Tetrahedron Letters Vol. 22, pp 287 - 290
0040-4039/81/0122-0287$02.00/0

SYNTHESIS OF THE FIRST TOPOLOGICALLY NON-PLANAR MOLECULE

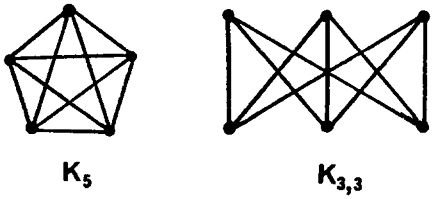
Howard E. Simmons, III* and John E. Maggio

Department of Chemistry, Harvard University, Cambridge, Massachusetts 02138 U.S.A.

Abstract: We report here the synthesis and characterization of the tris-ether 2,5,14-trioxahexacyclo-[$5.5.2.1.2^{4,10}.0^{4,17}.0^{10,17}$] -heptadecane 3; this topologically unique (graph theory) molecule is prepared via a novel intramolecular rearrangement of either of two isomeric propellane spiro-epoxides, 1 and 2.

In graph theory, any graph can be classified by Kuratowski's theorem as planar (those which can be drawn on a plane so that no two edges meet except at a vertex), or non-planar (when this cannot be done, e.g. $K_{3,3}$ or K_5). To our knowledge, no molecule corresponding to a non-planar graph has been reported to date.[1]

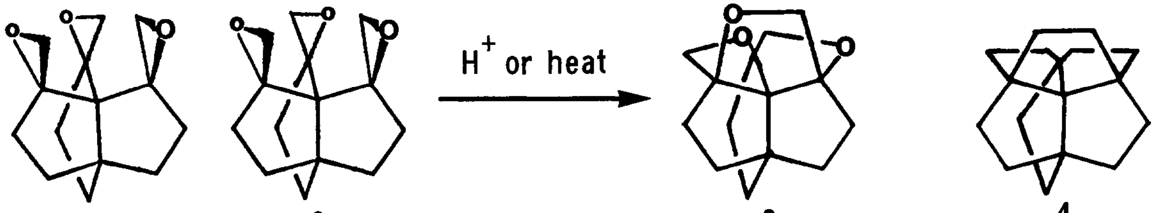
Scheme I



In the course of our work directed towards the synthesis of simple organic molecules corresponding to K_5 (e.g. 4, a beautiful hexaquinane of tetrahedral symmetry), we have prepared the first example of a topologically non-planar molecule 3.

Epoxidation of 2,8,9-trimethylene- [3.3.3] -propellane[2] (mCPBA, CH_2Cl_2, 4°C.) gave a ≃ 50:50 mixture (85% yield) of unsymmetrical 1 and symmetrical 2 tris-epoxides. Separation by preparative tlc (silica gel; hexane:ether, 2:1) gave pure 1 and 2.[3]

Scheme 2



1 or **2** **3** **4**

Both **1** and **2** rearrange to the heterocycle **3** either thermally or with acid catalysis (Scheme 2)[4,5]. The possibility that this novel rearrangement is an unprecedented $2\sigma + 2\sigma + 2\sigma$ to $2\sigma + 2\sigma + 2\sigma$ electrocyclic reaction is currently under investigation in this laboratory.

The K_5 compound **3** is a white crystalline solid, m.p. 326° (dec.), homogeneous by tlc, glc and NMR[6] (Figure 2A). This ball-shaped molecule has C_3 point-group symmetry[7]; its chirality was readily demonstrated by use of a chiral shift reagent (Figure 2B). The conformation of **3** (expected to be rigid) is readily deduced from coupling constants in the ^1H-NMR spectrum. $Eu(fod)_3$ was used to resolve the cyclopentyl protons into a first-order ABCD system (Figure 2C).

The magnitudes of the four three-bond vicinal coupling constants thus observed can be used to define the configuration of the cyclopentyl ethano bridges, and hence the approximate geometry of the entire molecule. Such analysis[8] indicates that the protons in each cyclopentyl ring are partially eclipsed as shown in Figure 1. The high-symmetry of **3** is immediately obvious from the ^1H (Figure 2A) and ^{13}C NMR spectra.[6]

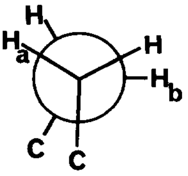


Figure 1. Newman projection of a cyclopentyl ethano bridge of **3** in the conformation deduced from Figure 2C[8]. The dihedral angle H_aCCH_b is ≃ 150°.

