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BASE-PROMOTED REARRANGEMENT OF CAGE α-HALOKETONES—II[1]

12-OXA-3,5,9,10-TETRACHLOROHEXACYCLO[5.4.1.$0^{2,6}$.$0^{3,10}$.$0^{5,9}$.$0^{8,11}$]-DODECANE-4-ONE

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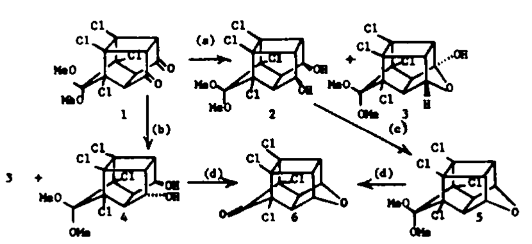
Abstract—A synthesis of 12-oxa-3,5,9,10-tetrachlorohexacyclo[5.4.1.$0^{2,6}$.$0^{3,10}$.$0^{5,9}$.$0^{8,11}$]dodecane-4-one (**6**) from 4,4-dimethoxy-2,3,5,6-tetrachloropentacyclo [[5.4.0.$0^{2,6}$.$0^{3,10}$.$0^{5,9}$]undecane-8,11-dione (**1**) is described. Reaction of **6** with sodium hydroxide in refluxing benzene, toluene, or tetrahydrofuran affords 11-oxa-3,4,5-*exo*-6-tetrachloropentacyclo [[6.2.1.$0^{2,7}$.$0^{4,10}$.$0^{5,9}$]undecane-*endo*-3-carboxylic acid (**7a**, 80·2% yield). The corresponding reaction of **6** with refluxing aqueous sodium hydroxide solution affords 4,12-dioxa-8,11-dichlorohexacyclo-[5.4.1.$0^{2,6}$.$0^{3,10}$.$0^{5,9}$.$0^{8,11}$]dodecane-1-carboxylic acid (**8a**, 66·5% yield). A mechanism which accounts for the formation of **7a** and **8a** from **6** is presented.

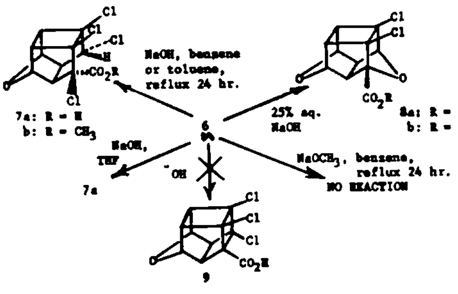
Semibenzilic acid rearrangement of α-haloketones has been commonly employed for the synthesis of highly strained ring systems.[2-6] We report herein the synthesis and base-promoted rearrangement of the title compound, (**6**). The synthesis of **6** is outlined in Scheme 1.



Scheme 1. Reagents: (a) NaBH$_4$-95% EtOH; (b) LAH-Et$_2$O; (c) *p*-TsOH-PhCH$_3$; (d) conc. H$_2$SO$_4$.

The reduction of the parent pentacyclo-[5.4.0.$0^{2,6}$.$0^{3,10}$.$0^{5,9}$]undecane-8,11-dione system with excess ethanolic sodium borohydride has been reported[7] to afford a mixture of isomeric diols, whereas lithium aluminum hydride reduction of this compound cleanly affords the *endo,endo* diol.[8] In our hands, reduction of **1** with excess sodium borohydride afforded a mixture of the corresponding *exo,endo* diol (**2**) and a hemiketal, **3**. The structure of **3** was assigned on the basis of spectral evidence and by the fact that it could be further reduced by LAH to the corresponding *endo,endo* diol (**4**). Reduction of **1** with excess LAH afforded products **3** and **4** in the ratio of *ca*. 4 : 1; no *exo,endo* diol (**2**) was formed in this reaction. That the diol **4** formed *via* LAH reduction of both **1** and **3** indeed possessed the *endo,endo* configuration was indicated by its successful conversion to a cyclic thiocarbonate derivative, (**12**; Experimental).

