

Complexes of Crown Ethers and Neutral Molecules; Synthesis and Crystal Structure of a Urea 18-Crown-6 (5:1) Complex

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Summary In the crystal structure of urea 18-crown-6 (5:1) the macrocyclic polyether binds to two urea molecules by N-H...O hydrogen bonds to two adjacent oxygen atoms of the crown ethers; the remaining urea molecules form hydrogen bonded layers, alternating with layers of urea-crown ether complexes.

PEDERSEN in his second paper on macrocyclic polyethers described several crystalline adducts with thiourea.¹ The ratio of thiourea to polyether varied between 1:3 and 6:1,

but the nature of the bonding between host and guest was not further investigated. Attempts to prepare the corresponding crystalline complexes of urea with macrocyclic polyethers were without success.

X-Ray crystallographic studies of complexes of linear polyethers and thiourea^{2,3} reveal that hydrogen bonding plays an important role in the bonding between host and guest.

We are involved in the synthesis of macrocyclic receptors for small molecules and in particular of those that can bind

urea selectively.† In order to obtain information on the nature of the interaction between urea and macrocyclic polyethers, required for a direct synthesis of such receptor molecules, we have prepared a molecular complex of 18-crown-6 (1,4,7,10,13,16-hexaoxacyclo-octadecane) and urea.⁴

A molecular complex of urea and 18-crown-6 (5:1) was prepared by addition of diethyl ether to a homogeneous solution of 264 mg of 18-crown-6 and 90 mg of urea in methanol-chloroform (1:2). Subsequent crystallization of the precipitate from methanol-ethyl acetate yielded the analytically pure 5:1 complex, m.p. 148–150 °C.‡

The crystal structure of the complex at 148 K was determined by X-ray crystallography.

Crystal data: C₁₇H₄₄N₁₀O₁₁, monoclinic, space group *P*2₁/*c*, *a* = 17.868(1), *b* = 8.307(1), *c* = 20.696(3) Å, β = 108.58(1)°, *Z* = 4, *D*_c = 1.29 g cm⁻³. 5154 reflexions with *I* > σ(*I*) (counting statistics) were measured using the ω–2θ scan mode (6 < 2θ < 60°) on a Philips PW1100 diffractometer with graphite-monochromated Mo-*K*_α radiation.

The structure was solved by direct methods⁵ and refined by least-squares methods to a final weighted *R*-factor of 3.9% (anisotropic thermal parameters for non-hydrogen atoms, isotropic for hydrogen; total number of parameters refined: 520).§

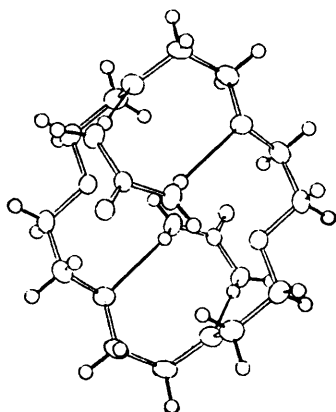


FIGURE. View of one of the 18-crown-6 molecules with the urea molecules belonging to it. The hydrogen bonds between urea molecules and crown ether ring are indicated.

† Such compound would be of practical importance for the selective removal of urea in dialysis and could be used as a substituent for the enzyme urease.

‡ Satisfactory elemental analysis (C,H,N) was obtained.

§ The atomic co-ordinates for this work are available on request from the Director of the Cambridge Crystallographic Data Centre, University Chemical Laboratory, Lensfield Road, Cambridge CB2 1EW. Any request should be accompanied by the full literature citation for this communication.

¹ C. J. Pedersen, *J. Org. Chem.*, 1971, **36**, 1690.

² I. H. Suh and W. Saenger, *Angew. Chem.*, 1978, **90**, 565.

³ G. Weber and W. Saenger, *Acta Crystallogr., Sect. B*, 1980, **36**, 424.

⁴ Complexes of linear polyethers and hexakis(acetylphenoxymethylbenzene) (octopus molecules) with thiourea and (*N*-alkyl)urea have been reported: W. Rasshofer and F. Vögtle, *Tetrahedron Lett.*, 1978, 309; E. Weber, W. M. Muller, and F. Vögtle, *ibid.*, 1979, 2335; F. Vögtle, G. Oepen, and W. Rasshofer, *Liebigs Ann. Chem.*, 1979, 1577; G. Oepen and F. Vögtle, *ibid.*, p. 2114; U. Heimann and F. Vögtle, *Chem. Ber.*, 1979, **112**, 3034; G. Oepen and F. Vögtle, *Liebigs Ann. Chem.*, 1980, 512.

⁵ G. Germain, P. Main, and M. M. Woolfson, *Acta Crystallogr., Sect. A*, 1971, **27**, 368.

⁶ A. Knöchel, J. Kopf, J. Oehler, and G. Rudolph, *J. Chem. Soc., Chem. Commun.*, 1978, 595.

⁷ For reviews see: J. Dale, *Israel J. Chem.*, 1980, **20**, 3; M. Bovill, D. J. Chadwick, I. O. Sutherland, and D. Watkin, *J. Chem. Soc., Perkin Trans. 2*, 1980, 1529.

The crystal structure contains two crystallographically different rings, both containing a centre of symmetry. The urea molecules in the structure can be divided into two different types. The first one consists of urea molecules not bonded to the crown ether molecules. These urea molecules are arranged in layers held together by a two-dimensional hydrogen bonding network. The urea molecules of the second type are bonded to crown ether molecules by means of two N–H···O bonds to adjacent oxygen atoms of the ring. One of the two independent rings is depicted in the Figure, together with the urea molecules attached to it. The geometry of the second ring is very similar. By virtue of the centre of symmetry each crown ether ring is connected to two urea molecules. The lengths of the four independent N–H···O hydrogen bonds between urea and macrocyclic ether molecules are 2.848(3) and 3.282(3) Å for the first ring and 3.214(3) and 2.893(3) Å for the second one: values within the range normally found for N–H···O hydrogen bonds. The structure can be described in terms of alternating layers of urea–crown ether complexes and urea molecules. The urea layers contain the oxygen atoms of the crown ether bonded urea molecules, which act as acceptors of some hydrogen bonds in the layers. The hydrogen atoms of the ‘crown ether’ urea molecules not involved in hydrogen bonding to the rings form hydrogen bonds to oxygen atoms in the urea planes.

The sequence of torsion angles (O–C, C–C, C–O, *etc.*) for the independent parts of the rings is: ag⁺a ag⁺a g⁺g⁺a (ring 1: 172.3, 64.9, 170.9, 179.7, 66.7, –176.9, 61.2, 59.3, –170.2°; ring 2: 173.1, 62.0, 173.6, –178.7, 62.8, –179.3, 60.4, 63.2, –171.1°). The shortest hydrogen bond is to the oxygen atom with the ag⁺ torsion angles.

The conformation of the rings found here is similar to the one found in the adduct of 18-crown-6 and benzenesulphonamide (1:2),⁶ which has a completely different hydrogen bonding scheme. The fact that, despite considerable differences in host–guest interaction, the same conformation is found, supports the view that only a small number of conformations is available for complexed 18-crown-6 molecules in the solid state.⁷

The urea 18-crown-6 complex described here represents the first example of the structure determination of a urea molecule bonded to a macrocyclic ether. The results demonstrate the potential importance of hydrogen bonds in the design of synthetic receptors for urea-like molecules.

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