lution (24 hr at 77°, no isomerization observed after 24 hr at 20°), a rapid process. Its instantaneous concentration, hence, will be higher than that of **4a**, permitting preparative separation. The ease of isomerization of **4a** to **5a** most likely results from relief of steric strain on ring opening in the 1,2-diphenyl derivative; no such (kinetic and thermodynamic) driving force exists for the conversion of **4b** to **5b**. A parallel situation can be found with the two ketones **6** and 1-hydroxy-2,3,3-triphenylcyclobuten-4-one.[3] While the former converts with great ease[5] to the corresponding triphenylnaphthol in boiling benzene, we have been unable to achieve (kinetically and energetically disfavored) naphthol formation from the strongly chelated[3] 1-hydroxy derivative under the same conditions.

Experimental Section

Friedel–Crafts Reaction of Perchlorocyclobuten-4-one with Benzene. A. 24 Hr at 6°. The solution of 0.51 g (2.5 mmol) of **1**[1,16] in benzene (5 ml, predried and distilled from Na) was stirred with 1.35 g (10 mmol) of freshly sublimed $AlCl_3$ for 24 hr at 6° under dry N_2. The reaction mixture was shaken with ice-cold 0.1 *M* aqueous hydrochloric acid (25 ml) and benzene (25 ml), and the organic phase was thoroughly washed with water and dried (Na_2SO_4). Solvent removal under reduced pressure and chromatography of the residue (silica gel, Merck 7734, fractionation monitored by tlc) produced three fractions (eluents in parentheses), which, after a single recrystallization from hexane, gave crude product yields as stated.

Fraction I (hexane): 3-chloro-1,2,3,4,4-pentaphenylcyclobutene (**8**), 0.21 g (17.9%). Three times recrystallized from hexane, the compound melted at 153–153.5° (lit.[2] mp 161°), undepressed on admixture of authentic[2] **8**.

Fraction II (1:1 hexane–benzene): 4-chloro-2,3-diphenyl-1-naphthol (**5a**), 0.004 g (0.48%), mp 149–152° (no further recrystallization attempted), undepressed on admixture of naphthol derivative (mp 150–153°) from previous work,[4] ir (KBr) 3503 (s), 3480 cm^{-1} (m) (ν_{OH}).

Fraction III (benzene): 1,2,3,3-tetraphenylcyclobuten-4-one (**6**), 0.50 g (53.7%). Twice recrystallized from hexane, the compound had mp 128–129° (lit. mp 139,[2] 129–130° [3]), undepressed on admixture of authentic[3] **6**.

B. 1 Hr at 10°. An experiment was set up as under A, but was conducted for 1 hr at 10°. Chromatographic work-up as before yielded four slightly overlapping bands; these were rechromatographed, and corresponding fractions were combined and once recrystallized from hexane to give the product yields stated.

Fraction I (hexane): **8**, 0.003 g (0.26%).

Fraction II (hexane): 1,3,3-trichloro-2-phenylcyclobuten-4-one (**2**), 0.018 g (2.9%). The faintly yellow crystals, once more recrystallized from hexane, had mp 125–126°. *Anal.* Calcd for $C_{10}H_5Cl_3O$ (247.5): C, 48.52; H, 2.04. Found: C, 48.45; H, 1.91. Electronic spectrum λ_{max} (EtOH) 301 nm (ϵ 30,000); ir (KBr) 1798 cm^{-1} (s) ($\nu_{C=O}$); mass spectrum *m/e* 246 (P^+ for ^{35}Cl).

Fraction III (1:1 hexane–benzene): 1-chloro-2,3,3-triphenylcyclobuten-4-one (**4b**), 0.005 g (0.6%), mp 129.5–130.5° (twice recrystallized from hexane). *Anal.* Calcd for $C_{22}H_{15}ClO$ (330.8): C, 79.87; H, 4.58. Found: C, 80.00; H, 4.70. Electronic spectrum λ_{max} (EtOH) 310 nm (ϵ 21,000); ir (KBr) 1777, 1773 cm^{-1} (s) ($\nu_{C=O}$); mass spectrum *m/e* 330 (P^+ for ^{35}Cl).

