

The Bird-Cage Ketone, Hexacyclo[5.4.1.0^{2,6}.0^{3,10}.0^{5,9}.0^{8,11}]dodecan-4-one, and Some of Its Derivatives

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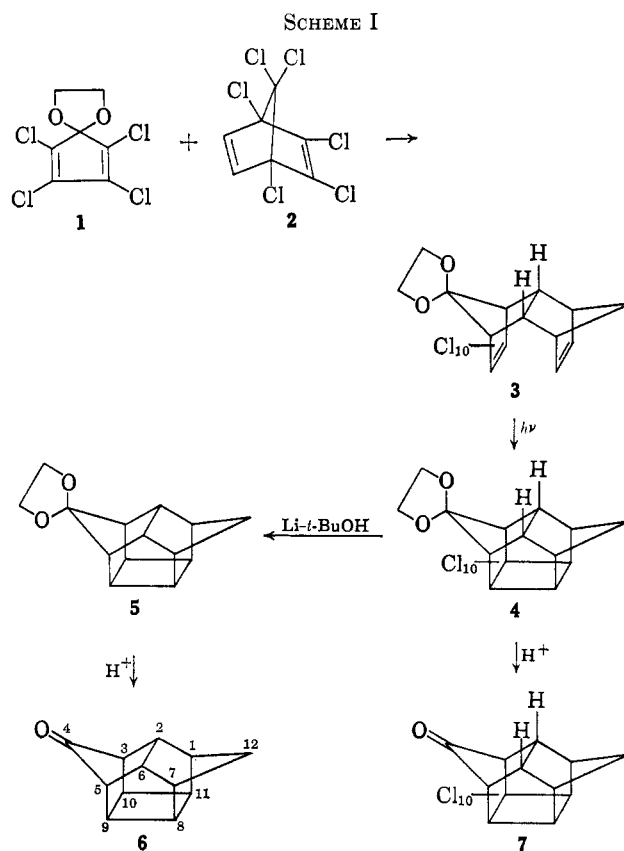
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The bird-cage ketone (6), its cyclic ethylene ketal (5), and various chlorinated derivatives of these compounds have been prepared. Two synthetic routes were employed, both involving stereoselective Diels-Alder reactions leading to chlorinated *endo,endo*-dimethanonaphthalene ketals (3 and 10). These were cyclized photochemically to the cage ketals 4 and 11, both of which could be dehalogenated with lithium to give 5. The nmr spectra of 5 and 6 showed unexpected shielding of two of the cage methine protons by the functional groups.

In the course of a program designed to investigate the biological activity of a variety of cage compounds, we needed to devise a synthesis of the bird-cage ketone 6.¹ To date, rather few derivatives of the parent bird-cage hydrocarbon² have been reported. Various halogenated bird cages are known³⁻⁶ and hydroxyl^{4,7} and amino⁸ substituents have been introduced on the cyclobutane ring of the cage. Preparation of the ketone opens the way to the synthesis of a variety of derivatives substituted on the methylene bridge.

The most practical synthetic route to the bird-cage hydrocarbon uses the insecticide isodrin, a chlorinated hexahydro-*endo,endo*-dimethanonaphthalene (carbon skeleton as in 3), which has two double bonds in very close proximity and is readily cyclized, either chemically or photochemically,⁴⁻⁶ to a chlorinated bird-cage derivative. This in turn may be dehalogenated to the hydrocarbon.^{4,5} Isodrin is prepared by the Diels-Alder addition of hexachloronorborene 2 to cyclopentadiene.^{9,10} The unusual stereochemistry of this addition^{4,6,11} is an exception to the generalization that a norbornene dienophile presents its *exo* face to a diene. This behavior is attributable to the steric hindrance which the bulky *gem*-dichloro group of 2 offers to reagents approaching its *exo* side; unsubstituted norbornadiene reacts with cyclopentadiene in the normal manner. The addition, however, does obey the rule that the substituents on a dienophile take up the *endo* position in the norbornene system generated by addition to cyclopentadiene. The availability of the ethylene ketal of tetrachlorocyclopentadienone (1), a reactive diene,¹² suggested that 6 might best be approached by constructing a chlori-

nated bird-cage ketal using a reaction sequence governed by the above stereochemical principles. It seemed likely that dechlorination and removal of the ketal protecting group would present no great problem.¹³ Two parallel synthetic routes (Schemes I and II) were developed along these lines, proceeding through the ketal 5 as a common intermediate.



