Synthesis, Complexation Behaviour and Reactions of Thia-crown Ethers Incorporating Propan-2-one Units

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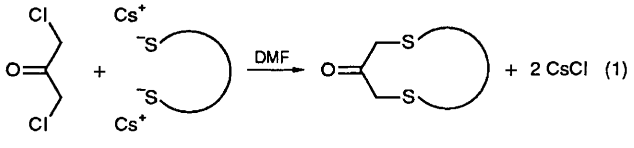
Thia-crown ethers containing ketone functionality derived from 1,3-dichloroacetone have been prepared in 70–80% yields; the crystal structures of one free macrocycle and two Ag^I complexes have been determined.

Macrocyclic sulphides in general, and thia-crown ethers in particular, are compounds of increased interest, both for their properties and the realization in recent years that they can be made without undue difficulty. The unique complexing abilities of thia-crown ethers and the profound differences with the oxygen and aza counterparts have been documented.[1] The design of thia-crown ethers to achieve properties predicted ahead of experiment will require techniques to *functionalize* the periphery of the macrocyclic skeleton. We report here a method to introduce keto groups.

Various long chain dithiolates **2** react cleanly with 1,3-dichloroacetone **1** to form macrocyclic sulphides, 'thia-crown ethers', **3** as illustrated in eqn. 1. Complications from enolization and/or attack on the carbonyl group of **1** have not been encountered.[2]† Specific examples of compounds that



1 **2** **3**

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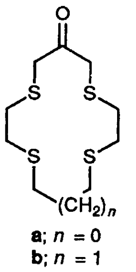
† The preparation of 1,4,7-trithiacyclodecan-9-one in 18% yield has been reported in ref. 2. We are unaware of other examples of keto-substituted thia-crown ethers.

have been prepared are **4–9**.† Reactions have been carried out on a 10 mmol scale and the yields of analytically and spectroscopically pure materials are between 70–80%.‡ The routes *via* the caesium salts of dithiols to the assembly of the various bridges, including the isobutenyl segment in **5**, have been described previously.[2] Compound **4b** was prepared in equally good yield using Na_2CO_3 in dimethylformamide (DMF) rather than Cs_2CO_3. Whether Cs_2CO_3 can be replaced by Na_2CO_3 or K_2CO_3 in all cases is not known, although past experience would suggest that this is not so.[4]

In thia-crown ethers there is often a pronounced tendency to place the sulphurs exodentate to the macrocyclic ring.[1,5] In the 13-membered ring of **4a** the sulphides of the $-SCH_2CH_2S-$ units are indeed arranged *anti* and, as a consequence, exodentate (Fig. 1). The sulphur atoms S(1), S(5), S(8) and S(12) together with C(3) lie almost exactly in a common plane. The dihedral angle between the planes S(1)–S(5)–S(8)–S(12) and C(2)–C(3)–C(4)–O(15) is 102.4(9)°; the C(3)–O(15) carbonyl bond is therefore roughly perpendicular to the remaining macrocyclic framework. Selected bond angles and lengths are given.§



a; $n = 0$
b; $n = 1$
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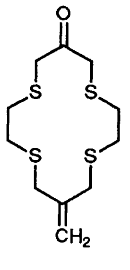

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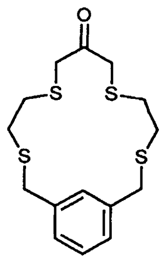

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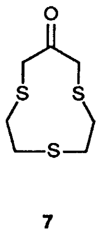

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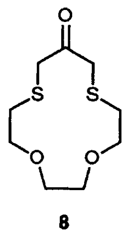

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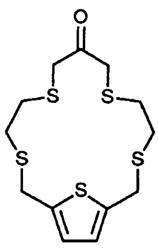