Fraction IV (benzene): **6**, 0.075 g (8.1%).

Isomerization of 4b. A sample (0.002 g) of **4b** recovered from spectroscopic analysis was fused for 0.5 hr at 130° in a capillary tube, and the solidified product, 2-chloro-3,4-diphenyl-1-naphthol (**5b**), was once recrystallized from hexane: mp 145–148° (purity not optimized), depressed on admixture of **5a**; ir (KBr) 3470 cm^{-1} (s) (ν_{OH}), remaining details similar to, but not identical with, those in spectrum of **5a**; mass spectrum *m/e* 330 (P^+ for ^{35}Cl).

Acknowledgment. Financial support of this investigation by the Council for Scientific and Industrial Research and the National Institute for Metallurgy is gratefully acknowledged. Thanks are due also to Dr. K. Pachler, Pretoria, for recording the 100-MHz nmr spectrum of **4b**, and to Professors W. Ried and J. D. Roberts for providing samples or spectral data of several cyclobutenones from their laboratories.

Registry No.—**1**, 3200-96-2; **2**, 51965-98-1; **4b**, 51965-99-2; **5a**, 51966-00-8; **5b**, 51966-01-9; benzene, 71-43-2.

References and Notes

(1) R. C. De Selms, C. J. Fox, and R. C. Riordan, *Tetrahedron Lett.*, 781 (1970).
(2) W. Ried and R. Lantzsch, *Synthesis*, 303 (1970).
(3) E. W. Neuse and B. R. Green, *J. Org. Chem.*, **39**, 1585 (1974).
(4) B. R. Green and E. W. Neuse, *Synthesis*, 46 (1974).
(5) An almost quantitative yield of 2,3,4-triphenyl-1-naphthol can be obtained by electrocyclic ring opening of 1,2,3,3-tetraphenylcyclobuten-4-one. This reaction is brought about by heating the ketone in the melt or in benzene solution.
(6) We find (acetone-d_6, 60 MHz) the analogous multiplets for ortho and meta plus para protons, respectively, at δ 8.0 and 7.55 ppm in 1-phenylcyclobutene-3,4-dione[8a,d] and at 8.0 and 7.5 ppm in 1-hydroxy-2-phenylcyclobutene-3,4-dione[8a,c] (samples of both compounds kindly supplied by Professor Ried). A similar pattern has been reported[8d] for 1-hydroxy-2-phenyl-3-alkylcyclobuten-4-ones.
(7) The related 1-chloro-2-phenylcyclobutene-3,4-dione absorbs at 296 and 306 nm (isooctane),[8a] and maxima at 295 and 304 nm are found in the spectrum of 1-chloro-2,3-diphenylcyclobuten-4-one (J. D. Roberts, private communicatons). In contrast, a red shift by 10–15 nm would be expected for the 1,2-diphenylenone chromophore in **4a**. For example, both 1,2-diphenylcyclobutene-3,4-dione[8b] and **6**[2] show λ_{max} (EtOH) at 322 nm.
(8) (a) E. J. Smutny, M. C. Caserio, and J. D. Roberts, *J. Amer. Chem. Soc.*, **82**, 1793 (1960); (b) A. T. Blomquist and F. A. LaLancette, *ibid.*, **83**, 1387 (1961); (c) W. Ried, W. Kunkel, and G. Isenbruck, *Chem. Ber.*, **102**, 2688 (1969); (d) W. Ried and H. Kohl, *ibid.*, **104**, 2896 (1971).
(9) The observed stability of **4b** suggests that the compound should have been among the products of the main experiment. The similarity of the R_f values of **4b** and **6** possibly caused the chloro ketone to be "buried" in the large quantities of **6** present in that experiment (54% as against 8% in the 1-hr run) and so simply prevented its detection and isolation.
(10) One might argue that **4b**, although indifferent to phenylation at C-1, could react in an analogous fashion through benzene addition and subsequent substitution at C-4, giving first 1-chloro-4-hydroxy-2,3,3,4-tetraphenylcyclobutene and then 1-chloro-2,3,3,4,4-pentaphenylcyclobutene. We were unable, however, to detect either product in these reactions. It appears that *gem*-diphenyl substitution at C-3 provides sufficient steric hindrance for successful approach of a benzene molecule. The same situation holds for **6** and, going one step farther, for **8**: neither in previous work[2-5] nor in the present investigation were even traces of hexaphenylcyclobutene detected, which would have resulted from further Lewis acid catalyzed reaction with benzene.
(11) Sequences providing alternative pathways to **6** and **8** from **2** and **4a**, almost certainly of higher activation energy, have for reasons of clarity been omitted from Chart I.
(12) The closely related 1,3-dichloro-2-phenylcyclobuten-4-one shows λ_{max} (cyclohexane) at 298 nm.[13] (See also ref 7.) For the alternative isomer structure, 1,2,3-trichloro-3-phenylcyclobuten-4-one, on the other hand, absorption at wavelengths below 250 nm can be predicted. Thus, we find **1** to absorb at 234 nm.
(13) M. C. Caserio, H. E. Simmons, Jr., A. E. Johnson, and J. D. Roberts, *J. Amer. Chem. Soc.*, **82**, 3102 (1960).
(14) (a) W. Ried and F. Bätz, *Justus Liebigs Ann. Chem.*, **755**, 32 (1972); (b) E. Neuse and B. Green, *ibid.*, 619 (1973); (c) E. W. Neuse and B. R. Green, *Polymer*, **15**, 339 (1974).
(15) Preferred attack of the precursor cation at benzene is expected to proceed through the C atom bearing the (Lewis acid complexed) Cl substituent.
(16) G. Maahs, *Justus Liebigs Ann. Chem.*, **686**, 55 (1965).