(1) The naming of other bird-cage derivatives by *Chemical Abstracts* suggests that 6 will be indexed as decahydro-1,5,2,4-ethanediyliidencyclopenta[*cd*]pentalen-3-one. See Scheme I for the numbering used in this paper.

(2) S. Winstein, *Experientia, Suppl.*, **2**, 137 (1955).

(3) R. E. Lidov and H. Bluestone, U. S. Patent 2,714,617 (1955).

(4) S. B. Soloway, A. M. Damiana, J. W. Sims, H. Bluestone, and R. E. Lidov, *J. Am. Chem. Soc.*, **82**, 5377 (1960).

(5) P. Bruck, D. Thompson, and S. Winstein, *Chem. Ind. (London)*, 405 (1960).

(6) C. W. Bird, R. C. Cookson, and E. Crundwell, *J. Chem. Soc.*, 4809 (1961).

(7) (a) P. Carter, R. Howe, and S. Winstein, *J. Am. Chem. Soc.*, **87**, 914 (1965); (b) T. Fukunaga, *ibid.*, **87**, 916 (1965).

(8) R. J. Stedman, A. C. Swift, and J. R. E. Hoover, *Tetrahedron Letters*, 2525 (1965).

(9) (a) H. Bluestone, U. S. Patent 2,676,132 (1954); (b) R. E. Lidov, U. S. Patent 2,717,851 (1955); (c) Arvey Corp., British Patent 714, 688 (1954).

(10) A closely related Diels-Alder addition has been described by K. Mackenzie [*J. Chem. Soc.*, 457 (1962)].

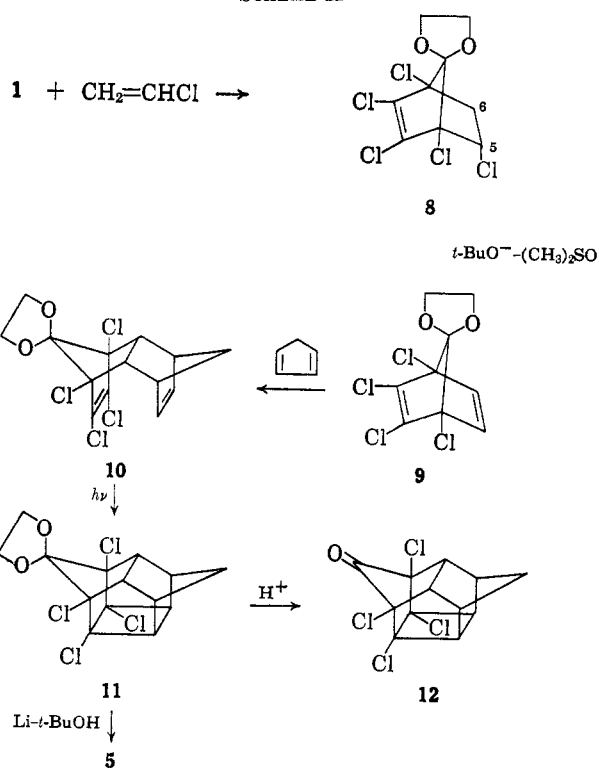
(11) See J. G. Martin and R. K. Hill, *Chem. Rev.*, **61**, 537 (1961), for a review of the stereochemistry of the Diels-Alder reaction, including a discussion of the synthesis of isodrin.

(12) (a) W-H. Chang, *Chem. Ind. (London)*, 709 (1964); (b) W-H. Chang, *J. Chem. Soc.*, 2305 (1965).

In the more direct, and preferred, procedure (Scheme I) 2 was added to 1 in a Diels-Alder reaction to give the decachloro ketal adduct 3. The yield of 3 was poor because of competitive dimerization of 1. The *endo,endo* stereochemistry of 3 was confidently expected on the basis of the stereochemical considerations discussed above and was proven by its ready photochemical cyclization to the corresponding cage compound 4. Dechlorination of 4 with lithium and *t*-butyl alcohol⁵ gave the bird-cage ketal 5. In the alternative sequence (Scheme II), 1 was converted into the norbornene

(13) Dehalogenation of a somewhat more strained ketal, a bishomocubane derivative, has been accomplished, albeit in low yield, by G. W. Griffin and A. K. Price [*J. Org. Chem.*, **29**, 3192 (1964)].