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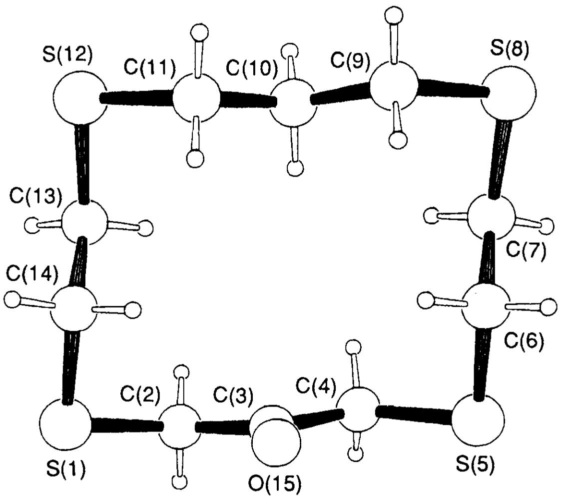

Fig. 1 Crystal structure of 3-oxo-1,5,8,11-tetrathiacyclo-tridecane **4a**. Representative bond distances (Å) and bond angles (°): S(1)–C(2) 1.799(6), S(1)–C(14) 1.829(5), S(8)–C(7) 1.829(5), S(8)–C(9) 1.816(5), O(15)–C(3) 1.210(6); C(2)–S(1)–C(14), 101.3(3), C(7)–S(8)–C(9) 102.4(2), C(11)–S(12)–C(13) 100.4(2), O(15)–C(3)–C(2) 123.0(5), C(2)–C(3)–C(4) 113.9(4), S(5)–C(4)–C(3) 116.8(3), S(5)–C(6)–C(7) 113.4(3), S(8)–C(7)–C(6) 113.3(3).

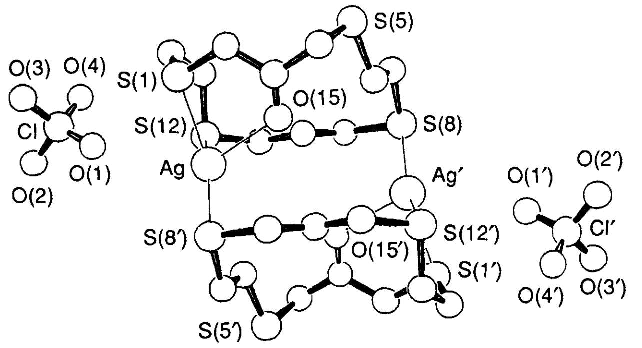

Fig. 2 Crystal structure of the $AgClO_4$ complex of 3-oxo-1,5,8,12-tetrathiacyclotetradecane **4b**. Important bond distances (Å) and bond angles (°): Ag–S(8) 2.457(1), Ag–S(1) 2.616(2), Ag–S(12) 2.510(1), Ag–O(15) 2.612(3); S(1)–Ag–S(12) 85.22(5), S(1)–Ag–O(15) 70.61(8), S(12)–Ag–O(15) 109.51(8).

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‡ Solutions of dithiol and **1**, both 1.6×10^{-2} mol dm^{-3} in dimethylformamide (DMF), were added to a 1.8×10^{-2} mol dm^{-3} suspension of Cs_2CO_3 in DMF at 55–60 °C over a period of 6–9 h. The crude products were purified by chromatography over silica gel using mixtures of CH_2Cl_2 and n-hexane as eluent. All compounds were characterized by ^1H NMR, IR, and mass spectral analyses.

§ *Crystal data* for **4a**: $C_9H_{16}S_4O$, $M = 268.49$, monoclinic, space group $P2_1$ (from MeOH–$CHCl_3$ 10:1), $a = 4.895(1)$, $b = 14.874(4)$, $c = 8.681(1)$ Å, $\beta = 98.51(1)°$, $V = 625.1$ Å^3, $D_c = 1.439$ g cm^{-3}, $Z = 2$, Mo-Kα radiation at room temp. using an Enraf-Nonius CAD-4 diffractometer, 2234 reflections $1° \leq \theta \leq 32°$, 1624 reflections had intensities ≥ 3.0 standard deviations and were used in the final refinement. The structure was partly solved by direct methods. The remaining atoms, including H-atoms, were revealed from succeeding Fourier syntheses. Scaling factors, Lorentz, and polarization correction were applied. Block-diagonal least-squares analysis of F, with unit weights, converged to $R = 0.038$ and $R_w = 0.044$. The indicated structure provides a better fit than the enantiomorph thereof.