Of particular interest to us was to study the reaction of ketone **6** with base in the hope of promoting a semibenzilic acid rearrangement. If successful, the expected product of this reaction would be the interesting "oxohomopentaprismane" derivative, **9**. To this end, the α-haloketone **6** was treated with base under a variety of conditions. In no instance was the hoped-for semibenzilic acid rearrangement product (**9**) obtained (Scheme 2). Instead, two abnormal products were obtained: acid **7a** was formed by the action of sodium hydroxide on **6** in nonaqueous media (benzene, toluene or tetrahydrofuran) whereas acid **8a** was obtained from the corresponding reaction when carried out in aqueous medium.

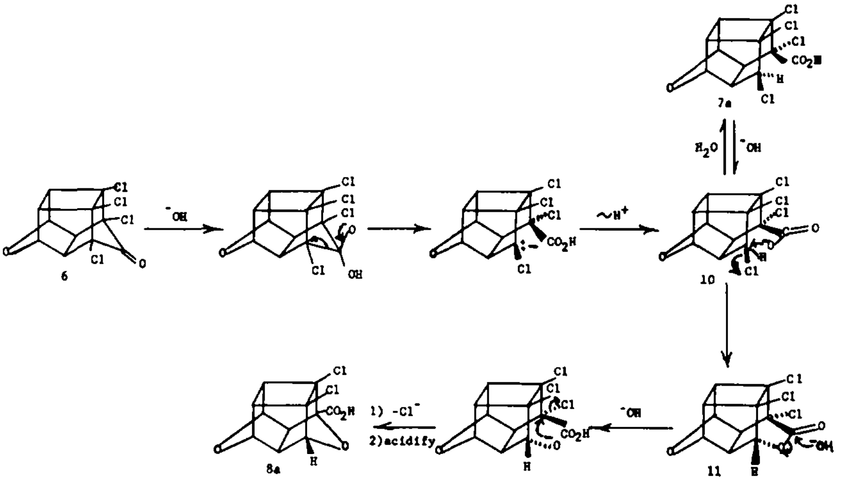


Scheme 2.

The stereochemistries at C(3) and C(6) in product **7a** were established via our observation that **7a** could be converted to **8a** when refluxed with 25% aqueous sodium hydroxide solution, (the same conditions whereby direct conversion of **6** to **8a** could be effected). On the basis of this observation, we assign *endo* stereochemistry to the C(3)-carboxyl group and *exo* stereochemistry to the C(6)-C–Cl bond.

A reasonable mechanism for the formation of **7a** and **8a** via base-promoted rearrangement of **6** is shown in Scheme 3. We suggest that intermediate **10** survives when the reaction is carried out in nonpolar solvent, and that it is isolated after workup as **7a**. However, in polar solvents, further intramolecular reaction of **10** may proceed in the manner shown in Scheme 3 to afford **8a**.

In support of the postulated mechanism, we have separately synthesized and characterized two intermediates, **7a** and **11**. Compound **7a** was prepared in the manner indicated in Scheme 2; compound **11** was prepared by refluxing an ethanolic solution of **7a** over solid barium carbonate. As noted earlier, **7a** could be converted to **8a** when subjected to the same experimental conditions by which **6** is converted to **8a**. Compound **11** could similarly be converted to **8a**. These results lend credence to the mechanism shown in Scheme 3.[9]*



Scheme 3.

We are continuing to search for methods which will permit the synthesis of highly strained cage systems related to **9**. We hope to report the results of these efforts shortly.

EXPERIMENTAL

M.ps are uncorrected. IR spectra were obtained as dispersions in KBr on a Perkin-Elmer Model IR-8 infrared spectrophotometer. NMR spectra were obtained on a Varian T-60 NMR spectrometer (TMS internal standard). Mass spectra were obtained on a Hitachi Perkin-Elmer Model RMU 7E mass spectrometer operating at 70 eV. *M/e* values of each significant peak in the mass spectra of new compounds are reported, followed parenthetically by the intersity of that peak expressed as a percent of the intensity of the base peak (where the intensity of the base peak = 100).