SCHEME II



derivative **8** by a Diels–Alder reaction with vinyl chloride. The stereochemistry of **8** at C-5 is assumed to be as shown on the basis of the *endo* rule¹¹ and the strong spin–spin coupling of the proton at C-5 with the downfield (presumably *exo*)¹⁴ proton of the C-6 methylene group.¹⁵ After some failures with weaker bases, dehydrohalogenation of **8** to the norbornadiene **9** was achieved with potassium *t*-butoxide in dimethyl sulfide.^{16,17} The stereochemistry of the next step, the Diels–Alder addition of **9** to cyclopentadiene, could not be predicted with confidence, since it was not certain that the steric influence of the ethylene ketal group at C-7 would be as great as that of the corresponding 7-*gem*-dichloro group in **2**. Indeed, the high reactivity of **1** as a diene has been associated with the compactness of its cyclic ketal group.¹² However, the only product isolated from the addition was **10**, which, since it was easily cyclized to **11** on irradiation, must have the *endo,endo* configuration shown. The yield of **10** was poor; thermal decomposition¹⁷ of **9** during the prolonged reaction time may have been a contributory factor. Dechlorination of **11** gave **5**, identical with material prepared according to Scheme I.

Acid hydrolysis of the ketal **5** gave the desired ketone **6** as a high-melting, volatile solid. The decachloro

(14) (a) R. R. Fraser, *Can. J. Chem.*, **40**, 78 (1962); (b) K. L. Williamson, *J. Am. Chem. Soc.*, **85**, 516 (1963); (c) P. Laszlo and P. von R. Schleyer, *ibid.*, **86**, 1171 (1964); (d) J. C. Davis, Jr., and T. V. Van Auken, *ibid.*, **87**, 3900 (1965).

(15) The protons on C-5 and C-6 constitute an ABX system, but, since $\Delta\delta_{AB}/J_{AB}$ is quite large (*ca.* 4), approximate values for the vicinal coupling constants, J_{AX} and J_{BX} , can be determined by first-order analysis. The magnitude of the *cis* coupling constant (*ca.* 8 cps) provides further evidence for the proposed stereochemistry, since it is more consistent with a *cis,exo* than a *cis,endo* relationship of the eclipsing protons.^{14d}

(16) Unsuccessful attempts to dehydrohalogenate a 5-halonorbornene ketal with milder bases were noted by P. E. Hoch [*J. Org. Chem.*, **26**, 2066 (1961)], although the successful use of potassium *t*-butoxide in *t*-butyl alcohol in a favorable case has been reported by R. W. Hoffman and H. Häuser, [*Tetrahedron*, **21**, 891 (1965)].

(17) An alternative synthesis of **9** has since been reported by K. MacKenzie [*J. Chem. Soc.*, 5710 (1964)].

(**7**) and the tetrachloro (**12**) derivatives of **6** were also prepared by acid cleavage of the appropriate chlorinated ketals. Very vigorous conditions were required for the cleavage of the decachloro ketal **4**, and the resulting ketone **7** rapidly formed a hydrate on exposure to the atmosphere.

The infrared carbonyl-stretching wavelengths of the three ketones **6**, **7**, and **12** are of interest. The difference (0.12 μ) between **6** and **12** (ignoring the possible effect of changing the solvent) is in accordance with expectations for the influence of two chlorine atoms α to the carbonyl group and coplanar with it.¹⁸ The further shortening of the wavelength (0.09 μ) in **7** must be attributed to the six additional chlorine atoms at a greater distance from the carbonyl group. The effect of these chlorines is also seen in the apparently greater aversion shown by **7** than by **12** to the trigonal state, as evidenced by the resistance of its ketal to cleavage and its strong tendency to hydrate.

The nmr spectra of ketal **5** and ketone **6** are compared with the spectrum of the bird-cage hydrocarbon in Table I. Both **5** and **6** show the appropriate ratio of

TABLE I
NMR SPECTRA OF BIRD-CAGE COMPOUNDS

	Methylene protons ^a	Upfield methine protons ^b	Remaining methine protons ^c
Hydrocarbon ^d			
δ_{CDCl_3}	1.65	...	2.2–2.7
$\delta_{\text{C}_6\text{H}_6}$	1.62	...	2.2–2.7
Ketal 5 ^e			
δ_{CDCl_3}	1.57	2.03	2.3–2.9
$\delta_{\text{C}_6\text{H}_6}$	1.54	2.11	2.2–3.1
Ketone 6			
δ_{CDCl_3}	1.61	2.10	2.45–3.1
$\delta_{\text{C}_6\text{H}_6}$	1.27	1.96	2.05–2.7

