The Acyloin Condensation. Synthesis of a [4,2,2]-Propellane (Tricyclo[4,2,2,$0^{1,6}$]decane)[1] Derivative

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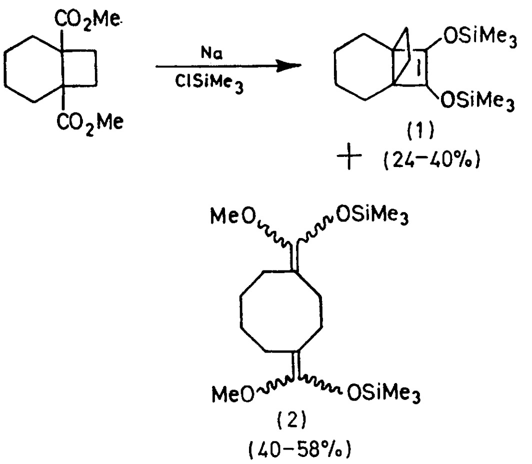
Summary Acyloin condensation of dimethyl bicyclo-[4,2,0]octane-1,6-dicarboxylate in the presence of chlorotrimethylsilane produces 7,8-bis(trimethylsilyloxy)-[4,2,2] propell-7-ene (25—40%) and the bis-(trimethylsilyloxy)-dimethoxy-keten acetal of 1,4-cyclo-octane dicarboxylate (40—58%); solvolysis of the propellane in weakly acidic methanol gave 1-methoxy-8-hydroxybicyclo[4,2,2]decane-7-one by apparent homoconjugate attack at the central carbon–carbon bond.

Ginsburg[2] has pointed out that when at least two of the rings contain five atoms, synthesis of propellanes is fairly easy. However, a greater challenge is offered by the smaller ring systems because of increased ring strain.

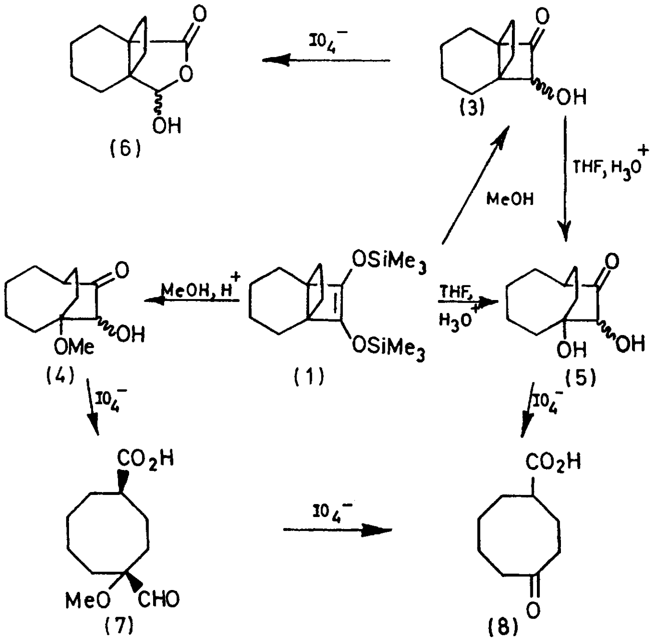
Wiberg[3] and Gassman[4] have described the synthesis and properties of [3,2,1]-propellanes, the smallest system to date. In contrast, we have investigated the synthesis of [*n*,2,2] propellanes by the acyloin method which succeeded for [4,4,2]- and [4,4,4]-propellanes.[5] The recent results of Eaton[6] and Paquette[7] on the synthesis of [4,4,2]-propellanes prompts this preliminary account of our simple, relatively high yield entry into this ring system.



Dimethyl bicyclo[4,2,0]octane-1,6-dicarboxylate was prepared by esterification (94% yield) of the anhydride produced *via* photochemical addition of ethylene to 3,4,5,6-tetrahydrophthalic anhydride (95% yield).[8,10] The diester was converted into the bis(trimethylsilyloxy)propellene (**1**), b.p. 69—73° at 0·1 Torr, (25—40%) using highly dispersed sodium in an inert solvent. In addition a higher boiling compound (**2**) b.p. 108—110° at 0·1 Torr, was obtained (40—58%). Compound (**2**) was the sole product when a large excess of 1:1 NaK alloy was used.

From the n.m.r. spectrum,‡ it was deduced that (**2**) was a mixture of isomers of bis(trimethylsilyloxy)dimethoxy-keten acetal of 1,4-cyclo-octandicarboxylate. Confirmation of this assignment was obtained by adding (**2**) to methanol (vigorously exothermic) which produced a mixture of *cis*- and *trans*-dimethylcyclo-octane-1,4-dicarboxylate.§[9]

Treatment of freshly distilled (**1**), with dry oxygen-free methanol, under nitrogen, produced the free acyloin (**3**) (97%); m.p. 76-77°, ν_{CO} (cyclobutanone) 1775 cm^{-1}; *m/e* 166. Under less stringent conditions a major contaminant, ν_{max} 1715 cm^{-1} (large ring CO), was detected. Prolonged treatment with MeOH or treatment for a short time with methanol containing a drop of conc. HCl gave (**4**) (49—60%), m.p. 116—118°; M^+, *m/e* 198; ν_{max} 3340 (OH) cm^{-1}; δ (60 MHz; $CDCl_3$; Me_4Si): 3·73 (s, 1H, C*H*·OH), 3·29 (s, 3H, OMe) and multiplets at 2·6, 2·13, and 1·75 p.p.m. In $(CD_3)_2SO$ doublets appeared at 5·6 (CH·O*H*)