4,4 - *Dimethoxy* - 2,3,5,6 - *tetrachloropentacyclo*$[5.4.0.0^{2,6}.0^{3,10}.0^{5,9}]$*undecane*-endo-8-exo-11-*diol* (**2**). A soln of **1**[1] (82 g, 0·22 mol) in 95% EtOH (450 ml) was cooled in an ice bath. $NaBH_4$ (17 g, 0·45 mol) was added portionwise, with stirring, to the cooled soln of **1** in EtOH. After the exothermic reaction subsided, the mixture was allowed to gradually warm to room temp., and stirring was continued for an additional 3 hr. After this period, the mixture was heated under reflux for 30 min, whereupon water (200 ml) was added. The resulting soln was heated to boiling for 15 min, diluted with water (500 ml), and then extracted with diethyl ether (500 ml × 4). The combined extracts were washed with water (500 ml × 3), dried ($MgSO_4$), filtered, and then concentrated on a rotary evaporator. The NMR spectrum of the crude product thereby obtained displayed a triplet centered at δ 5·00, suggesting that a small amount of **3** was formed along with **2**; (details of the NMR spectrum of **3** are presented in the section which deals with the synthesis of **4**). The crude product was recrystallized from ethyl acetate-hexane to afford **2** as a colorless microcrystalline solid (68 g, 82%), m.p. 244–255°. Further recrystallization (EtOAc) followed by sublimation (175°/0·1 mm) afforded pure **2**, m.p. 256–257°. IR: 3420 (br), 2840 (w), 1425 (m), 1225 (s), 1110–1000 (complex absorption pattern, s), and 775 cm^{-1} (s); NMR (acetone-d_6): δ 2·83–3·13 (mult, 4H, methine protons), δ 3·55 (s, 3H, $-OC\underline{H}_3$), δ 3·65 (s, 3H $-OC\underline{H}_3$), δ 3·76 (d, 1H, $O\underline{H}$), δ 4·50 (br s, 1H, $C\underline{H}OH$), δ 4·83 (br d, 1H, $O\underline{H}$) and δ 5·41 (br d, 1H, $C\underline{H}OH$); (assignment of the various signals in the NMR spectrum of **2** was facilitated through examination of the NMR spectrum of 8,11-dideuterated **2**, which was prepared via reduction of **1** with excess $NaBD_4$ utilizing the procedure described above); mass spectrum: *m/e* 382/380/378/376/374 (molecular ion, with the intensity profile characteristic of the Cl_4 multiplet),[10] 343(32), 341(93), 339(100), 255(16), 253(16), 191(19), 190(17), 189(58), 188(31) and 59(17). (Found: C, 41·20; H, 3·63. $C_{13}H_{14}Cl_4O_4$ requires: C, 41·52; H, 3·75%).

4,4 - *Dimethoxy* - 2,3,5,6 - *tetrachloropentacyclo*$[5.4.0.0^{2,6}.0^{3,10}.0^{5,9}]$*undecane*-endo,endo-8,11-*diol* (**4**). A stirred slurry of LAH (8·90 g, 0·234 mol) in anhyd diethyl ether (200 ml) was cooled in an ice bath. To this cooled soln was added dropwise, under N_2, a soln of **1**[1] (21·6 g, 0·058 mol) in diethyl ether (350 ml). After the addition had been completed, the mixture was stirred at room temp. for 24 hr and then refluxed for *ca.* 30 min. The mixture was then cooled to 0°; to the cooled soln, the following were successively added dropwise: water (10 ml), 15% NaOH aq (10 ml), and water (100 ml). The inorganic residue was removed by filtration, and the residue was then washed with EtOAc. The combined organic layers were washed with water (200ml × 3) and then dried (Na_2SO_4), filtered, and concentrated (rotary evaporator), affording a colorless oil (19·1 g) which solidified on standing. This material was found to contain **4** and **3** in the ratio (by NMR) of *ca.* 1:4. Compound **3** could be isolated from the product mixture *via* fractional recrystallization (ether-hexane). The material thus isolated had m.p. 189–191°. Compound **3** was characterized via its IR, NMR, and mass spectra: IR: 3320 (s), 1340 (s), 1210 (s) and 1200–970 cm^{-1} (complex absorption pattern, s); NMR (acetone-d_6): δ 2·83–3·30 (mult, 5H, $O\underline{H}$ and methine protons), δ 3·53 (s, 3H, $-OC\underline{H}_3$), δ 3·62 (s, 3H, $-OC\underline{H}_3$), and δ 5·00 (br t, 1H, $C\underline{H}OH$); mass spectrum: *m/e* 380/378/376/374/372 (molecular ion, with the intensity profile characteristic of the Cl_4 multiplet),[10] 341(65), 339(98), 337(100), 305(6), 303(9), 301(4), 273(8), 257(8), 183(8), 147(9), and 59(29). Compound **3** could be further reduced by LAH to afford **4**. When the mixture of **3** and **4** was further reduced with excess LAH in the manner described above, crude **4** (18·2 g, 96%) was produced free from contamination by **3** (as determined by the absence of absorption at δ 5·00 in the NMR spectrum of this crude product). Recrystallization from chloroform afforded **4** as colorless needles (15·8 g, 82%), m.p. 190–197°. An analytical sample was obtained via further recrystallization of this material from benzene followed by sublimation (140°/0·1 mm). The material thus obtained had m.p. 200·5–201·5°. IR: 3220 (br), 2840 (w), 1440 (m), 1270 (s), 1235 (s), 1120 (s), 1100 (s) and 1010 cm^{-1} (s); NMR (acetone-d_6): δ 3·30 (mult, 6H, OH and methine protons; the OH proton absorptions disappeared upon addition of D_2O), δ 3·57 (s, 3H, $-OC\underline{H}_3$), δ 3·63 (s, 3H, $-OC\underline{H}_3$), and δ 4·45 (br s, 2H,

