (a) to generate analogous ions, for example from 2-(3-azidopropyl)-1,3-dioxane, 2-(4-azido-butyl)-1,3-dioxolane, and 4-azidobutanal dimethyl acetal. Thus even the azide/nitrosonium ion reaction has very limited scope for the preparation of these ions. Both the successful cases involve RO5 participation, which is known[12,13] to be the most favourable; the reaction of 2-(4-azidobutyl)-1,3-dioxane requires RO6 participation,[12] expected to be substantially less favourable. We do not understand the failure of 2-(3-azido-

propyl)-1,3-dioxolane and 4-azidobutanal dimethyl acetal to yield observable α-alkoxyoxonium ions.

Finally, we have trapped ions (3) and (5) by reaction with triethylsilane[14] to give 1,5-dioxacyclononane (10) and 1,6-dioxacyclodecane[15] (11) in 40 and 51% yields respectively after distillation, thus providing simple syntheses of these interesting compounds. Clearly even (3) possesses enough electron deficiency at the CH group for attack of hydride to take place there rather than at the less sterically-hindered methylene groups. Synthesis was in fact the original motivation for this work; we had earlier[16,17] shown that the related hydridic cleavage of α-aminoammonium ions provides an extremely flexible route to medium-ring bicyclic diamines. Unfortunately, this method of making medium-ring diethers is at present very limited in scope, owing to the problems of ion generation.

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References

1 E. H. Cordes, *Prog. Phys. Org. Chem.*, 1967, **4**, 1; E. H. Cordes and H. G. Bull, *Chem. Rev.*, 1974, **74**, 581; for some recent new evidence see T. L. Amyes and W. P. Jencks, *J. Am. Chem. Soc.*, 1988, **110**, 3677.

2 A. J. Kirby, 'The Anomeric Effect and Related Stereoelectronic Effects at Oxygen,' Springer-Verlag, Berlin, 1983.

3 F. H. Allen and A. J. Kirby, *J. Am. Chem. Soc.*, 1984, **106**, 6197; A. J. Biggs, R. Glenn, P. G. Jones, A. J. Kirby, and P. Ramaswamy, *ibid.*, 1984, **106**, 6200; P. G. Jones and A. J. Kirby, *ibid.*, 1984, **106**, 6207.

4 P. Deslongchamps, 'Stereoelectronic Effects in Organic Chemistry,' Pergamon Press, Oxford, 1983.

5 For a contrary view of the importance of stereoelectronic effects in acetal hydrolysis see A. J. Bennet and M. L. Sinnott, *J. Am. Chem. Soc.*, 1986, **108**, 7287.

6 For a brief survey see ref. 2, pp. 15—18.

7 O. V. Lubinskaya, A. S. Shashkov, V. A. Chertkov, and W. A. Smit, *Synthesis*, 1976, 742; G. A. Olah, D. G. Parker, N. Yoneda, and F. Pelizza, *J. Am. Chem. Soc.*, 1976, **98**, 2245; D. A. Forsyth, V. M. Osterman, and J. R. DeMember, *ibid.*, 1985, **107**, 818.

8 E. V. Dehmlow, R. Zeisberg, and S. S. Dehmlow, *Org. Magn. Reson.*, 1975, **7**, 418.

9 I. H. Williams, G. M. Maggiora, and R. L. Schowen, *J. Am. Chem. Soc.*, 1980, **102**, 7831.

10 U. Burkert and N. L. Allinger, 'Molecular Mechanics,' ACS Monograph 177; American Chemical Society, Washington, 1982; N. L. Allinger, *J. Am. Chem. Soc.*, 1977, **99**, 8127.

11 M. P. Doyle and W. Wierenga, *J. Am. Chem. Soc.*, 1970, **92**, 4999; G. A. Olah, N. Friedman, J. M. Bollinger, and J. Lukas, *ibid.*, 1966, **88**, 5328; for a recent use of related nitrosation methods see E. H. White, J. T. DePinto, A. J. Polito, I. Bauer, and D. G. Roswell, *ibid.*, 1988, **110**, 3708.

12 S. Winstein, E. Allred, R. Heck, and R. Glick, *Tetrahedron*, 1958, **3**, I; E. L. Allred and S. Winstein, *J. Am. Chem. Soc.*, 1967, **89**, 3991; B. Capon, *Quart. Rev. Chem. Soc.*, 1964, **18**, 45; H. Perst, 'Oxonium Ions in Organic Chemistry,' Verlag Chemie, Weinheim/Bergstrasse, 1971, pp. 100—127; M. I. Page, *Chem. Soc. Rev.*, 1973, **2**, 295; B. Capon and S. P. McManus, 'Neighbouring Group Participation,' vol. 1, Plenum, New York, 1976.

13 D. R. Mootoo, V. Date, and B. Fraser-Reid, *J. Am. Chem. Soc.*, 1988, **110**, 2662.

14 Triethylsilane has been used as an effective reducing agent for reduction of acetals to ethers in the presence of Lewis acid catalysts: E. Frainmet and C. Esclamadan, *Compt. rend.*, 1962, **254**, 1814; T. Tsunoda, M. Suzuki, and R. Noyori, *Tetrahedron Lett.*, 1979, 4679.

15 For previous reports of 1,6-dioxoacyclodecane see W. Reppe *et al.*, *Liebigs Ann. Chem.*, 1955, **596**, 132; J. M. McKenna, T. K. Wu, and G. Pruckmayr, *Macromolecules*, 1977, **10**, 877.

16 R. W. Alder, *Acc. Chem. Res.*, 1983, **16**, 321.

17 R. W. Alder, P. Eastment, R. E. Moss, R. B. Sessions, and M. A. Stringfellow, *Tetrahedron Lett.*, 1982, **23**, 4181.