^a Center of AB pattern, $J = 10$ cps. ^b Hump or broad singlet. ^c Broad envelope. ^d Reference 5. ^e 4 H singlet (OCH₂CH₂O) at δ_{CDCl_3} 3.90, $\delta_{\text{C}_6\text{H}_6}$ 3.53.

methylene to methine protons. However, in chloroform solution, both compounds have two methine protons resonating substantially upfield (*ca.* 0.3 ppm) from the general methine envelope and, indeed, at higher field than any of the methine protons in the parent hydrocarbon. The special location of the two protons α to the carbonyl and ketal functions suggests that, contrary to normal expectations, these may be the ones responsible for the upfield signals. This belief is confirmed by the absence of any upfield methine signals in the spectra of the tetrachloro derivatives **11** and **12**. Since solvent shifts in conformationally fixed ketones have been extensively investigated,¹⁹ it is possible to strengthen the assignment of the anomalous methine peaks in **6** by comparing its spectra in chloroform and benzene. In the latter solvent, the methylene quartet and the methine envelope are displaced 0.3–0.4 ppm upfield from their positions in chloroform, while the up-

(18) L. J. Bellamy, "The Infrared Spectra of Complex Molecules," 2nd ed, John Wiley and Sons, Inc., New York, N. Y., 1958, pp 139–141.

(19) (a) N. S. Bhacca and D. H. Williams, *Tetrahedron Letters*, 3127 (1964); (b) J. D. Connolly and R. McCrindle, *Chem. Ind. (London)*, 379 (1965); (c) D. H. Williams and N. S. Bhacca, *Tetrahedron*, **21**, 1641 (1965); (d) D. H. Williams and N. S. Bhacca, *ibid.*, **21**, 2021 (1965); (e) S. Bory, M. Fétizon, P. Laszlo, and D. H. Williams, *Bull. Soc. Chim. France*, 2541 (1965); (f) D. H. Williams and D. A. Wilson, *J. Chem. Soc., B*, 144 (1966).

field methine signal is displaced by only 0.14 ppm. This small solvent shift is appropriate for the α protons, which lie close to a plane perpendicular to the C-O axis and passing through the trigonal carbon atom.²⁰ Unexpected net shielding²¹ of coplanar α protons by a carbonyl group has been discussed in the case of cyclic α -halo ketones,²² and has recently been noted in a strained cage system.²³ Such shielding seems to occur when other factors, *i.e.*, the proximity of an electronegative substituent or attachment to a highly strained system,²⁴ are tending to deshield the protons, though these factors may, of course, be exerting their influence in other ways, *e.g.*, through their effect on the C-O bonding. In strain-free, nonhalogenated cyclic ketones, the equatorial α protons may sometimes resonate at higher field than their axial counterparts,²⁵ but net deshielding by the carbonyl group is not found and even the anomalous axial-equatorial relationship is not always observable.²⁶ The assignment of the upfield methine signal in the ketal **5** is less secure than in **6**, since systematic solvent shifts are not available to assist in interpreting the spectrum. In fact, the spectrum of the cage protons in **5**, like that of the bird-cage hydrocarbon, is essentially the same in benzene as in chloroform. Net shielding of α protons by a ketal group, if this is indeed what is occurring, does not seem to have been previously discussed.²⁷ De Jongh and Wynberg²⁸ have reported a case in which equatorial protons situated α to a thio ketal group resonate at higher field than their axial counterparts, but it is not clear that this anomalous relative shift is directly attributable to the influence of the thio ketal function.

Experimental Section²⁹

1,2,3,4,5,6,7,8,10,10-Decachloro-1,4,4a,5,8,8a-hexahydro-1,4-endo-endo-5,8-dimethanonaphthalen-9-one, Cyclic Ethylene Ketal (3).—To 460 g (1.40 moles) of **2**³⁰ heated in a bath at 145° was

(20) The main methine envelope maintains the same general shape in both solvents. It is still, however, possible that there are relative shifts within it and that some of the protons in the envelope have quite a small solvent shift. Therefore, we cannot be certain that the anomalous upfield signal is the only absorption which qualifies for assignment to the α protons.

(21) That is, the protons in question resonate at lower field if the carbonyl group is replaced by methylene.

(22) (a) A. Nickon, M. A. Castle, R. Harada, C. E. Berkoff, and R. O. Williams, *J. Am. Chem. Soc.*, **85**, 2185 (1963); (b) K. M. Wellman and F. G. Bordwell, *Tetrahedron Letters*, 1703 (1963).