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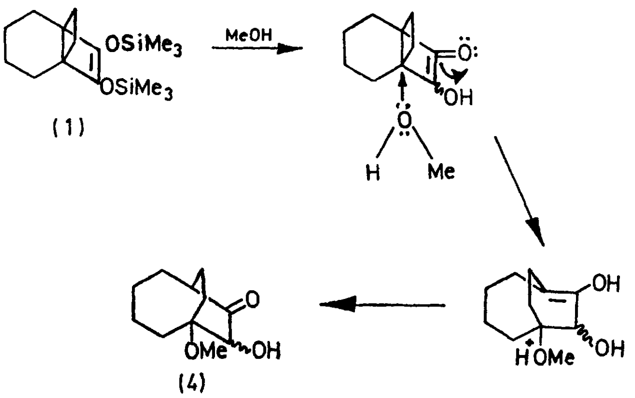
‡ N.m.r. spectral shifts in CCl_4 were measured downfield from the $OSiMe_3$ peaks. (**1**) gave two peaks centred at −98 Hz (area 21) and −68 Hz (area 42) and 0·0 Hz ($OSiMe_3$) (area 90). (**2**) gave three peaks, a doublet −191 (corresponding to different isomer positions) (d, OMe, area 33), −121 (m, area 44), −88 (m, area 23), and 0·0 Hz ($OSiMe_3$, area 97).

§ Identical by g.l.c. with mixtures prepared by hydrogenation of dimethyl 1,3,5-cyclo-octatriene-1,6-dicarboxylate (E. Vogel, O. Roos, and K. H. Disch, *Annalen,* 1962, **653**, 55) or dimethyl 1,3-cyclo-octadiene-1,4-dicarboxylate (J. J. Bloomfield, unpublished work.)

and 3·6 (*CH*·OH). Treatment of (**3**) in aqueous acidic tetrahydrofuran produced the analogous hydroxy-compound (**5**), m.p. 175 (decomp.) Confirmatory evidence for the structures of (**4**) and (**5**) was obtained by treatment of (**3**) with periodate to produce pseudo-acid (**6**), m.p. 130 (decomp.); while (**4**) gave 4-formyl-4-methoxycyclo-octanecarboxylic acid, b.p. 172—176 at 1 Torr, with no observable splitting of the aldehyde hydrogen in the n.m.r. spectrum, thus establishing the relative positions of the three substituents. Prolonged treatment of (**4**) or direct treatment of (**5**) with periodate gave 4-oxocyclo-octanecarboxylic acid, m.p., 59·0—60·0°.

Because the rearrangement of the acyloin is acid catalysed it is suggested that the reaction proceeds by protonation of the carbonyl oxygen on carbon atom 7 followed by nucleophilic attack of methanol at carbon atom 1, to produce an enol of (**4**). Thus the bicyclohexanone skeleton is readily opened by what appears to be homoconjugate addition of methanol to the central bond. The acid lability of the central bond in propellane (**3**) is in considerable contrast to the behaviour observed in other [4,2,2] propellanes.[6,7]

Although we are continuing to investigate the acyloin route to other [*n*,2,2]-propellanes as well as to [*n*,2,1] systems we do not believe we shall be successful because attempts to prepare the [3,2,2]-propellane derivative from dimethyl bicyclo[3,2,2]heptane 1,5-dicarboxylate[10] gave only the keten acetal of cycloheptane-1,4-dicarboxylate.[11]



All new compounds described gave satisfactory elemental analyses.

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[1] Abstracted in part from Ph.D. thesis of R.A.M., University of Oklahoma, 1969.

[2] D. Ginsburg, *Accounts Chem. Res.*, 1969, **2**, 121.

[3] (a) K. B. Wiberg, J. E. Hiatt, and G. Burgmaier, *Tetrahedron Letters*, 1968, 5855; (b) K. B. Wiberg and G. J. Burgmaier, *ibid.*, 969, 317.

[4] P. G. Gassman, A. Topp, and J. W. Keller, *Tetrahedron Letters*, 1969, 1093.

[5] J. J. Bloomfield, *Tetrahedron Letters*, 1968, 587, 591.

[6] (a) P. E. Eaton, 155th National Meeting American Chemical Society, April 1968, p. 1, described in ref. 2; (b) P. E. Eaton and K. Nyi, *J. Amer. Chem. Soc.*, 1971, **93**, 2786.

[7] L. A. Paquette and R. W. Houser, *J. Amer. Chem. Soc.*, 1971, **93**, 4522.

[8] This compound was identical in physical properties to the anhydride produced by hydrogenation of the anhydride prepared in several steps starting with butadiene and dimethyl 1,2-cyclobutenedicarboxylate (E. Vogel, O. Roos, and K. Disch., *Annalen*, 1962, **653**, 55.

[9] Thus this reduction of a carbon–carbon single bond is similar to one (E. Bertele, H. Boos, J. D. Dunitz, F. Elsinger, A. Eschenmoser, I. Felfer, H. P. Gribi, M. G. Schwend, E. F. Meyer, M. Pesaro, and R. Scheffold, *Angew. Chem. Internat. Edn.*, 1964, **3**, 490) involving Na, NH_3 reduction of the Diels–Alder adduct of isoprene and tetracarbomethoxyethylene, which produced the open-chain tetra-ester (87%) and also similar to the fragmentation rearrangement in the attempted acyloin condensation of cyclobutane-1,2-dicarboxylate (J. J. Bloomfield, R. G. Todd, and L. T. Takahashi, *J. Org. Chem.*, 1963, **28**, 1474).

[10] (a) D. C. Owsley and J. J. Bloomfield, *Org. Prep. Proc., Int.*, 1971, **3**, 61; (b) D. C. Owsley and J. J. Bloomfield, *J. Org. Chem.*, 1971, **36**, 3768.

[11] J. J. Bloomfield and D. C. Owsley, unpublished results.