

THE SYNTHESIS AND X-RAY CRYSTAL STRUCTURE
OF A TETRACYCLO[4.2.1.1.^{2,5}0^{3,7}]DECANE DERIVATIVE.

A RIGID, TWIST BOAT-CONTAINING RING SYSTEM.

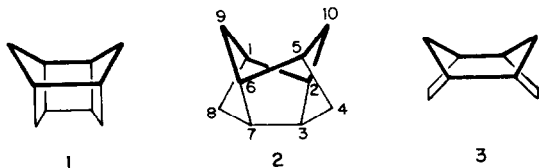
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Abstract. Attempted intramolecular pinacolization of cage diketone **4** unexpectedly gave ketol **5** instead. Compound **5** was shown to possess the rare tetracyclo[4.2.1.1.^{2,5}0^{3,7}]decane ring system by means of an X-ray crystal structure of hydroxy-mesylate **10** derived from **5** by sodium borohydride reduction followed by mesylation. A possible mechanism for the transformation of **4** into **5** is presented, and certain noteworthy features of the crystal structure of **10** are discussed. The base-catalyzed fragmentation of **10** to give enone **11** is also described.

The tetrahydropentaprismane ring system **1** possesses a plane of symmetry and contains an eclipsed boat cyclohexane ring (heavy lines). Placing the zero carbon bridge between carbons 3 and 7, on the other hand, produces the isomeric tetracyclo[4.2.1.1.^{2,5}0^{3,7}]decane ring system **2** which has a C₂ axis of symmetry and includes a six-membered ring with twist boat geometry. Other interesting features of **2** include its intrinsic chirality and the question of its strain energy relative to **1**.¹

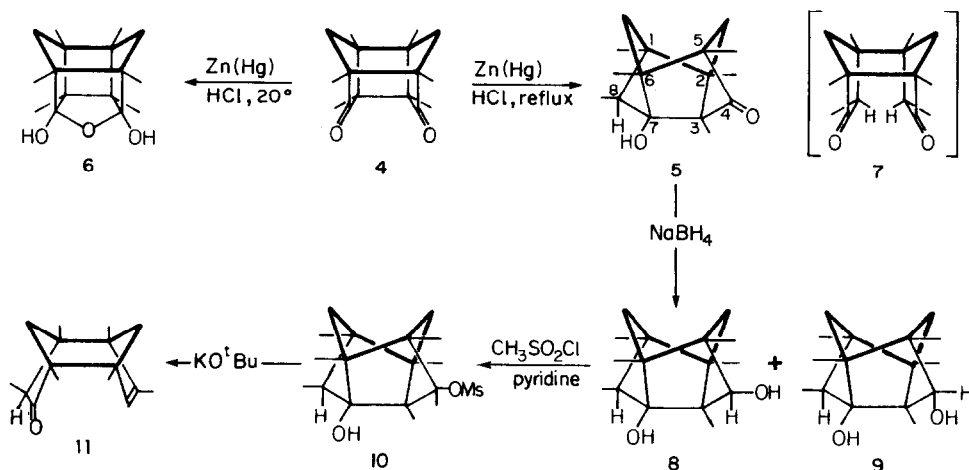
In this paper we describe the rearrangement of a derivative of **1** into a derivative of **2**. In addition we report the X-ray crystal structure of a derivative of **2** and delineate its conversion into a syn-tricyclo[4.2.1.1.^{2,5}]decane (**3**) derivative via C(3)-C(7) bond cleavage.

We have recently described a general synthetic entry into the tetrahydropentaprismane ring system **1** and in particular have outlined the preparation of dione **4** (Scheme), the substance which serves as the starting



material for this investigation.² With the goal of forming the dihydropentaprismane ring system, we attempted the intramolecular pinacolization of **4** via treatment of its aqueous THF solution with zinc amalgam and HCl at reflux.³ Rather than the symmetric pinacol, this reaction furnished 1,2,3,5,6,8β-hexamethyl-4-hydroxytetracyclo[4.2.1.1.^{2,5}0^{3,7}]decane-4-one (**5**), mp 137-138.5°, in nearly quantitative yield.⁴ Interestingly, treatment of **4** at room temperature under otherwise identical conditions yielded the hydrate **6**, mp 143-144°. The

structures of $\tilde{5}$ and $\tilde{6}$ were assigned on the basis of their spectral data and, in the case of $\tilde{5}$, on the X-ray crystal structure of a derivative (*vide infra*).

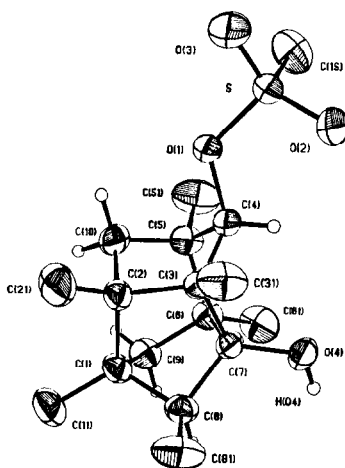
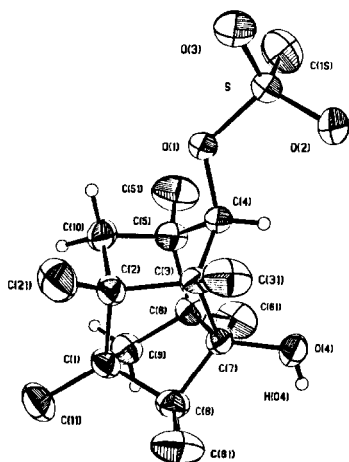


The formation of $\tilde{5}$ from $\tilde{4}$ probably involves reductive cleavage to $\tilde{7}$ followed by an intramolecular aldol condensation. Similar reductive cleavages of cage 1,4-diketones in the presence of zinc and acetic acid have been reported by Wekert and Yoder,⁵ Eaton, Hudson and Giordano,⁶ and by Paquette, Snow, Muthard and Cynkowski.⁷ To date we have been unable to isolate diketone $\tilde{7}$. For example, treatment of $\tilde{4}$ with zinc and acetic acid, even for prolonged periods at elevated temperatures, gave no reaction, and attempted reverse aldolization of $\tilde{5}$ under a variety of conditions was similarly uneventful.