(23) (a) G. L. Dunn, V. J. DiPasquo, and J. R. E. Hoover, *ibid.*, 3737 (1966); (b) R. C. Fort, Jr., and P. von R. Schleyer [*J. Org. Chem.*, **30**, 789 (1965)] have reported that the unstrained ketone, adamantanone, shows the expected deshielding of the α protons.

(24) Deshielding of methine protons on strained cage systems (relative to unstrained systems) seems to be generally observed; see examples in ref 23a and 27a. It may perhaps be ascribed to the anisotropic effect of the three C-C bonds lying unusually close to the C-H axis.

(25) B. Waegell, *Bull. Soc. Chim. France*, 855 (1964).

(26) N. S. Bhacca, J. E. Gurst, and D. H. Williams, *J. Am. Chem. Soc.*, **87**, 302 (1965). These authors point out, however, that observation of the influence of the carbonyl group is subject to interference by other molecular features.

(27) (a) The spectrum of a bromohomocubane ketal, published without comment by P. E. Eaton and T. W. Cole, Jr. [*J. Am. Chem. Soc.*, **86**, 3157 (1964)] apparently shows this phenomenon. (b) M. Anteunis, D. Tavernier, and F. Borremans [*Bull. Soc. Chim. Belges*, **75**, 396 (1966)] have discussed the anisotropy of oxygen p orbitals as a possible cause of deshielding of protons lying close to the extended axes of these orbitals. If this is the explanation of the deshielding seen in the present case, the effect should be found only in those ketals (generally cyclic) in which the oxygen atoms are constrained in such a way that their p-orbital axes pass close to the α protons. The nmr spectra of the dimethyl ketals of two pentacyclodecanones, reported by G. W. Griffin and A. K. Price [*J. Org. Chem.*, **29**, 3192 (1964)], show in one case deshielding of two cage protons and in the other shielding of a single cage proton. Definition of the factors leading to shielding or deshielding by ketal groups will require further study.

(28) H. A. P. De Jongh and H. Wynberg, *Tetrahedron*, **21**, 515 (1965).

added 45 g (0.172 mole) of **1**¹² in portions, over a period of 4 hr. After heating for a further 3 hr, the mixture was diluted with 1 l. of methanol and the resulting solid was collected and stirred with 2 l. of cyclohexane at room temperature. After removal of the insoluble material (dimeric **1**) and decolorization with charcoal, the solution was evaporated and the residue was recrystallized from 2-propanol to give 17.4 g (18%) of **3**, mp 229–232°. Further recrystallization from ethanol gave material with mp 231–232°; infrared absorption (mull) at 6.22 μ (C=C); nmr peaks (CDCl₃) at δ 3.93 (2 H singlet, 4a- and 8a-CH) and at 4.30 (4 H A₂B₂ pattern, OCH₂CH₂O).

Anal. Calcd for C₁₄H₈Cl₁₀O₂: C, 29.99; H, 1.08. Found: C, 30.23; H, 0.99.

1,3,5,7,8,9,10,11,12,12-Decachlorohexacyclo[5.4.1.0^{2,6}.0^{3,10}.0^{5,9}.0^{8,11}]dodecan-4-one, Cyclic Ethylene Ketal (4).—A solution of 15.5 g (0.0276 mole) of **3** in 800 ml of acetone was irradiated for 1 hr under nitrogen with a 450-w Hanovia medium-pressure mercury vapor lamp contained in a water-cooled quartz immersion well. Evaporation of the solvent and trituration of the residue with methanol gave 13.3 g (86%) of **4**, mp 181–185°. Recrystallization from ethanol raised the melting point to 186–188°; no infrared absorption (mull) in olefin stretching region; nmr signals (CDCl₃) at δ 3.79 (2 H singlet, 2- and 6-CH) and at 4.33 (4 H singlet, OCH₂CH₂O).

Anal. Calcd for C₁₄H₈Cl₁₀O₂: C, 29.99; H, 1.08; mol wt, 568.8. Found: C, 30.27; H, 1.20; mol wt (osmometric), 558.2.