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*An analogous mechanism has recently been suggested to account for the base-promoted rearrangement of 1,6,7,8 - Tetrachloropentacyclo $[4.3.0.0^{2,5}.0^{3,8}.0^{4,7}]$nonan - 9 - one.[9]

8,11- protons); mass spectrum: *m/e* 382/380/378/376/374 (molecular ion, with the intensity profile characteristic of the Cl_4 multiplet),[10], 343(31), 342(16), 341(94), 340(20), 339(100), 323(17), 321(20), 257(23), 255(49), 253(44), 66(49), 59(31), and 43(33). (Found: C, 41·32; H, 3·73. $C_{13}H_{14}Cl_4O_4$ requires: C, 41·52; H, 3·75%). Further evidence for the *endo,endo* configuration of the 8,11-OH groups in **4** was provided by the fact that a cyclic thiocarbonate of **4** could be prepared (**12**, *vide infra*).

4,4 - *Dimethoxy* - 2,3,5,6 - *tetrachloropentacyclo*[5.4.0.$0^{2,6}$.$0^{3,10}$.$0^{5,9}$]*undecane*-8,11-*thiocarbonate* (**12**). A soln of **4** (3·7 g, 10 mmol) and N,N′-thiocarbonyldiimidazole[11] (1·80 g, 10·1 mmol) in dry toluene (75 ml) was refluxed with stirring under N_2 for 2 hr.[12,13] The solvent was then removed under reduced pressure (rotary evaporator) and the yellow residue was taken up in EtOAc (200 ml). The resulting soln was washed successively with 3·6 N HCl (50 ml), water (50 ml), sat. $NaHCO_3$ aq (50 ml), and water (50 ml). The organic layer was then dried (Na_2SO_4), filtered, and concentrated, affording a tan solid. Recrystallization of the tan solid from benzene-hexane afforded **12** (3·74 g, 89%), m.p. 224–227·5°. An analytical sample of **12** was obtained by sublimation of this material (130°/0·05 mm) followed by several recrystallizations of the sublimate from acetone. Pure **12** was thereby obtained as colorless prisms, m.p. 229–230·5°. IR: 1405 (m), 1305 (s), 1267 (s) and 1232 cm^{-1} (s); NMR ($CDCl_3$): δ 3·43–3·72 (mult, 4H, 1,7,9,10-methine protons), δ 3·52 (s, 3H, $-OC\underline{H}_3$), δ 3·58 (s, 3H, $-OC\underline{H}_3$), and δ 4·95 (symm mult, 8,11-protons); mass spectrum: *m/e* 424/422/420/418/416 (molecular ion, with the intensity profile characteristic of the Cl_4 multiplet),[10] 325(33), 323(100), 321(96), 259(36), 257(50), 183(50), 182(32), 149(48), 125(35), 113(32), 109(33), 75(55), and 63(31). (Found: C, 40·57; H, 2·91. $C_{14}H_{12}Cl_4O_4S$ requires: C, 40·22; H, 2·89%).

