

Functionalized Thia-crown Ethers. Synthesis, Structure, and Properties

J. Buter,^a Richard M. Kellogg,^{a*} and F. van Bolhuis^b

^a Department of Organic Chemistry, University of Groningen, Nijenborgh 16, 9747 AG Groningen, The Netherlands

^b Crystal Structure Center, Department of Chemistry, University of Groningen, Nijenborgh 16, 9747 AG Groningen, The Netherlands

A caesium promoted synthesis of thia-crown ethers containing isobutenyl units in the periphery is described, including structural data and a method involving diborane for functionalization of the methylene group.

The strategy for the synthesis of thia-macrocycles depicted in equation (1) is known to give excellent results when the metal cation used is caesium and dimethylformamide (DMF) is used as the solvent.¹ This approach has now been extended to the use of (1)² as a source of isobutenyl units for the macrocyclic

backbone. Herein, we describe examples of the scope, structural data, and an approach for further functionalization of the *exo*-methylene group, together with comments on an unusual property of the derived products.

The synthesis of (3) [equation (2)] is illustrative. A solution

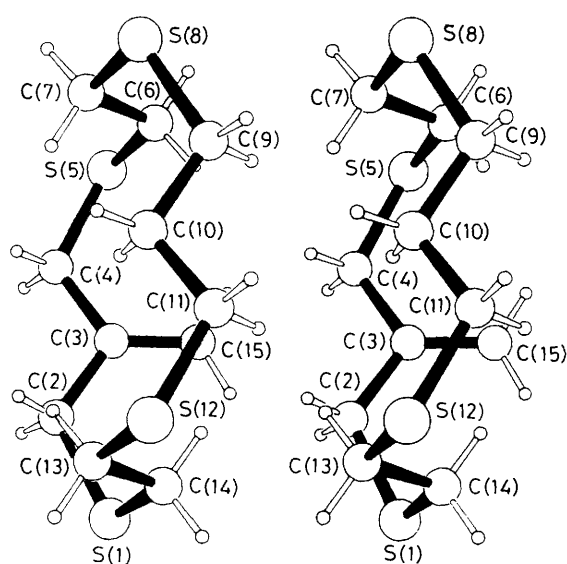
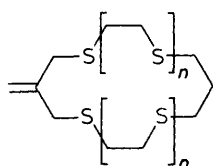
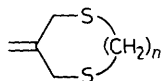


Figure 1. Crystal structure of 3-methylene-1,5,8,12-tetrathia-cyclo-tetradecane (**4a**). Important bond distances (Å) and bond angles (°): S(1)–C(2) 1.809(3), S(1)–C(14) 1.821(4), S(5)–C(4) 1.807(3), S(5)–C(6) 1.820(4), S(8)–C(7) 1.820(4), S(8)–C(9) 1.812(3), S(12)–C(11) 1.815(3), S(12)–C(13) 1.818(4), C(2)–C(3) 1.512(4), C(3)–C(4) 1.517(4), C(3)–C(15) 1.322(4), C(6)–C(7) 1.521(4), C(9)–C(10) 1.525(4), C(10)–C(11) 1.527(4), C(13)–C(14) 1.521(4); C(2)–S(1)–C(14) 102.7(2), C(4)–S(5)–C(6) 102.2(1), C(7)–S(8)–C(9) 102.5(2), C(11)–S(12)–C(13) 102.5(1), S(1)–C(2)–C(3) 119.2(2), C(2)–C(3)–C(4) 110.7(2), C(2)–C(3)–C(15) 124.6(3), S(5)–C(4)–C(3) 118.6(2), C(9)–C(10)–C(11) 109.9(3), S(1)–C(14)–C(13) 113.4(2).



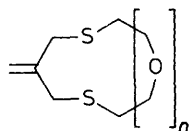
(4)

a; $n = 1$ (100%)
b; $n = 2$ (85%)



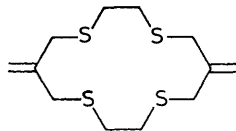
(5)

a; $n = 5$ (60%)
b; $n = 10$ (87%)
c; $n = 12$ (75%)
d; $n = 16$ (60%)



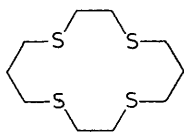
(6)

a; $n = 1$ (52%)
b; $n = 2$ (72%)

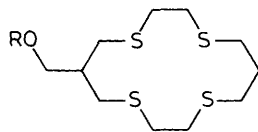


(7)

(70%)

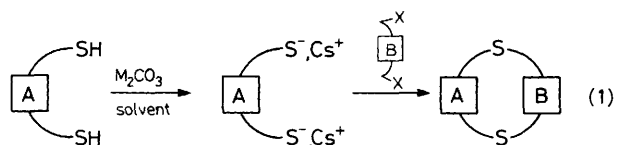


(8)

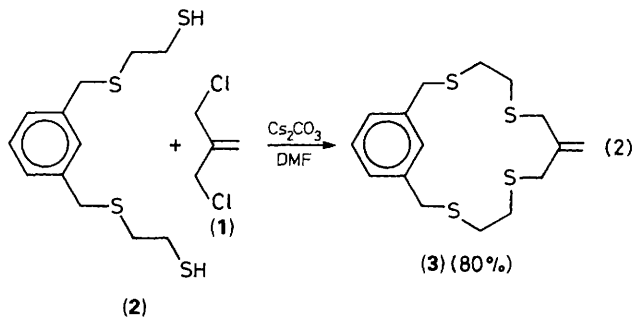


(9)

a; R = H
b; R = MeCO



(1)