1,2,3,4,5-Pentachlorobicyclo[2.2.1]hept-2-en-7-one, Cyclic Ethylene Ketal (8).—A mixture of 70 g (0.267 mole) of **1**¹² and 280 ml (4.12 moles) of vinyl chloride was heated in a sealed bomb at 100° for 36 hr. The excess vinyl chloride was allowed to evaporate and the bomb was washed out with benzene. The benzene solution, after filtration if necessary, was evaporated and the residue was recrystallized from hexane to give 69.4 g (80%) of **8**, mp 87–90°. Recrystallization from hexane and sublimation at 70° (0.07 mm) gave material with mp 88–90°; infrared absorption (mull) at 6.25 μ (C=C); nmr signals (CDCl₃) at δ 2.50 (2 H AB pattern, *J* = 13 cps, all peaks split into doublets, upfield portion with 3.5 cps and downfield portion with 8-cps separation, 6-CH₂), at 4.24 (4 H broad singlet, OCH₂CH₂O), and at 4.63 (1 H doublet of doublets, 5-CHCl).

Anal. Calcd for C₉H₇Cl₅O₂: C, 33.32; H, 2.17. Found: C, 33.57; H, 2.12.

1,2,3,4-Tetrachlorobicyclo[2.2.1]hepta-2,5-dien-7-one, Cyclic Ethylene Ketal (9).—To 20 g (0.178 mole) of potassium *t*-butoxide in 100 ml of dimethyl sulfoxide was added, with stirring, 20 g (0.0616 mole) of **8** in one portion. The reaction flask was immediately cooled in ice, the internal temperature rising to 60°. When 30 sec had elapsed after the addition of **8**, the dark solution was poured into 600 ml of ice-water.³² The mixture was extracted with 1:1 benzene-ether (centrifugation), and the extracts were washed with water, dried (MgSO₄), and evaporated to a dark oil. This was dissolved in benzene and stirred for 10 min with 60 g of Woelm grade I neutral alumina. Evaporation of the benzene gave a yellow oil, which crystallized on adding petroleum ether and cooling to -70°, giving 7.80 g of **9** (44%), mp 43–46°. Sublimation at 45° (0.07 mm) gave material with mp 45–47° (lit.¹⁷ mp 43–45°); infrared absorption (mull) at 6.24 μ (C=C); nmr peaks (CCl₄) at δ 4.18 (4 H singlet, OCH₂CH₂O) and at 6.49 (2 H singlet, CH=CH).

(29) Corrected capillary melting points are reported. Spectra were determined with the following instruments: a Perkin-Elmer Infracord (infrared in mull); a Perkin-Elmer Model 521 grating spectrophotometer (infrared in solution); a Varian A-60 spectrometer (nmr; 5–10% solutions where solubility permitted; TMS as internal standard); and a Hitachi Perkin-Elmer RMU-6D mass spectrometer (operated by the Morgan-Schaffer Corp., Montreal, Canada). Molecular weights were determined with a Mechrolab Model 301A vapor pressure osmometer. Petroleum ether refers to the fraction with bp 30–60°. *t*-Butyl alcohol used in dehalogenation experiments was dried over Linde 4A Molecular Sieve, and tetrahydrofuran over a mixture of 4A and 13X sieves.

(30) Shell technical grade, 91% purity.

(31) Larger scale runs were not satisfactory because of difficulty in controlling the temperature.

(32) While this work was in progress the dimethyl ketal corresponding to **8** was mentioned in the literature [P. G. Gassman and W. M. Hooker, *J. Am. Chem. Soc.*, **87**, 1079 (1965)], but the method of preparation was not given. We are indebted to Dr. Gassman (private communication) for the information that a similar *t*-butoxide-dimethyl sulfoxide dehydrohalogenation was used to obtain this compound and that a very short reaction time was beneficial. In our hands, longer exposure of **8** to the basic reagent had been giving variable yields of **9**.

Anal. Calcd for $C_9H_6Cl_4O_2$: C, 37.54; H, 2.10. Found: C, 37.88; H, 2.10.

5,6,7,8-Tetrachloro-1,4,4a,5,8,8a-hexahydro-1,4-endo-endo-5,8-dimethanonaphthalen-9-one, Cyclic Ethylene Ketal (10).—A mixture of 26 g (0.0903 mole) of 9 and 26 ml of cyclopentadiene³³ was heated in a bath at 70° for 6 hr. A further 25 ml of cyclopentadiene was then added and heating was continued for another 17 hr. The mixture was evaporated at 70° (0.3 mm) to remove accumulated cyclopentadiene dimer and the oily residue was treated as before with a further 51 ml of the monomer in two portions. Evaporation of the dimer and treatment of the residue with a little petroleum ether gave a first crop of crystalline 10. The mother liquors were evaporated and the residue was heated at 70° with a further 30 ml of cyclopentadiene for 18 hr. Evaporation and addition of petroleum ether as before gave a second crop of 10. The two crops amounted to 6.39 g (20%), mp 131–135°. A further treatment of the residue with cyclopentadiene gave a little more product of lower purity. Recrystallization from petroleum ether and sublimation at 100° (0.15 mm) gave material with mp 136–138°; infrared absorption (mull) at 6.28 μ (C=O); nmr signals ($CDCl_3$) at δ 1.57 (2 H AB pattern, $J = 8$ cps, downfield portion partially resolved into triplets, 10-CH₂), at 2.97 and 3.16 (partially resolved quartet and triplet, respectively, 2 H each, 1,4,4a and 8a-CH), at 4.21 (4 H A₂B₂ pattern, OCH₂CH₂O), and at 6.01 (2 H partially resolved triplet, CH=CH).

