Dynamic Nuclear Magnetic Resonance Spectroscopic Studies of (2.2.1)-Cryptand Incorporating a Pinacol Unit*

MAREK PIETRASZKIEWICZ
Institute of Physical Chemistry, Polish Academy of Sciences, 01224 Warszawa, Kasprzaka 44/52, Poland

Abstract. The conformational behaviour of the (2.2.1)-cryptand framework has been studied by VT ^{1}H and ^{13}C NMR spectroscopy, revealing a remarkable rigidity of the skeleton. Low-temperature measurements indicate a slowing down of the torsional motion of the methyl groups about the C—C bond in the pinacol unit with $\Delta G^{\neq} = 46 \ kJ \ mol^{-1}$ at 228 K.

Key words. Pinacol, cryptand, dynamic NMR spectroscopy.

1. Introduction

Considerable work has been undertaken in recent years on the design and synthesis of more elaborate cryptands and the study of their complexing properties. Cryptands provide highly specific binding sites and fusing them with appropriate subunits bearing desirable properties, e.g. lipophilic, photoactive, chiral, or luminescent characteristics, leads to more sophisticated structures, whose properties are determined by their molecular design.

A combination of the cryptand binding site with a chiral unit might lead to a molecular receptor capable of discriminating between enantiomeric primary ammonium cations upon complexation.

Molecular models show that an optimal fit for the primary ammonium cations can be ensured by (2.2.1)-cryptand as a 'monofacial' binding site. The important point is that the cryptand skeleton itself should be rigid enough so that a passage of the shorter bridging unit through the main macrocyclic ring is excluded.

The conformational motion of cryptands can be followed conveniently by variable-temperature NMR measurements. Generally, three topoisomers of a cryptand can be envisaged [1, 2]: out–out, in–in, and in–out. VT ^{1}H NMR studies of (2.2.2) and (3.3.3) cryptand [3] have revealed only an averaged D_{3h} symmetry for these species down to $-125°$C. For (2.2.2) a conformational process was observed at $-125°$C with $\Delta G^{\neq} = 27.2 \ kJ \ mol^{-1}$, indicating a significant flexibility of this molecule [3].

In the case of cryptands possessing carbon bridgehead atoms only, the passage of the chain linking the bridgeheads can be envisioned. It has been demonstrated that (3.3.3)-cryptand with two carbon bridgeheads revealed noticeable rigidity [4]. The free energy of activation for the conformational process out–out⇌in–in was estimated to be 100.3 kJ mol^{-1} at $+38°$C by means of ^{13}C NMR spectroscopy.

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The aim of this work was to investigate the conformational flexibility of (2.2.1)-cryptand incorporating a pinacol unit for convenience sake, since the four methyl groups were expected to be good NMR probes.

2. Experimental

Preparation of 5,5',6,6'-tetramethyl-4,7,13,15,21-pentaoxa-1,10-diazabicyclo-[8.8.5]tri-cosane(**3**): the *bis*(*O*-ethylene-*p*-toluenesulphonyloxy)pinacol [5] (**1**) (497 mg) was added to a stirred solution of diaza-15-crown-5 (**2**) (210.7 mg) in acetonitrile (200 mL) with 1100 mg of Ag_2CO_3. Reflux with stirring was maintained for 24 h. The hot solution was filtered off and treated with a saturated ethanolic solution of H_2S (5 mL). After 1 hour Ag_2S was filtered off and the solution evaporated to dryness. The residue was dissolved in $CHCl_3$ (50 mL) and shaken with an aqueous solution of Me_4NOH (400 mg in 10 mL), washed with water and evaporated. Column chromatography was effected on alumina (BDH 1-st grade of activity, 5% MeOH in CH_2Cl_2). Yield 107.3 mg, 28%.

Elemental anal.: calc. for $C_{20}H_{40}N_2O_5$; C 61.92, H 10.37, N 7.21. Found; C 61.63, H 10.24, N 7.15.

MS (CI): 389 ($M + 1$, 100%).

^1H NMR (CH_2Cl_2, TMS, 220 MHz, ppm): 3.75–3.34 (*m*, 16H OCH_2); 2.84 (*m*, 8H, NCH_2); 2.33 (*t*, 4H, NCH_2); 1.18 and 1.15 (2*s*, 12H, $4CH_3$).

The low-temperature ^1H NMR spectra of cryptand **3** were recorded on a Perkin-Elmer P34 220 MHz spectrometer and ^{13}C NMR spectra on a Bruker WH 400 spectrometer at 100.614 MHz in CD_2Cl_2 solution with TMS as a lock and standard. The high-temperature spectra were recorded in DMSO-d_6 solution with octamethylcyclotetrasiloxane as a reference and lock.