Enol Ethers and Monoketals of Biacetyl

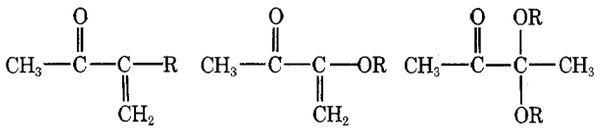
Lee Brodsky and William C. Agosta*

Laboratories of The Rockefeller University, New York, New York 10021

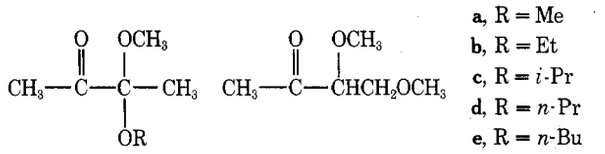
Received May 1, 1974

In extension of recent studies[1] on the photochemistry of various α-methylene ketones (**1**) we were interested in examining the photochemical behavior of the formally related compounds bearing oxygen directly on the olefinic double bond. These substances (**2**) are alkyl enol ethers of biacetyl, and we were somewhat surprised to learn that such compounds have never been described. The photochemical behavior of these systems ultimately proved disappointing, but we report below an indirect procedure permitting

transformation of biacetyl into these rather unstable enol ethers (2) by way of the related simple and mixed monoketals 3 and 4.