Anal. Calcd for $C_{14}H_{12}Cl_4O_2$: C, 47.49; H, 3.42. Found: C, 47.57; H, 3.24.

3,5,9,10-Tetrachlorohexacyclo[5.4.1.0^{2,6}.0^{3,10}.0^{5,9}.0^{8,11}]dodecan-4-one, Cyclic Ethylene Ketal (11).—A solution of 2.60 g (7.34 mmoles) of 10 in 500 ml of acetone was irradiated for 40 min under the conditions described in the preparation of 4. Evaporation of the acetone and trituration of the residue with methanol gave 2.11 g (81%) of 11, mp 162–165°. Recrystallization from methanol gave material with mp 164–166°; no infrared absorption (mull) in olefin stretching region; nmr signals ($CDCl_3$) at δ 1.72 (2 H AB pattern, $J = 11.5$ cps, 12-CH₂), at 3.00 (6 H singlet 1-, 2-, 6-, 7-, 8-, and 11-CH) and at 4.22 (4 H singlet, OCH₂CH₂O).

Anal. Calcd for $C_{14}H_{12}Cl_4O_2$: C, 47.49; H, 3.42; mol wt, 354.1. Found: C, 47.52; H, 3.36; mol wt (osmometric), 357.1.

Hexacyclo[5.4.1.0^{2,6}.0^{3,10}.0^{5,9}.0^{8,11}]dodecan-4-one, Cyclic Ethylene Ketal (5). A. **From 4.**—To a solution of 13.3 g (0.0237 mole) of 4 in 200 ml of dry tetrahydrofuran were added 45 ml (0.48 mole) of dry *t*-butyl alcohol and 6.60 g (0.951 g-atom) of lithium wire, cut into small pieces. The reaction mixture was kept under nitrogen. A vigorous reaction commenced after a few minutes and was moderated by cooling as necessary. When it had subsided somewhat, the reaction mixture was refluxed for 30 min and then a further 22 ml (0.235 mole) of *t*-butyl alcohol and 3.30 g (0.476 g-atom) of lithium were added. No spontaneous exotherm was apparent. The mixture was refluxed for 1 hr and then poured into 1 l. of ice-water. The product was extracted into 1:1 benzene-ether. The extracts were washed with water and evaporated to an oil which was dissolved in 8 ml of methanol. On cooling to -30°, 1.59 g (31%) of crystalline 5, mp 59–63°, was deposited. Recrystallization from methanol and sublimation at 50° (0.08 mm) gave material with mp 67–69°; no infrared absorption (mull) in the olefin stretching region.

Anal. Calcd for $C_{14}H_{16}O_2$: C, 77.75; H, 7.46. Found: C, 77.87; H, 7.41.

B. **From 11.**—Dehalogenation of 0.90 g (2.54 mmoles) of 11 was carried out essentially as above. A single treatment with 0.30 g (42 mg-atom) of lithium and 1.94 ml (21 mmoles) of *t*-butyl alcohol in 25 ml of tetrahydrofuran was used. There was a very slight spontaneous exotherm, after which the reaction mixture was refluxed for a further 1.5 hr. The yield of crystalline product was 0.25 g (45%), mp 63–66°, indistinguishable from

5 prepared above by mixture melting point, infrared and nmr spectra, or glpc.³⁴

Hexacyclo[5.4.1.0^{2,6}.0^{3,10}.0^{5,9}.0^{8,11}]dodecan-4-one (6).—A 1-g (4.62 mmoles) sample of 5 was dissolved in a mixture of 13 ml of concentrated H₂SO₄ and 7 ml of water. After 10 min the solution was poured into 200 ml of ice-water to precipitate 0.54 g (68%) of 6, mp 167–172°. Recrystallization from *n*-pentane and sublimation at 65° (0.05 mm) gave material with mp 180–182°; infrared absorption (CCl_4), complex band centered at 5.66 μ (C=O).³⁵ The mass spectrum shows a strong molecular ion peak at m/e 172³⁶ with other prominent peaks at 144, 129, 79, 78, 77, 51, and 39.