Sodium borohydride reduction of $\tilde{5}$ afforded an approximately 1:4 mixture of diols $\tilde{8}$ (mp 167-168°) and $\tilde{9}$ (mp 163-164°). The major product $\tilde{9}$ is the result of hydride approach from the less hindered direction. Diol $\tilde{8}$ was treated with methane sulfonyl chloride and pyridine to afford the crystalline mesylate $\tilde{10}$, mp 115.5-116°, whose X-ray crystal structure was determined.

Crystals of $\tilde{10}$ are monoclinic, space group $P2_1/c$, $a = 9.246(2)$, $b = 10.938(1)$, $c = 17.335(4)$ Å, $\beta = 102.11(1)^\circ$, $V = 1714.1(6)$ Å³, $\rho_c = 1.273$ gcm⁻³, $Z = 4$. The structure was solved by direct methods and refined to a final R_w of 0.058.⁸ The degree of twist in the twist-boat portion of $\tilde{10}$ is indicated by the $\text{CH}_3\text{-C}(1)\text{-C}(2)\text{-CH}_3$ and $\text{CH}_3\text{-C}(5)\text{-C}(6)\text{-CH}_3$ dihedral angles which are $23.9(2)^\circ$ and $27.9(2)^\circ$, respectively. The NMR spectra of all four of the

tetracyclo[4.2.1.1.^{2,5}₀^{3,7}]decane derivatives prepared in this work (compounds 5, 8, 9 and 10) indicate that the inner C(9) and C(10) hydrogen atoms in this ring system experience deshielding via steric compression resulting in a large chemical shift difference between the



Stereodiagram of hydroxy-mesyate 10. The methyl hydrogen atoms have been omitted for clarity.

inner and outer hydrogens at these positions.^{1,9} In ketol 5, for example, where all four hydrogen atoms are clearly resolved, the C(9) and C(10) methylene groups appear as pairs of doublets ($J = 12$ Hz) centered in one case at δ 0.77 and δ 1.78 and in the other at δ 1.05 and δ 1.85. It was thus of interest to determine the crystallographic distance between the compressed hydrogen atoms in 10. This was found to be 2.03 Å, well below the van der Waals radii sum of 2.40 Å for two hydrogen atoms. One additional point of interest in the X-ray structure of 10 was the finding that the molecule contains four extremely long carbon-carbon bonds. These are C(1)-C(2) (1.602 Å), C(5)-C(6) (1.584 Å), C(2)-C(3) (1.599 Å) and C(6)-C(7) (1.614 Å). Without them, the steric compression experienced by the inner C(9) and C(10) hydrogen atoms would undoubtedly have been even greater.

Finally we report that base-induced fragmentation of hydroxy-mesyate 10 proceeded smoothly to afford 1,2,3,5,6,8 β -hexamethyltricyclo[4.2.1.1.^{2,5}]dec-3-ene-7-one (11), mp 65-67°, in 93% (recrystallized) yield. The success of this reaction presumably stems

in part from the trans-antiparallel relationship between the mesylate leaving group and the C(3)-C(7) bond undergoing fragmentation.

In summary, the chemistry reported in this communication provides ready access to a series of interesting and unusual tri- and tetracyclic ring systems. Further studies on analogues of diketone 4 are planned.

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1. The only previous preparation of a tetracyclo[4.2.1.1.^{2,5}0^{3,7}]decane derivative of which we are aware is that due to L.A. Paquette, C.W. Doecke and G. Klein, J. Am. Chem. Soc., 101, 7599 (1979). Their approach involved regiospecific sigma bond hydrogenolysis of a bishomocubane derivative.
2. W.K. Appel, T.J. Greenhough, J.R. Scheffer, J. Trotter and L. Walsh, J. Am. Chem. Soc., 102, 1158 (1980).
3. (a) W.T. Borden and T. Ravindranathan, J. Org. Chem., 36, 4125 (1971), (b) R. Greenhouse, W.T. Borden, K. Hirotsu and J. Clardy, J. Am. Chem. Soc., 99, 1664 (1977), (c) R. Greenhouse, W.T. Borden, T. Ravindranathan, K. Hirotsu and J. Clardy, ibid., 99, 6955 (1977).
4. All new compounds reported gave satisfactory elemental analyses and exhibited spectra completely in accord with their assigned structures.
5. E. Wenkert and J.E. Yoder, J. Org. Chem., 35, 2986 (1970).
6. P.E. Eaton, R.A. Hudson, C. Giordano, Chem. Commun., 978 (1974).
7. L.A. Paquette, R.A. Snow, J.L. Muthard and T. Cynkowski, J. Am. Chem. Soc., 100, 1600 (1978).
8. Full details of the X-ray crystal structure determination will be published separately, A.S. Secco and J. Trotter, manuscript in preparation.
9. S. Winstein, P. Carter, F.A.L. Anet and A.J.R. Brown, J. Am. Chem. Soc., 87, 5247 (1965)

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