1 2 3



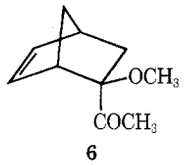
4 5

a, R = Me
b, R = Et
c, R = *i*-Pr
d, R = *n*-Pr
e, R = *n*-Bu
f, R = *sec*-Bu

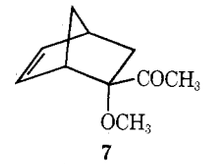
The dimethyl ketal **3a** is readily available from direct ketalization of biacetyl with methanol, although the method is essentially useless for higher members of the series.[2] We found that under carefully defined acidic conditions methanol could be eliminated from **3a** to furnish **2a** in 65% yield. Our best procedure involved dropwise addition of **3a** to a stirred melt of *o*-nitrobenzoic acid maintained at 170° and 80 Torr, with continuous distillation of the product from the reaction mixture. Final purification of the distillate by preparative vapor phase chromatography (vpc) furnished analytically pure **2a**. Although this enol ether is reasonably stable as a dilute solution in inert solvent, even highly purified neat samples undergo noticeable polymerization when stored overnight at −20°.

Exposure of **2a** to aqueous acid gave biacetyl, while reaction with dry acidic methanol led to efficient reversion to **3a** with no detectable formation of the isomeric 3,4-dimethoxy-2-butanone (**5**) through competing Michael addition to the double bond. These results suggested that simple acid-catalyzed interchange of the methoxyl groups of **3a** with other alcohols might well proceed without complication and provide access to other ketals. This proved to be correct. Treatment of readily available **3a** with a variety of alcohols in the presence of dry hydrogen chloride led to good yields of simple and mixed monoketals **3** and **4**.[3] The exact product composition varied somewhat with the alcohol used and with the reaction time. These products were readily purified by preparative vapor phase chromatography and fully characterized; in this way were prepared the 3,3-dialkoxy-2-butanones **3b–f** and the 3-alkoxy-3-methoxy-2-butanones **4c–f**. Use of these ketals in the acid-catalyzed elimination reaction now provided a route to other enol ethers **2**. Since methanol appeared to be preferentially eliminated from the mixed ketals **4**, the elimination reaction could be carried out to advantage on the crude mixture of **3** and **4** obtained by alcohol interchange. In this fashion the isopropyl and propyl enol ethers **2c** and **2d** were prepared.

The methyl enol ether **2a** was further characterized by its Diels–Alder reaction with cyclopentadiene. As anticipated on electronic,[4] and probably to some extent steric,[5] grounds, **2a** is a considerably less reactive dienophile than methyl vinyl ketone. At 120° it furnished a modest yield of adducts **6** and **7** in the ratio 63:37. The stereochemistry of these norbornenes could be assigned from their nmr spectra on the basis of the known chemical shift differences of endo and exo substituents in related systems.[5–7]



6



7

Experimental Section

Materials and Equipment. Previous descriptions and comments[1] apply with the following changes. Vpc columns used were A, 30% SE-30, 10 ft; B, 25% Carbowax 20M, 10 ft. Nmr spectra were obtained on a Varian HR-220 (220 MHz) or a Bruker HX-90 (90 MHz) spectrometer.

General Procedure for Alcohol Exchange with 3,3-Dimethoxy-2-butanone (3a). A 10-g sample of **3a**[2] was added to 500 ml of dry alcohol through which hydrogen chloride had been bubbled for 30 sec. In some cases 3A or 4A molecular sieves were added as a water scavenger. The resulting solution was stirred for 48 hr at room temperature. Solid Na_2CO_3 (3 g) was then added and stirring was continued for 24 hr; the solution was filtered and worked up by distillation. The resulting mixture contained **3** and **4** which were separated and purified by vpc on column A. Yields were >90% for primary and ~75% for secondary alcohols. Characterization data for each product are given below.

3,3-Diethoxy-2-butanone (**3b**): ir 3010, 1730, 1345, 1115, 1035, and 940 cm^{-1}; nmr δ 1.18 (t, J = 7 Hz, 6 H), 1.23 (s, 3 H), 2.11 (s, 3 H), 3.40 (q, J = 7 Hz, 2 H), and 3.43 (q, J = 7 Hz, 2H).

Anal. Calcd for $C_8H_{16}O_3$: C, 59.98; H, 10.07. Found: C, 59.83; H, 10.07.