Anal. Calcd for $C_{12}H_{12}O$: C, 83.69; H, 7.02. Found: C, 83.38; H, 6.90.

1,3,5,7,8,9,10,11,12-Decachlorohexacyclo[5.4.1.0^{2,6}.0^{3,10}.0^{5,9}.0^{8,11}]dodecan-4-one (7).—A suspension of 10 g (0.178 mole) of 4 in 100 ml of 20% fuming H₂SO₄³⁷ was stirred for 2.5 hr at 105°. The reaction mixture was cooled and poured into 1 l. of ice-water. The ketone which was collected was transformed to its hydrate (9.33 g, 98%) on exposure to the atmosphere for a few hours. Recrystallization from CCl_4 (producing a mixture of ketone and hydrate) and air equilibration (40% humidity) gave the hydrate with: mp ~ 340° after previous darkening and shrinking; infrared absorption (mull) at 2.84 μ (OH); nmr peaks (CD_3COCD_3) at δ 3.93 (2 H singlet, CH) and at 6.97 (2 H hump, OH).³⁸

Anal. Calcd for $C_{12}H_4Cl_{10}O_2$: C, 26.95; H, 0.75. Found: C, 26.93; H, 0.76.

Sublimation of the hydrate at 150° (0.04 mm) gave the ketone with melting point the same as that of the hydrate; infrared absorption (CH_2Cl_2) at 5.45 μ (C=O); nmr peak ($CDCl_3$) at δ 3.82 (singlet).³⁹

Anal. Calcd for $C_{12}H_2Cl_{10}O$: C, 27.89; H, 0.39. Found: C, 28.10; H, 0.51.

3,5,9,10-Tetrachlorohexacyclo[5.4.1.0^{2,6}.0^{3,10}.0^{5,9}.0^{8,11}]dodecan-4-one (12).—A sample of 1.80 g (5.08 mmoles) of 11 was stirred for 1.5 hr with 18 ml of concentrated H₂SO₄ at 90°. The mixture was cooled and poured into 200 ml of ice-water to precipitate 1.20 g (76%) of 12, mp 170–175°. Recrystallization from CCl_4 , after distillation of a portion of the solvent to remove possible water of hydration,⁴⁰ and sublimation at 95° (0.05 mm), gave material with mp 173–175°; infrared absorption (CH_2Cl_2) at 5.54 μ (C=O); nmr spectrum ($CDCl_3$) showing signals at δ 1.82 (2 H broad singlet, 12-CH₂) and at 3.03 and 3.25 (2 H and 4 H, respectively, broad singlets, 1-, 2-, 6-, 7-, 8-, and 11-CH).

Anal. Calcd for $C_{12}H_8Cl_4O$: C, 46.49; H, 2.60. Found: C, 46.78; H, 2.62.

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(34) Column packed with 5% silicone gum rubber SE-30 on 60–80 mesh Chromosorb W.

(35) The possible reasons for the appearance of complex carbonyl stretching bands in another caged ketone have been considered by P. E. Eaton and T. W. Cole, Jr. [*J. Am. Chem. Soc.*, **86**, 962 (1964)].

(36) The isotope peak at m/e 173 has the expected intensity, but that at 174 has 1.5% of the intensity of the parent instead of the calculated 0.9%. This indicates the presence of a trace of a dihydro compound, possible arising from rupture of one of the cage bonds at the dehalogenation step. The impurity was not detected by glpc.³⁴

(37) No reaction occurred when concentrated H₂SO₄ was used.

(38) Chloral hydrate in CD_3COCD_3 shows an OH signal at δ 6.5.

(39) A small peak at δ 3.78 was attributable to the presence of a little hydrate which has a signal at this position in $CDCl_3$. It could have been formed from traces of water in the solvent.

(40) The infrared spectrum of 12 showed some evidence of partial hydration after exposure to 40% atmospheric humidity for 3 weeks.

(33) "Organic Syntheses," Coll. Vol. IV, N. Rabjohn, Ed., John Wiley and Sons, Inc., New York, N. Y., 1963, p 238. The total monomer used was 132 ml (1.61 moles).