3. Results and Discussion

The methyl groups served as NMR probes and displayed two singlets at $+20°C$ (1.18 and 1.15 ppm). On cooling the sample they coalesced at $-50°C$ into a broad singlet and finally resolved into four singlets (1.08, 1.11, 1.16 and 1.18 ppm) at $-66°C$. Further cooling did not lead to a better resolution. On the other hand, in the high-temperature spectra recorded in DMSO-d_6, no coalescence of the methyl singlets was observed, even
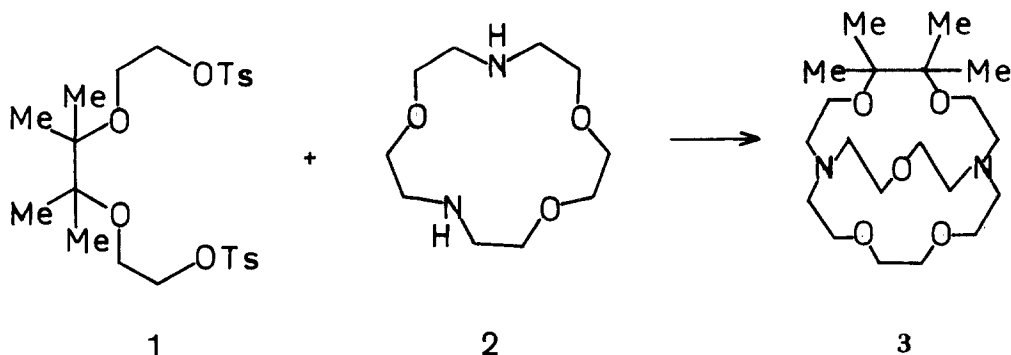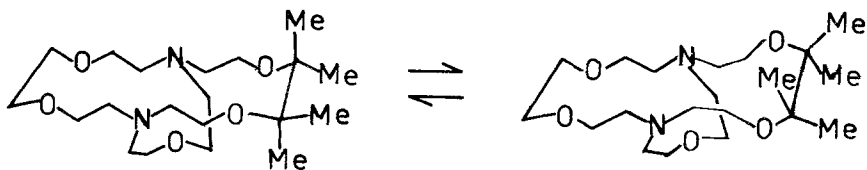

Fig. 1.

Fig. 2.

at $+120°C$. The VT ^{13}C NMR measurements were consistent with the results presented above. The four methyl groups displayed a pair of singlets at 20.231 and 19.620 ppm. At $-80°C$ there were two pairs of well-resolved singlets at 21.539, 20.536, 18.235, and 17.836 ppm. The coalescence of each pair of methyl singlets was observed at $-45°C$ as well as broadening of CH_2N signals. The rate constant for the conformational process at coalescence temperature was calculated [6] to be $122 s^{-1}$ and the free energy of activation estimated to be $46 kJ mol^{-1}$.

The interpretation of these results leads to the conclusion that the conformational process observed in the tetramethyl (2.2.1)-cryptand was the torsional motion about the C—C quaternary carbon atoms (Fig. 2).

Although another possible alternative is the passage of the $CH_2CH_2OCH_2CH_2$ unit through the 18-membered ring, this process does not seem to occur. Fast interconversion, as illustrated in Figure 3, would lead to coalescence of the two singlets for the methyl protons in the high temperature limit, but this has not been observed in the ^1H NMR spectra up to $+120°C$.

Recent conformational analysis of cryptands (1.1.1) and (2.2.2) based on molecular mechanics calculations [7] revealed the remarkable rigidity of (1.1.1) and the conformational flexibility of (2.2.2)-cryptand due to the fast inversion on nitrogen atoms, but not associated with more dramatic conformational motions. Therefore, the (2.2.1)-cryptand should exhibit a rigidity approximately between that of the (1.1.1) and (2.2.2) cryptands and be a good candidate as a monofacial binding site for the primary ammonium cations.
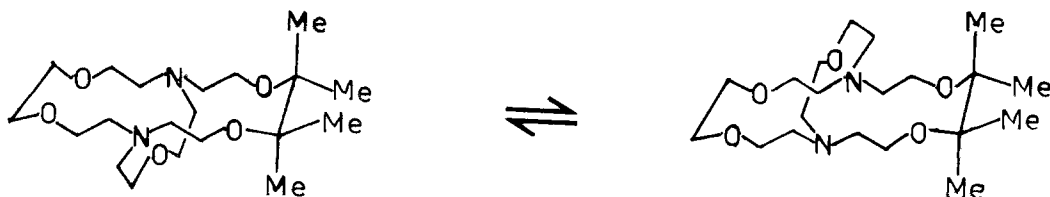

Fig. 3.

Acknowledgement

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