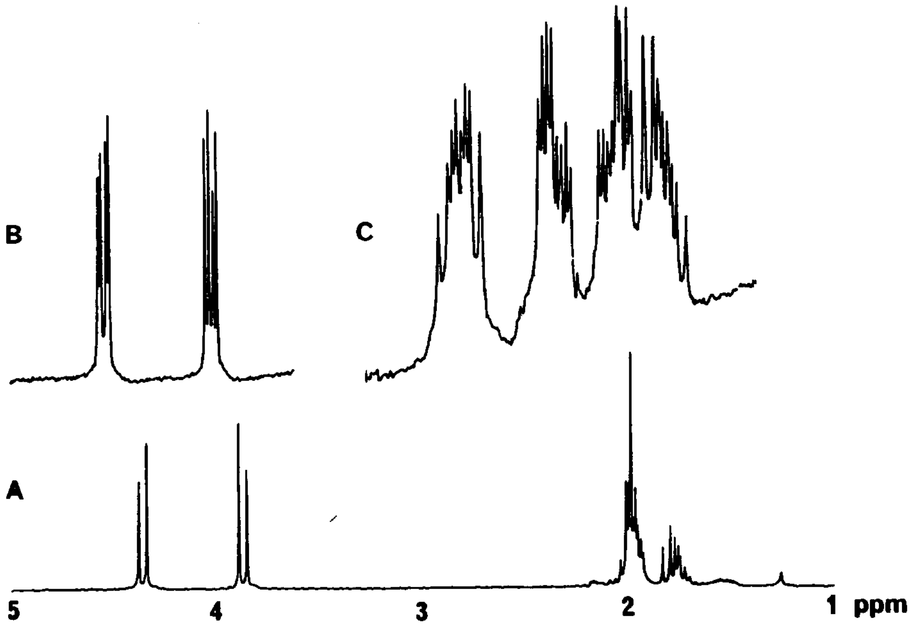


Figure 2 (A-C). 270 MHz ^1H NMR spectra of 3 in $CDCl_3$.
A) Normal spectrum; chemical shifts are reported below.[6]
Inset B) Furan methylene region of 3 in the presence of the chiral shift reagent tris- [3-(trifluoromethylhydroxymethylene)-d-camphorato]-europium (III).
Inset C) Cyclopentyl region of 3 in the presence of $Eu(fod)_3$.

Acknowledgements. The authors thank Professors R.B. Woodward and K.E. Bloch, in whose laboratories this work was done, for support and encouragement. High-field NMR experiments were performed at the F. Bitter National Magnet Laboratory (Massachusetts Institute of Technology), supported by the NIH (Grant RR00995) and the NSF (Contract C-670). Support under NSF Grant CHE-7825699 (to R.B. Woodward) is also gratefully acknowledged.

References and Notes.

1. Balaban, A.T., Ed., Chemical Applications of Graph Theory, 1976, N.Y., Academic Press, p.84
Harary, F., Graph Theory, Addison-Wesley, 1969.

2. Drouin, J.; Leyendecker, F.; Conia, J. Tetrahedron Lett., 1975, 4053-4056; idem., Tetrahedr
1980, 36, 1203-1208.

3. Both 1 and 2 were fully characterized by mass spectrometry, infra-red spectroscopy, elementa analysis, melting point, and thorough ^{1}H and ^{13}C NMR studies. Properties of these interestin spiranes will be reported elsewhere.

4. Thermal reactions were carried out at 225° C, 1 hour for 2, 245° C, 5 hours for 1, in sealed lead-potash glass tubes. Acid-catalyzed rearrangements were carried out in refluxin CHCl$_3$ over Amberlite 120 resin that had been previously dried by azeotropic distillation with benzene.

5. While 2 gives exclusively 3 by either thermal or acid-catalyzed rearrangement, 1 does not. Thermal rearrangement of 1 gives 3 ($\approx$12% yield) and acid-catalyzed rearrangement of 1 gives 3 ($\approx$50% yield). Several other uncharacterized rearrangement products of 1 are also produced in each case.

6. ^{1}H-NMR (CDCl$_3$): 4.36d, 3.88d, J=-10.4 (ether methylenes); 1.99-1.77m (cyclopentyl).
^{13}C-NMR (CDCl$_3$): 98.3, 55.3 (central axis quat); 103.6 (ether quat); 77.6 (ether methylene);
32.6, 36.9 (cyclopentyl methylenes).

7. Molecules of C$_3$ point-group symmetry such as 2 and 3 are very rare in the chemical literature.

8. Karplus, M. J. Chem. Phys., 1959, 30, 11-15. Booth, H. Prog. Nucl. Magn. Reson. Spectrosc. 1969, 5, 211-381.

9. We note that Professor Leo Paquette and his collaborators at Ohio State University, to whom we have previously communicated many of our unpublished results, have also succeeded in converting 1 and 2 to 3 by Lewis acid catalysis. Their interest in this and other aspects of our work (in particular, the rearrangements of the carbon analog of 2) is gratifying.

(Received in USA 8 November 1980)