3,3-Diisopropoxy-2-butanone (**3c**): ir 3000, 1730, 1370, 1100, 1075, and 940 cm^{-1}; nmr δ 1.02 (d, J = 6 Hz, 6 H), 1.04 (d, J = 6 Hz, 6 H), 1.33 (s, 3 H), 2.13 (s, 3 H), 4.91 (septet, J = 6 Hz, 2 H).

Anal. Calcd for $C_{10}H_{20}O_3$: C, 63.79; H, 10.71. Found: C, 63.97; H, 10.82.

3-Isopropoxy-3-methoxy-2-butanone (**4c**): ir 3000, 1730, 1375, 1360, 1345, 1110, 1040, and 995 cm^{-1}; nmr δ 1.24 (d, J = 6.5 Hz, 6 H), 1.26 (s, 3 H), 2.11 (s, 3 H), 3.17 (s, 3 H), 3.83 (septet, J = 6.5 Hz, 1 H).

Anal. Calcd for $C_8H_{16}O_3$: C, 59.98; H, 10.07. Found: C, 59.83; H, 10.04.

3,3-Dipropoxy-2-butanone (**3d**): ir 3000, 2960, 2900, 1730, 1345, 1110, 1060, 1040, and 980 cm^{-1}; nmr δ 0.94 (t, J = 7 Hz, 6 H), 1.27 (s, 3 H), 1.55 (m, 4 H), 2.11 (s, 3 H), 4.20 (t, J = 7 Hz, 2 H), 4.22 (t J = 7 Hz, 2 H).

Anal. Calcd for $C_{10}H_{20}O_3$: C, 63.79; H, 10.71. Found: C, 64.02; H, 10.81.

3-Methoxy-3-propoxy-2-butanone (**4d**): 3000, 2960, 1730, 1360, 1340, 1110, 1060, and 985 cm^{-1}; nmr δ 0.94 (t, J = 7 Hz, 3 H), 1.25 (s, 3 H), 1.55 (m, 2 H), 2.09 (s, 3 H), 3.15 (s, 3 H), 3.27 (m, J = 7 Hz, 2 H).

Anal. Calcd for $C_8H_{16}O_3$: C, 59.98; H, 10.07. Found: C, 60.12; H, 10.12.

3,3-Dibutoxy-2-butanone (**3e**): ir 3000, 2970, 2910, 1735, 1120, and 1060 cm^{-1}; nmr δ 0.98 (t, J = 6 Hz, 6 H), 1.28 (s, 3 H), 1.48 (m, 8 H), 2.10 (s, 3 H), 3.34 (t, J = 6 Hz, 4 H).

Anal. Calcd for $C_{12}H_{24}O_3$: C, 66.63; H, 11.18. Found: C, 66.77; H, 11.21.

3-Butoxy-3-methoxy-2-butanone (**4e**): ir 2995, 2960, 2900, 1735, 1370, 1350, 1120, and 1040 cm^{-1}; nmr δ 0.96 (m, 3 H), 1.32 (s, 3 H), 1.50 (m, 4 H), 2.15 (s, 3 H), 3.22 (s, 3 H), 3.38 (m, J = 6 Hz, 2 H).

Anal. Calcd for $C_9H_{18}O_3$: C, 62.04; H, 10.41. Found: C, 62.18; H, 10.54.

3,3-Di-*sec*-butoxy-2-butanone (**3f**): ir 3010, 2970, 1730, 1375, 1105, and 980 cm^{-1}; nmr δ 0.89 (m, 6 H), 1.04 (q, J = 3 Hz, 3 H), 1.12 (q, J = 3 Hz, 3 H), 1.33 (m, 3 H), 1.43 (m, 4 H), 2.11 (s, 3 H), 3.68 (m, 2 H). No attempt was made to separate the diastereomers of **3f**.

