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NOVEL CAGE SYSTEMS: SOME PENTACYCLODECANE AND TETRACYCLODECANE DERIVATIVES

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We wish to report the synthesis of two derivatives of the novel cage system pentacyclo[4.4.0.$0^{2,5}$.$0^{3,9}$.$0^{4,8}$]decane (IV and V), and the partial opening of this system to yield products believed to be derivatives of another new cage skeleton, tetracyclo[4.4.0.$0^{3,9}$.$0^{4,8}$]decane (VIa and VIb). This latter may be regarded as the Winstein bird-cage hexacyclododecane with the methylene bridges (the "wings") missing. A more direct approach to the synthesis of this system was reportedly unsuccessful (1).

The ethylene ketal of tetrachlorocyclopentadienone (2) was heated with an excess of 1,4-cyclohexadiene to give an 85% yield of the adduct I (3) (m.p. 100-102°; chlorinated C=C stretching at 6.30μ).* When a 1% solution of I in acetone was irradiated under nitrogen with unfiltered light from a 450 watt Hanovia medium pressure mercury lamp, the cyclized product II (m.p. 219-221°; M.W. 337 by osmometry, theory 342) was obtained in 82% yield. Treatment of II with concentrated sulfuric acid at room temperature for several days gave 91% of the ketone III (m.p. 199-201°; C=O stretching in CH_2Cl_2 solution at 5.53μ; forms a hydrate which loses water on vacuum

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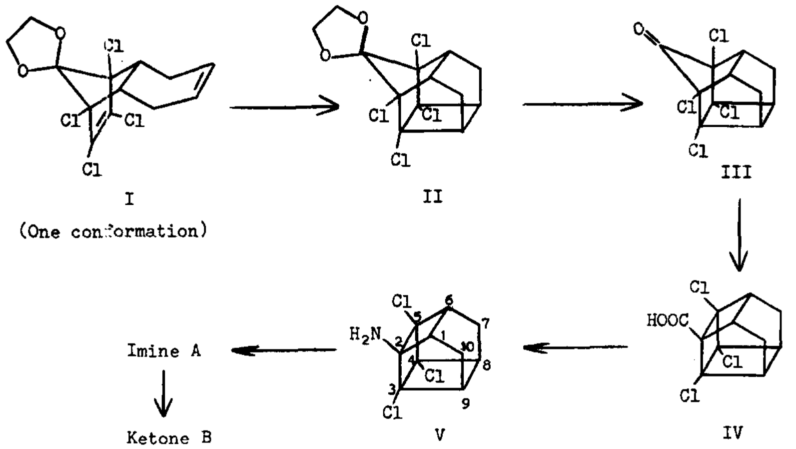
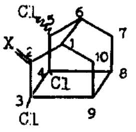
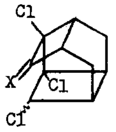
*All new compounds gave satisfactory elemental analyses, and had p.m.r. spectra (Varian A-60; in $CDCl_3$ with TMS internal standard) consistent with the proposed structures. I.R. spectra were taken in Nujol mull, unless otherwise stated.

drying). A solution of III in toluene was refluxed over solid sodium hydroxide (4) to give 65% of the acid IV (m.p. 249-251° dec.; C=O stretching at 5.88μ), which was converted by a Curtius procedure (acid chloride, azide, isocyanate) to the amine V (m.p. 166-168° dec.; N-H stretching doublet at 2.99μ, N-H bending at 6.23μ) in 76% yield. When V was treated with potassium tert-butoxide in tert-butyl alcohol for a few minutes at room temperature it was isomerized almost quantitatively to an imine A (m.p. 107-109° dec.; C=N stretching at 5.95μ). The same imine was obtained in 47% yield by refluxing V in pyridine for many hours. Hydrolysis of A with dilute hydrochloric acid at 55° gave an 88% yield of a ketone B (m.p. 113-115°; C=O stretching in CCl_4 solution, complex band centered at 5.64μ).





VI



VII

(a) X = =NH
(b) X = =O

The base catalyzed opening of the highly strained amine V to an imine is formally the converse of the reported closure of a highly congested imine to a bird-cage amine (5). It was presumed that V would open most readily by cleavage of the 2-5 or the 2-3 rather than the 1-2 bond, since the supposed carbanionoid transition state would then be stabilized by a chlorine substituent. Breaking of the 2-5 bond (giving VIa) would be favored over breaking of the 2-3 bond (giving VIIa) in the likely event that the reaction proceeds in the direction which leads to the more stable product. The p.m.r. spectra of A and B show one-proton signals at δ=4.10 and 4.08, respectively, confirming the generation of a new > CHCl grouping. Of the structures thus possible for B, VIb is a cyclopentanone with a pseudo-equatorial α-chlorine substituent and VIIb is a similarly substituted cyclobutanone. Although it is conceivable that the infrared characteristics of these polycyclic systems are anomalous, the carbonyl stretching wave length of 5.64μ supports VIb as the correct structure for B (6,7,8). The structure of A is therefore considered to be VIa. The stereochemistry at C-5 is unknown. In both A and B the p.m.r. signal from the C-5 proton is a single peak *ca.* 1.5 c.p.s. wider at half-height than the TMS standard, but the flexibility of the system is such that it would be rash to try to deduce the C-5 stereochemistry from this one piece of evidence.

X-ray crystallographic studies are being undertaken (9) with a view to defining completely the structure of the ketone B.

Acknowledgment. The authors wish to thank Mr. J. J. Taggart for his skilled assistance in many of these experiments.

References

1. R. C. Cookson, E. Crundwell, R. R. Hill and J. Hudec, J. Chem. Soc., 3062 (1964).

2. W-H. Chang, Chem. and Ind., 709 (1964).

3. We considered the possibility that the 1,4-cyclohexadiene might have isomerized to the 1,3-diene before undergoing the Diels-Alder addition. This was, in our view, unlikely under the mild reaction conditions used; consideration of the p.m.r. spectra of compounds I, II and III confirmed the belief that no rearrangement had occurred. These spectra are consistent with the proposed structures but not (except by the fortuitous concidence of several chemical shifts) with the less symmetrical structures derived from 1,3-cyclohexadiene as either diene or dienophile. However, since the question of this isomerization has now been raised by a referee, we have reinvestigated the Diels-Alder reaction and established that: (a) No isomerization of the excess 1,4-diene can be detected when the reaction is carried out under our usual conditions (1 hour in the refluxing 1,4-diene as solvent); (b) The reaction of the tetrachloroketal with 1,3-cyclohexadiene under the same conditions does not yield compound I.

4. General procedure of Dr. G. L. Dunn for the Favorskii-type contraction (private communication). cf. K. V. Scherer, Jr., R. S. Lunt, III, and G. A. Ungefug, Tetrahedron Letters, 1199 (1965).

5. R. J. Stedman, A. C. Swift and J. R. E. Hoover, Tetrahedron Letters, 2525 (1965). See also references contained therein to related homoenolizations and homoketonizations.

6. The complexity of the carbonyl band is not unexpected in view of similar findings in other caged ketones, e.g. ref. 1 and P. E. Eaton and T. W. Cole, Jr., J. Amer. Chem. Soc., **86**, 962 (1964).

7. K. B. Wiberg and B. J. Nist, J. Amer. Chem. Soc., **83**, 1226 (1961).

8. L. J. Bellamy, "The Infra-red Spectra of Complex Molecules," John Wiley and Sons, Inc., New York, N.Y., 1958, Second Edition, p. 139.

9. Work in progress under the direction of Dr. G. A. Jeffrey at the University of Pittsburgh.