

### 173. The Conformation of 1,6-Diaza-2,7-cyclodecadione in Solution

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#### Summary

From  $^1\text{H}$ - and  $^{13}\text{C}$ -NMR. data, a crown conformation with *trans* amide bonds is deduced for 1,6-diaza-2,7-cyclodecadione (**1**) in solution. Compound **1** was obtained by reaction of 2-pyrrolidone with  $\text{POCl}_3$ .

**Introduction.** – The conformations of medium-ring lactams have been thoroughly investigated by X-ray analysis ([1] and ref. therein) and IR. spectroscopy [2]. A preliminary investigation of 1,6-diaza-2,7-cyclodecadione (**1**) [3] was reported by *Srikrishnan & Dunitz* [1] with the X-ray analysis of 1,5-diaza-6,10-cyclodecadione indicating that **1** possesses a center of symmetry and that the amide groups are *trans*. 'The poor quality of the crystals' prevented, however, a detailed analysis [1]. We recorded the  $^{13}\text{C}$ -NMR. spectrum of **1** in continuation of our studies of the  $^{13}\text{C}$ -NMR. spectra of simple amides [4], since **1** was available by reaction of 2-pyrrolidone with  $\text{POCl}_3$ . While the  $^{13}\text{C}$ -NMR. spectrum showed only the four expected signals, the  $^1\text{H}$ -NMR. spectrum contained seven different signals indicating that ring inversion is slow on the NMR. time scale. This allowed us to determine the proton chemical shifts and coupling constants, and to deduce the conformation of **1** in solution.

**Results and discussion.** – The  $^{13}\text{C}$ -NMR. data are in *Table 1*. The assignment of C(2) and C(4) is straightforward. C(3) and C(5) were distinguished by their

Table 1.  $^{13}\text{C}$ -Chemical shifts of medium-ring lactams

Compound	C(2) (CO)	C(3) (Ca to CO)	C(4)	C(5) (CatoN)	Solvent
<b>1</b>	173.6	34.8	26.0	38.5	( $\text{D}_6$ )DMSO <sup>a)</sup>
	176.7	35.8	26.9	39.8	95% ( $\text{D}_6$ )EtOH
<i>trans</i> -1-Aza-2-nonanone [5]	175.9	37.4		39.3	95% EtOH
<i>cis</i> -1-Aza-2-nonanone [5]	177.5	32.2		42.5	95% EtOH
<i>trans</i> -1-Aza-2-tridecanone [5]	174.1	36.6		39.1	95% EtOH

<sup>a)</sup> At 305 K. The  $^1\text{H}$ -NMR. spectrum shows ring inversion to be still slow at this temperature (same solvent): 7.30 (H–N(6)); 3.80 (H<sub>ax</sub>–C(5)); 2.69 (H<sub>eq</sub>–C(5)); 1.60–2.10 (H–C(3) + H–C(4), one  $\text{CH}_2$  group above  $T_c$ , the other near  $T_c$ ). The proton-decoupled spectra do not show exchange broadening, demonstrating a degenerate conformational interconversion.

$^1J(\text{C}, \text{H})$ , estimated from the proton-coupled spectra (*ca.* 130, 130 and 137 Hz for C(3), C(4) and C(5) respectively in  $(\text{D}_6)\text{DMSO}$ ). A comparison of the chemical shifts of C(3) and C(5) with those of the analogous C-atoms in *cis*- and *trans*-lactams of similar ring size ([5], *cf.* Table 1) shows that the amide groups are *trans*. The largest difference between *cis*- and *trans*-isomers is found in the  $\text{CH}_2$ -group *a* to CO, where the *syn*- $\gamma$ -effect of the  $\text{N}-\text{CH}_2$ -group results in a resonance at higher field in the *cis*-isomer. The smaller *syn*- $\gamma$ -effect exerted by the  $\text{CH}_2$ -group *a* to CO upon the  $\text{NCH}_2$ -group as compared with that exerted by the CO-group [6] can also be used to distinguish the isomers.

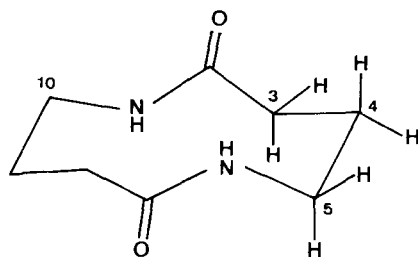
The  $^1\text{H-NMR}$ . data in Table 2 were measured in  $\text{CDCl}_3$  at 250 MHz and 273 K. Under these conditions, ring inversion is slow on the NMR. time scale (the barrier is estimated to be  $\Delta G^\ddagger = 70$  kJ/mol at the coalescence temperature ( $T_c$ ) of 345 K in  $\text{CDBr}_3$ ), and seven different chemical shifts were observed. Therefore, an element of symmetry is present below  $T_c$ . The assignments of the protons are based on decoupling experiments.