12 - *Oxa* - 4,4 - *dimethoxy* - 3,5,9,10 - *tetrachlorohexacyclo*[5.4.1.$0^{2,6}$.$0^{3,10}$.$0^{5,9}$.$0^{8,11}$]*dodecane* (**5**). A mixture of **2** (64 g, 0·17 mol) and *p*-toluenesulfonic acid (5·0 g, 0·029 mol) in dry toluene (600 ml) was refluxed in a Dean-Stark apparatus for 42 hr. During this period, about 400 ml of turbid toluene was removed. Removal of the remaining solvent (rotary evaporator) afforded a tan solid which was taken up in chloroform (600 ml). The resulting soln was washed successively with water (250 ml × 2), 5% $NaHCO_3$ aq (250 ml), and water (250 ml × 2). The organic layer was then dried (Na_2SO_4), filtered, and concentrated (rotary evaporator). The residue was recrystallized from EtOAc to afford a colorless solid (45·7 g, 75%), m.p. 170–189°. An analytical sample of **5** was obtained via further recrystallization of the crude product from acetone. Colorless platelets, m.p. 189–190°, were thereby obtained. IR: 2950 (m), 2840 (w), 1435 (m), 1210 (s), 1090 (s), 1025 (s), and 780 cm^{-1} (s); NMR ($CDCl_3$); δ 3·03–3·23 (mult, 4H, 2,6,8,11-methine protons), δ 3·57 (s, 3H, $-OC\underline{H}_3$), δ 3·63 (s, 3H, $-OC\underline{H}_3$), and δ 5·18 (quintet, 2H, 1,7-methine protons); mass spectrum: *m/e* (molecular ion not observable), 327(7), 325(33), 324(14), 323(97), 322(15), 321(100), 259(11), 257(16), 256(6), 190(6), 188(19), 183(6), 149(7), 125(14), 113(6), 75(6), 63(8), and 59(18). (Found: C, 43·90; H, 3·31. $C_{13}H_{12}Cl_4O_3$ requires: C, 43·61; H, 3·38%).

12 - *Oxa* - 3,5,9,10 - *tetrachlorohexacyclo*[5.4.1.$0^{2,6}$.$0^{3,10}$.$0^{5,9}$.$0^{8,11}$]*dodecane*-4-*one* (**6**). A suspension of **5** (42 g, 0·12 mol) in conc. H_2SO_4 (200 ml) was stirred at room temp. for 48 hr. The mixture was then poured into ice water (1000 ml) and the precipitated solid material was collected, washed with water, and then dried *in vacuo*. Crude **6** (32·1 g, 87·7%) was thereby obtained. Recrystallization of the crude product from benzene-hexane, followed by sublimation (130°/1 mm) afforded an analytical sample of **6** as a colorless, microcrystalline solid, m.p. 198·5–200°. IR: 1795 (s), 1260 (s), 1100 (s), 1025 (s), 1005 (s), 930 (s) and 745 cm^{-1} (s); NMR (acetone-d_6): δ 3·17 (br t, 4H, 2,6,8,11-methine protons) and δ 5·25 (quintet, 2H, 1,7-methine protons); mass spectrum: *m/e* 318/316/314/312/310 (molecular ion, with the intensity profile characteristic of the Cl_4 multiplet),[10] 277(45), 275(44), 249(45), 247(41), 223(34), 221(94), 219(94), 185(72), 183(100), 151(45), 149(91), 133(40), 85(21), and 63(34). (Found: C, 42·21; H, 1·98. $C_{11}H_6Cl_4O_2$ requires: C, 42·34; H, 1·94%).