For **4b**.$AgClO_4$: $C_{10}H_{18}S_4O_5AgCl$, $M = 489.83$, monoclinic, space group $P2_1/n$ (from CH_2Cl_2–MeCN), $a = 10.019(1)$, $b = 9.478(1)$, $c = 17.560(1)$ Å, $\beta = 94.88(1)°$, $V = 1661.5$ Å^3, $D_c = 1.958$ g cm^{-3}, $Z = 4$, Mo-Kα radiation at 293 K, 3613 reflections $1° \leq \theta \leq 27°$, 2473 reflections had intensities > 3.0 standard deviations and were used in the final refinement. The structure was partly solved by direct methods. The remaining atoms were revealed in succeeding Fourier syntheses. Scaling factors, Lorentz, and polarization corrections were applied. Block-diagonal least-squares analysis of F, with unit weights, converged to $R = 0.035$ and $R_w = 0.038$, respectively, using anisotropic temperature factors for the non-hydrogen atoms and isotropic fixed thermal parameters ($B = 0.5$ Å^2) for the hydrogen atoms.

For **4b**·AgO_3SCF_3: $C_{11}H_{18}F_3O_4S_5Ag$, $M = 539, 45$, orthorhombic, space group $P2_12_12_1$ (from CH_2Cl_2–MeCN), $a = 8.258(6)$, $b = 14.371(4)$, $c = 16.189(3)$ Å, $\alpha = \beta = \gamma = 90.0°$, $V = 1921.2$ Å^3, $D_c = 1.865$ g cm^{-3}, $Z = 4$, Mo-Kα radiation at 293 °K, 3147 reflections $1° \leq \theta \leq 30°$, 2544 reflections had intensities > 3.0 standard deviations and were used in the final refinement. The structure was partly solved by direct methods. The remaining non-H atoms were revealed from succeeding Fourier syntheses. The remaining H-atoms were calculated using a distance of 0.96 Å. Scaling factors, Lorentz, and polarization corrections were applied. Block-diagonal least-squares analysis of F, with unit weights, converged to $R = 0.047$ and $R_w = 0.052$, respectively, using anisotropic temperature parameters for the non-hydrogen atoms. For the atoms C(15), F, and H isotropic thermal parameters were used whereas for the H-atoms a fixed value was taken with $B = 5.0$ Å^2. The structure has as a result of disorder a (*pseudo*) two-fold axis perpendicular to the plane through the S-atoms. This results in a 0.5 occupancy of O(3) and O(15) and C(3) and C(10), respectively.

Atomic coordinates, bond lengths, bond angles, and thermal parameters have been deposited at the Cambridge Crystallographic Data Centre. See Notice to Authors, Issue No. 1.