Table 2.  $^1\text{H-NMR}$ . data of **1** in  $\text{CDCl}_3$  at 273 K<sup>a)</sup>

	$\text{H}_{\text{ax}}-\text{C}(3)$	$\text{H}_{\text{eq}}-\text{C}(3)$	$\text{H}_{\text{ax}}-\text{C}(4)$	$\text{H}_{\text{eq}}-\text{C}(4)$	$\text{H}_{\text{ax}}-\text{C}(5)$	$\text{H}_{\text{eq}}-\text{C}(5)$	$\text{H}-\text{N}(6)$
$\delta$	2.00	2.35	2.18	1.80	4.12	2.93	5.72
$^2J$	13	13	14	14	14	14	
$^3J$	12 ( $4_{\text{ax}}$ ) 2 ( $4_{\text{eq}}$ )	2.5 ( $4_{\text{ax}}$ ) 6 ( $4_{\text{eq}}$ )	12 ( $3_{\text{ax}}$ ) 2.5 ( $3_{\text{eq}}$ ) 13 ( $5_{\text{ax}}$ ) 3 ( $5_{\text{eq}}$ )	2 ( $3_{\text{ax}}$ ) 6 ( $3_{\text{eq}}$ ) 3.5 ( $5_{\text{ax}}$ ) 3 ( $5_{\text{eq}}$ )	13 ( $4_{\text{ax}}$ ) 3.5 ( $4_{\text{eq}}$ ) 11 (6)		11 ( $5_{\text{ax}}$ )
$^4J$		1 ( $5_{\text{eq}}$ )					

a) Well below  $T_c$  for all  $\text{CH}_2$ -groups. The remaining line broadening limits the accuracy of the coupling constants to  $\pm 0.5$  Hz.

On the basis of the data, a chain of three  $\text{CH}_2$ -groups is present, in which one proton of the center C-atom is antiperiplanar to one proton on each terminal C-atom. One of these protons at the terminal C-atoms is in turn antiperiplanar to the proton at the N-atom and the other antiperiplanar to the CO-group. This five atom segment must appear twice in the molecule from the symmetry of the  $^1\text{H-NMR}$ . spectrum. The  $^{13}\text{C-NMR}$ . data require that the two segments are joined in such a fashion that *trans*-amide bonds are formed. The resulting conformation is the crown conformation of the cyclodecanering.



A detailed argument for the conformation of the five atom segment is given below:  $H_{ax}-C(3)$  and  $H_{ax}-C(4)$ ,  $H_{ax}-C(4)$  and  $H_{ax}-C(5)$  as well as  $H_{ax}-C(5)$  and  $H-N(6)$  are antiperiplanar as shown by their large vicinal coupling constant (12, 13 and 11 Hz respectively).  $H_{ax}-C(10)$  ( $\sim H_{ax}-C(5)$ ) is strongly deshielded with respect to its equatorial counterpart and the same is true to a lesser degree for  $H_{ax}-C(4)$  relative to  $H_{eq}-C(4)$ . These deshieldings show that the CO-group occupies a *syn*-axial position to  $H_{ax}-C(10)$  and  $H_{ax}-C(4)$ , since downfield shifts in similar orientations relative to the amide CO-group are well documented [7]. The axial position of the CO-group is in agreement with the observation that the geminal coupling of  $H-C(3)$  is only 13 Hz, *i.e.* there is no  $\pi$ -contribution of the adjacent C=O-bond [8] (*cf.*  $^2J = -12.6$  Hz in cyclohexane). This requires an angle of *ca.*  $90^\circ$  between the  $\pi$ -lobes of the double bond and one of the protons of the methylene group in 3-position, an angle which exists in a *trans*-diaxial arrangement of CO-group and  $H_{ax}-C(3)$ . The proton chemical shifts exclude the energetically very unfavourable boat-chair-boat (BCB) conformation with *trans* amide bonds, since  $H_{ax}-C(3)$  would then be deshielded by the CO-group compared with  $H_{eq}-C(3)$ , which is not the case, and the strong deshielding of  $H_{ax}-C(5)$  would not be explained. Furthermore,  $H_{ax}-C(5)$ , which should occupy a *syn*-periplanar position with respect to  $H-N(6)$  in the BCB-conformation, would show a much smaller coupling constant with this proton than 11 Hz [9].

The crown conformation contains a planar W-arrangement of bonds between  $H_{eq}-C(3)$  and  $H_{eq}-C(5)$ . This is a very favourable arrangement for a four-bond coupling which is indeed observed. The vicinal coupling between  $H_{eq}-C(3)$  and  $H_{eq}-C(4)$  is 6 Hz indicating a torsion angle of significantly less than  $60^\circ$ , which shows that  $H_{ax}-C(3)$  is slightly tilted towards the center of the ring in deviation from a perfect antiperiplanar arrangement. This means that the more circular crown conformation is preferred over the similar all-chair conformation. Such a crown conformation was shown for the isomeric 1,5-diaza-6,10-cyclodecadione in the solid state [1] as well as for a derivative of (1E,6E)-1,6-cyclodecadiene both in the solid state and in solution [10].

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### Experimental Part

The NMR. spectra were recorded with a Bruker WM250 and a Varian XL 100 spectrometer. We obtained **1** (*cf.* [3]) by refluxing 38 ml 2-pyrrolidone (0.5M) and 35 ml  $POCl_3$  (0.375M) in 375 ml toluene for 3 days. The mixture was concentrated, poured onto ice and neutralized with  $NaHCO_3$ . Compound **1** was isolated by continuous extraction with  $CH_2Cl_2$ . Yield 3.25 g (7.7%, *m.p.* after sublimation  $347^\circ$  (dec.), measured by differential scanning calorimetry). The identity of the material was established by elemental analysis, molecular weight determination and mass spectrometry.

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