Reaction of **6** *with sodium hydroxide in toluene.*[5] To a suspension of **6** (12·5 g, 40 mmol) in dry toluene (100 ml) was added crushed NaOH pellets (15 g, excess). The resulting mixture was refluxed with stirring for 2 hr. The cooled mixture was poured into ice water (600 ml), the layers were separated, and the aqueous layer was extracted with diethyl ether (200 ml). The aqueous soln was acidified with excess conc. HCl soln, whereupon a solid material precipitated. The solid was taken up in diethyl ether (500 ml), and the resulting soln was extracted with 5% $NaHCO_3$ aq (100 ml × 2). The aqueous soln was acidified and then extracted with diethyl ether (100 ml × 3). The combined extracts were washed with water, dried (Na_2SO_4), filtered, and then evaporated to afford crude **7a** as a tan solid. Recrystallization of this material from diethyl ether-hexane afforded pure **7a** (10·6 g, 80·2%), m.p. 242–245° (dec). IR: 3000 (br, s) and 1725 cm^{-1}(s); NMR (acetone-d_6): δ 3·03–3·47 (mult, 4H, 2,7,9,10-methine protons). δ 4·50 (s, 1H, 6-$C\underline{H}Cl$), and δ 5·27–5·60 (mult, 2H, 1,8-methine protons); mass spectrum: *m/e* (molecular ion not observable), 201(25), 187(47), 185(83), 151(43), 149(100), 73(33), 68(25), 60(26), 57(30), 55(27), 44(48), 43(43), 41(28), 39(25), 38(60), and 36(73). Acid **7a** was further characterized via its methyl ester (**7b**). Acid **7a** (1 g, 3 mmol) was refluxed with thionyl chloride (10 ml, excess) for 28 hr. After this period, the mixture was cooled and dry MeOH (20 ml, excess) was added dropwise over a 30 min period. Refluxing was resumed and continued for an additional 12 hr. The mixture was then concentrated (rotary evaporator). The residue was taken up in diethyl ether, washed first with 5% $NaHCO_3$ aq and then with water, and then dried (Na_2SO_4). The solution was then filtered and concentrated, affording an oily material which recrystallized from benzene-hexane to afford **7b** (610 mg, 59%) as colorless needles, m.p. 104–107°. Sublimation (90°/1 mm) followed by recrystallization of the sublimate from hexane afforded an analytical sample of **7b** as colorless platelets, m.p. 107–108°. IR: 1745 (s), 1425 (m), 1295 (s), 1235 (s) and 1005 cm^{-1} (s); NMR ($CDCl_3$): δ 2·83–3·40 (mult, 4H, 2,7,9,10-methine protons), δ 3·88 (s, 3H, $-OC\underline{H}_3$), δ 4·10 (d, 1H, 6-$C\underline{H}Cl$), and δ 5·22–5·60 (mult, 2H, 1,7-methine protons); mass spectrum: *m/e* 350/348/346/344/342 (molecular ion, with the intensity profile characteristic of the Cl_4 multiplet),[10] 326(32), 309(45), 307(51), 291(32), 290(39), 289(35), 288(33), 207(37), 206(38), 205(48), 204(56), 185(32), 183(41), 173(31), 151(37), 149(100), 115(49), 105(33), 103(93), 75(31), 68(27), and 59(66). (Found: C, 42·01; H, 2·94. $C_{12}H_{10}Cl_4O_3$ requires: C, 41·89; H, 2·93%).

Reaction of **6** *with sodium hydroxide in tetrahydrofuran.*[14] To a soln of **6** (0·56 g, 1·8 mmol) in freshly distilled THF (14 ml) maintained at 0–5° via external cooling (ice bath) was added crushed NaOH pellets (1 g). The resulting mixture turned milky after *ca.* 20 min. The ice bath was then removed, and the mixture was stirred overnight at ambient temp. The mixture was then poured into cold 1·5 N HCl acid (30 ml), and the resulting mixture was extracted with diethyl ether (15 ml × 3). The combined ethereal extracts were washed with water and then dried (Na_2SO_4), filtered, and concentrated, affording a viscous oil (0·53 g) which solidified on standing. The IR and NMR spectra of this material were identical in all respects with those of **7a**. The yield of **7a** in this reaction was 89·8%.