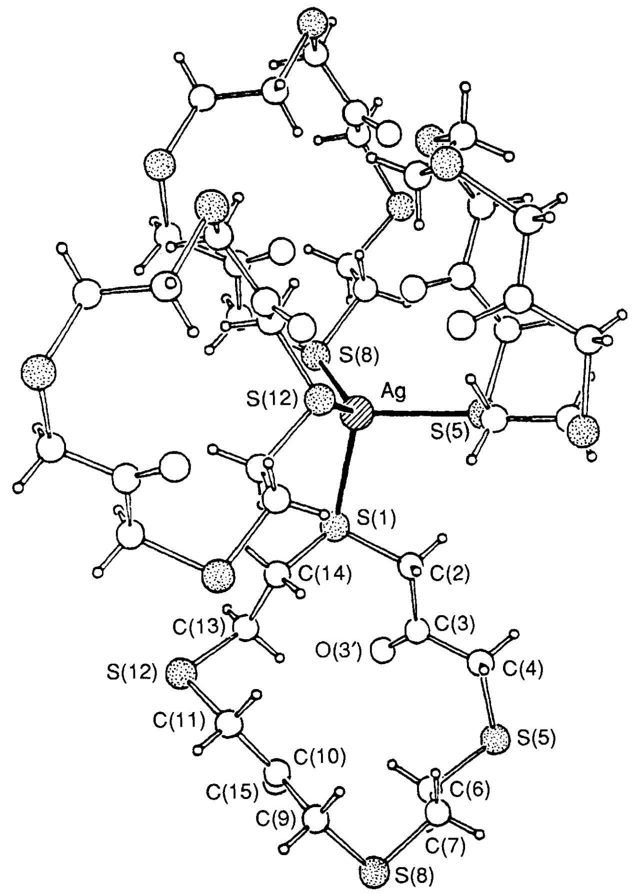

Fig. 3 Crystal structure of the AgO_3SCF_3 complex of 3-oxo-1,5,8,12-tetrathiacyclotetradecane **4b**. The anion is not illustrated for reasons of clarity. Important bond distances (Å) and bond angles (°): Ag–S(1) 2.641(2), Ag–S(5) 2.591(1), Ag–S(8) 2.573(2), Ag–S(12) 2.662(2), Ag–O(3') 2.985(15), S(1)–C(2) 1.807(9); S(1)–Ag–S(5) 96.63(7), S(1)–Ag–S(8) 118.72(7), S(1)–Ag–S(12) 104.51(7), S(5)–Ag–S(8) 129.01(7), S(5)–Ag–S(12) 117.38(7), S(8)–Ag–S(12) 89.55(7).

Some indications of conformational reorganization on complexation are apparent in $AgClO_4$ complex of **4b** (trimethylene bridge) although the Ag ions remain exterior to the macrocyclic ring. A dimeric structure is formed in which the two Ag ions are tetracoordinated by three sulphurs and one keto oxygen as shown in Fig. 2. One sulphur (S12,12') in each ring is turned into the ring to coordinate with Ag ion. The dihedral angle between the planes S(1)–S(5)–S(8)–S(12) and C(3)–O(15) is 38.1(9)° indicative of a severe inward turning of the carbonyl group on complexation. The torsion angle about S(12)–C(13)–C(14)–S(1) changes from nearly *anti* in uncomplexed **4a** [S(11)–C(12)–C(13)–S(1) torsion angles 179.0°] to essentially *gauche* in the complex of **4b** [S(12)–C(13)–C(14)–S(1) torsion angle 51.4°]. Selected bond distances and angles are listed.§

Change of anion leads, however, to a totally different structure. In the 1 : 1 complex of **4b** with AgO_3SCF_3 each Ag ion is coordinated by four different sulphurs from four different macrocycles as illustrated by the partial structure in Fig. 3. The total crystal structure is built up from these repeating clusters to give a tetrahedrally connected network. The cavities between the clusters are filled with $CF_3SO_3^-$ ions the oxygens of which (O2) are oriented towards to Ag^+ ion. The Ag–S distances range between 2.591 and 2.662 Å. The structure is disordered leading to a 50 : 50 distribution of carbonyl oxygens between the positions C(3) and C(10). There is relatively little conformational reorganization of the macrocycle, compared to its uncomplexed structure. It is interesting to note that the complex (1,4,7-trithiacyclodecan-9-one)$_2$Ni$(BF_4)_2$ also does not involve oxygen complexation to the metal ion.[2]

The presence of keto groups in the periphery of the ring opens a route to functionalization of thia-crown ethers. Reaction of, for example, **4** with amines and hydrazine proceeds normally. McMurry couplings have thus far been sluggish. Mannich condensations [CH_2O, $(Me)_2NH$] with the activated methylene groups of **4b** proceed readily thereby opening chemical perspectives that are under investigation.

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References

1 S. R. Cooper and S. C. Rawle, *Struct. and Bonding (Berlin)*, 1990, **72**, 3 and references cited therein.
2 W. N. Setzer, E. L. Cacioppo, Q. Guo, G. J. Grant, D. D. Kim, J. L. Hubbard and D. G. VanDerveer, *Inorg. Chem.*, 1990, **29**, 2672.
3 J. Buter, R. M. Kellogg and F. van Bolhuis, *J. Chem. Soc., Chem. Commun.*, 1990, 282; J. Buter and R. M. Kellogg, *Org. Synth.*, 1987, **65**, 150.
4 G. D. H. Dijkstra and R. M. Kellogg, *J. Org. Chem.*, 1987, **52**, 4230.
5 See also: C. R. Lucas, S. Liu, M. J. Newlands, J.-P. Charland and E. J. Gabee, *Can. J. Chem.*, 1990, **68**, 644; B. de Groot and S. J. Loeb, *Inorg. Chem.*, 1990, **29**, 4084.