(2)

(3) (80%)

of (**1**) and (**2**) (1.6×10^{-2} M in DMF) is added to Cs_2CO_3 in DMF (1.8×10^{-2} M suspension) at 55–60 °C over a period of 6–9 h. Compounds (**5a–d**), (**6a,b**), and (**7**) were prepared in the indicated yields using this technique. The effect of cations other than caesium has not been investigated in any detail for the present examples.¹

The solid state structure of compound (**4a**), m.p. 41–42 °C, is illustrated in Figure 1.† The four sulphur atoms lie almost exactly in a plane to which the plane C(2)–C(3)–C(15)–C(4) containing the methylene groups is nearly perpendicular (85.6°). In good accord with the predictions of Cooper *et al.*,³ as well as the previously determined structure of (**8**), the non-methylene containing analogue of (**4a**),⁴ the carbon substituents attached to each sulphur–carbon segment are arranged *gauche*, resulting in exodentate placement of the sulphur atoms.

Further functionalization of the methylene groups was envisaged *via* borane chemistry,⁵ the simplest case being the anti-Markovnikov addition of water. We hoped that the known strong complexation of BH_3 with sulphides⁶ might be used to protect these linkages from oxidation during work-up of the organoborane with hydrogen peroxide. Assessment of the interaction of BH_3 with thia-macrocycles is first necessary. Macrocyclic (**8**), devoid of alkene functionality, was found to form a solid complex with BH_3 , generated from $\text{NaBH}_4/\text{BF}_3 \cdot (\text{Et})_2\text{O}$ in tetrahydrofuran (THF). This complex is free of THF, has complex stoichiometry (approximately 3 borons per macrocycle), and reverts to (**8**) on treatment with acetone or cyclohexene. In sharp contrast to the dimethylsulphide

† Crystal data for (**4a**): $\text{C}_{11}\text{H}_{20}\text{S}_4$, $M = 280.55$, triclinic, space group $P\bar{1}$, $a = 8.075(1)$, $b = 9.862(1)$, $c = 9.761(1)$ Å, $\alpha = 92.70(1)$, $\beta = 107.10(1)$, $\gamma = 112.16(1)^\circ$, $U = 677.0$ Å³, $Z = 2$, $D_c = 1.376$ g cm⁻³, Mo- K_α radiation; 2944 reflections $1^\circ \leq \theta \leq 27^\circ$, 2548 reflections had intensities >3 standard deviation and were used in data refinement carried out on an Enraf-Nonius CAD-4 diffractometer. The structure determination was carried out at 130 K. Scaling factors, Lorentz, and polarization corrections were applied to the data. The structure was solved by direct methods. The positions of the hydrogen atoms were revealed from a single Fourier difference map. The final residuals were $R = 0.032$ and $R_w = 0.046$. Atomic co-ordinates, bond lengths and angles, and thermal parameters have been deposited at the Cambridge Crystallographic Data Centre. See Notice to Authors, Issue No. 1.

complex of BH_3 ,⁶ this material is completely stable in air. Open-chain analogues of (8) (not illustrated) fail to provide such stable and THF free materials. A macrocyclic effect appears to stabilize this complex of borane with (8).

Hydroboration of test compound (4a) with BH_3 generated as described followed by oxidation with H_2O_2 and thereafter acetylation affords (9b) in 80% yield. The organoborane intermediate is also remarkably stable and is converted to alcohol (9a) only slowly but very cleanly with no observable oxidation of the sulphide linkages.

The properties of alcohol (9a) are unusual. It is moderately soluble in water (*ca.* 5×10^{-2} M) whereas neither (4a) nor (8) is observably soluble. The corresponding Cu^{II} complex has a solubility of *ca.* 2.5×10^{-4} M, 25 times the solubility of the Cu^{II} complex of (8). Open chain analogues of (8) and the Cu^{II} complexes thereof are barely soluble. These observations extend the experience of Rorabacher *et al.*,⁷ and indicate that moderate solubility in water may be a more general characteristic of alcohol bearing thia-crown ethers. This could be of practical importance in the extraction of heavy metal ions from aqueous solutions.

We are grateful to Mr. J. Freriks and Mr. R. Heetebrij for experimental assistance.

Received, 18th July 1989; Com. 9/03032H

References

- 1 J. Buter and R. M. Kellogg, *Org. Synth.*, 1987, **65**, 150, and references cited therein; S. R. Cooper, *Acc. Chem. Res.*, 1988, **21**, 141.
- 2 K. Schulze, E.-M. Dietrich, and M. Muehlstaedt, *Z. Chem.*, 1975, **15**, 302.
- 3 R. E. Wolf, Jr., J. R. Hartman, J. M. E. Storey, B. M. Foxman, and S. R. Cooper, *J. Am. Chem. Soc.*, 1987, **109**, 4328.
- 4 R. E. De Simone and M. D. Glick, *J. Am. Chem. Soc.*, 1976, **98**, 762.
- 5 A. Pelter, K. Smith, and H. C. Brown, 'Borane Reagents,' Academic Press, London, 1988.
- 6 For example: H. C. Brown and N. Ravindran, *Inorg. Chem.*, 1977, **16**, 2938.
- 7 V. B. Pett, G. H. Leggett, T. H. Cooper, P. R. Reed, D. Situmeang, L. A. Ochrymowycz, and D. B. Rorabacher, *Inorg. Chem.*, 1988, **27**, 2164.