Reaction of **6** *with sodium hydroxide in benzene.* A mixture of crushed NaOH pellets (1 g) and benzene (50 ml) was dried via azeotropic distillation (Dean–Stark apparatus). To the resulting mixture was added **6** (1·0 g, 3·2 mmol), and the mixture was refluxed for 20 hr. The usual workup followed by recrystallization of the product from diethyl ether-hexane afforded a colorless solid (0·74 g) which was identical in all respects with **7a**. The yield of **7a** in this reaction was 70%.

Reaction of **6** *with sodium methoxide in benzene.* MeOH was dried by refluxing over Mg turnings in the presence of a few crystals of I_2 for 3 days.[15] To freshly-distilled dry MeOH (excess) was added Na metal (1 g); after the reaction subsided, the excess MeOH was removed under reduced pressure, and dried benzene (180 ml) was added to the residue. The resulting mixture was dried via azetropic distillation (Dean–Stark apparatus). Ketone **6** (1·25 g, 4·0 mmol) was then added, and the mixture was refluxed with stirring for 24 hr. Workup afforded only unreacted **6** (*ca.* 1·2 g); no other product could be detected.

Reaction of **6** *with aqueous sodium hydroxide.*[16] Compound **6** (630 mg, 2·0 mmol) was refluxed with 25% NaOH aq (10 ml) for 12 hr. The mixture was then cooled to 0° (ice bath) and acidified via dropwise addition of excess conc. HCl The mixture was then extracted with EtOAc, and the organic layer was washed with 5% $NaHCO_3$ aq (15 ml × 2). The combined aqueous washings were acidified and then extracted with EtOAc. The organic layer was washed (H_2O), dried (Na_2SO_4), filtered, and then concentrated, affording **8a** (385 mg, 66·5%). Recrystallization from EtOAc-hexane afforded pure **8a** (330 mg, 57·4%) as a colorless microcrystalline solid, m.p. 271–275° (dec); IR: 3300–2500 (br), 1730 (sh), 1705 (s), 1450 (s), 1310 (s), 1290 (s), 1260 (s), 1200 (s), 1065 (m), 1015 (s) and 910 cm^{-1} (s); NMR (DMSO-d_6): δ 3·17 (mult, 4H, 2,6,9,10-methine protons) and δ 4·80–5·13 (mult, 3H, 3,5,7-methine protons); mass spectrum: *m/e* 278/276/274 (molecular ion, with the intensity profile characteristic of the Cl_2 multiplet),[10] 231(69), 229(100), 203(29), 201(46), 195(28), 194(28), 167(28), 165(40), 101(16), 89(17), 77(34), 75(29), 73(16), 63(25), 51(65), 50(26), 45(30) and 39(36). Acid **8a** was further characterized via its methyl ester. Acid **8a** (167 mg, 0·572 mmol) was treated with thionyl chloride (*ca.* 2 ml, excess), and the mixture was refluxed for 22 hr. After this period, dry MeOH (5 ml, excess) was added dropwise to the cooled mixture over a 10 min period. The resulting soln was then refluxed for 5 hr. The mixture was then concentrated, and the solid residue was taken up in diethyl ether (30 ml) and washed successively with water (10 ml), 5% $NaHCO_3$ aq (10 ml × 2) and water (10 ml × 2). The organic layer was dried ($MgSO_4$), filtered, and concentrated (rotary evaporator), affording crude **8b** (108 mg, 63%). Recrystallization from benzene-hexane afforded an analytical sample of **8b** as colorless platelets, m.p. 138·0–138·5°. IR: 3030 (w), 1752 (s), 1430 (m), 1110 (s) and 1025 cm^{-1} (s); NMR ($CDCl_3$): δ 3·28 (mult, 4H, 2,6,9,10-methine protons), δ 3·93 (s, 3H, $-OC\underline{H}_3$), δ 4·90 (br t, 1H, 7-methine proton) and δ 4·90–5·20 (m, 2H, 3,5-methine protons); mass spectrum: *m/e* 292/290/288 (molecular ion, with the intensity profile characteristic of the Cl_2 multiplet),[10] 231(61), 229(100), 203(26), 201(42), 194(17), 165(41), 137(25), 117(27), 115(77), 102(24), 101(19) and 51(19). (Found: C, 49·87; H, 3·14. $C_{12}H_{10}Cl_2O_4$ requires: C, 49·85; H, 3·49%).

4,13 - *Dioxa* - 1,8,11 - *trichlorohexacyclo*$[5.4.2.0^{2,6}.0^{3,10}.0^{5,9}.0^{8,11}]$*tridecane*-12-*one* (**11**). A mixture of acid **7a** (2·5 g, 7·6 mmol) and $BaCO_3$ (*ca.* 1 g) in 95% EtOH (50 ml) was refluxed with stirring for 44 hr. After this period, the mixture was poured into ice water (100 ml), and the resulting mixture was filtered to remove insoluble material. The solid residue was then washed with EtOAc (50 ml). The layers in the filtrate were separated, and the aqueous layer was extracted with EtOAc (50 ml × 2). The combined extracts were washed (H_2O), dried ($MgSO_4$), filtered, and then concentrated, affording crude **11** (1·95 g, 78·4%). Recrystallization from EtOAc afforded pure **11** as colorless prisms, m.p. 294·5–295·5°. IR: 1778 (s), 1085 (s), 1025 (s) and 1000 cm^{-1} (s); NMR (DMSO-d_6): δ 3·07–3·53 (mult, 4H, 2,6,9,10-methine protons) and δ 5·10–5·53 (mult, 3H, 3,5,7-methine protons); mass spectrum: *m/e* 298/296/294/292 (molecular ion, with the intensity profile characteristic of the Cl_3 multiplet),[10] 221(21), 219(21), 187(60), 185(100), 183(18), 151(51), 149(95), 115(24) and 68(17). (Found: C, 44·79; H, 2·29. $C_{11}H_7Cl_3O_3$ requires: C, 45·01; H, 2·40%).

Reaction of **11** *with aqueous sodium hydroxide solution.* Compound **11** (400 mg; 1·36 mmol) was refluxed with 25% NaOH aq (5 ml, excess) for 5 hr. Workup afforded a colorless solid (267 mg), m.p. 274–276° (dec). The IR and NMR spectra of this solid were identical in all respects with those of **8a**. The yield of **8a** in this reaction was 71·4%.

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REFERENCES

[1] Part I: A. P. Marchand and T.-C. Chou, *J. Chem. Soc.* Perkin I, 1948 (1973).

[2] P. E. Eaton and T. W. Cole, Jr., *J. Am. Chem. Soc.* **86**, 962, 3157 (1964).

[3] W. G. Dauben, J. L. Chitwood and K. V. Scherer, Jr., *Ibid.* **90**, 1014 (1968).

[4] G. L. Dunn, V. J. DiPasquo and J. R. E. Hoover, *J. Org. Chem.* **33**, 1454 (1968).

[5] R. J. Stedman, L. S. Miller, L. D. Davis and J. R. E. Hoover, *Ibid.* **35**, 4169 (1970).

[6] N. B. Chapman, J. M. Key and K. J. Toyne, *Ibid.* **35**, 3860 (1970).

[7] R. C. Cookson, E. Crundwell, R. R. Hill and J. Hudec, *J. Chem. Soc.* 3062 (1964).

[8] T. Sasaki, S. Eguchi, T. Kiriyama and O. Hiroaki, *Tetrahedron* **30**, 2707 (1974).

[9] W. G. Dauben and L. N. Reitman, *J. Org. Chem.*, **40**, 841 (1975).

[10] J. H. Beynon, *Mass Spectrometry and its Applications to Organic Chemistry* pp. 298–299. Elsevier, New York (1960).

[11] H. A. Staab and G. Walther, *Liebigs Ann.* **657**, 98 (1962).

[12] E. J. Corey and R. A. E. Winter, *J. Am. Chem. Soc.* **85**, 2677 (1963).

[13] L. A. Paquette, J. C. Phillips and R. E. Wingard, Jr., *Ibid.* **93**, 4516 (1971).

[14] K. V. Scherer, Jr., *Tetrahedron Letters* 5685 (1966).

[15] A. I. Vogel, *A Text-Book of Practical Organic Chemistry* (3rd Edn) p. 169–170. Longmans, Green (1956).

[16] T. Y. Luh and L. M. Stock, *J. Org. Chem.* **37**, 338 (1972).