Anal. Calcd for $C_{12}H_{24}O_3$: C, 66.63; H, 11.18. Found: C, 66.54; H, 11.12.

3-*sec*-Butoxy-3-methoxy-2-butanone (**4f**): ir 3010, 2970, 1730, 1370, 1340, 1110, 1040, 1020, and 980 cm^{-1}; nmr δ 0.89 (m, 3 H), 1.08 (t, J = 6 Hz, 3 H), 1.24 (s, 3 H), 1.43 (m, 2 H), 2.10 (s, 3 H), 3.10 and 3.14 (2 s, 3 H), 3.63 (m, 1 H). No attempt was made to separate the diastereomers of **4f**.

Anal. Calcd for $C_9H_{18}O_3$: C, 62.04; H, 10.41. Found: C, 62.20; H, 10.51.

3-Methoxy-3-buten-2-one (2a). A stirred melt of 1 g of *o*-nitrobenzoic acid was maintained at 170° and 80 Torr in a flask fitted with a dropping funnel and arranged for continuous distillation. To this was added dropwise 10 g of **3a**. The distillate, a mixture of **2a** and **3a**, was collected at −78° and could be stored over 4A molecular sieves at this temperature without change. **2a** was conveniently purified on column B: yield 65% (by calibrated vpc and based on unrecovered **3a**); ir 3000, 2950, 2840, 1710, 1620,

1365, 1350, 1299, 1145, 1045, and 835 cm^{-1}; nmr δ 2.23 (s, 3 H), 3.63 (s, 3 H), 4.20 (d, J = 2 Hz, 1 H), 5.05 (d, J = 2 Hz, 1 H); mass spectrum m/e 100.0523 (M$^+$, calcd for $C_5H_8O_2$, 100.0523).

3-Isopropoxy-3-buten-2-one (2c). In the way just described for **2a**, **2c** was prepared in 50% yield from a mixture of **3c** and **4c** (2:3): ir 3000, 1720, 1610, 1355, 1280, 1140, and 1105 cm^{-1}; nmr δ 1.27 (d, J = 6 Hz, 6 H), 2.15 (s, 3 H), 4.15 (d, J = 2 Hz, 1 H), 4.20 (septet, J = 6 Hz, 1 H), 5.06 (d, J = 2 Hz, 1 H); mass spectrum m/e 128.0843 (M$^+$, calcd for $C_7H_{12}O_2$, 128.0837).

3-Propoxy-3-buten-2-one (2d). In the way just described for **2a**, **2d** was prepared from a mixture of **3d** and **4d:** ir 3000, 2970, 1715, 1615, 1370, 1355, 1300, 1150, and 840 cm^{-1}; nmr δ 1.04 (t, J = 6 Hz, 3 H), 1.77 (dt, $J = J_2$ = 6 Hz, 2 H), 2.20 (s, 3 H), 3.68 (t, J = 6 Hz, 2 H), 4.23 (d, J = 2 Hz, 1 H), 5.05 (d, J = 2 Hz, 1 H); mass spectrum m/e 128.0860 (M$^+$, calcd for $C_7H_{12}O_2$, 128.0837).

Hydrolysis of Enol Ethers to Biacetyl. A solution of **2a** (150 mg) in ether (15 ml) was treated with 10% aqueous HCl (0.5 ml) at room temperature for 12 hr. Then 2 g of Na_2CO_3 was added and the ethereal layer was filtered and dried over 4A molecular sieves. Solvent was removed by distillation, and biacetyl was isolated as the only product by vpc on column B. The same results were obtained with **2c**.

Reaction of 2a with Methanol. Treatment of **2a** with methanolic hydrogen chloride following essentially the procedure described above for alcohol interchange gave **3a** as the only isolated product.

endo- **and** *exo-***2-Methoxy-5-norbornen-2-yl Methyl Ketone (6 and 7).** A solution of 500 mg of **2a**, 450 mg of cyclopentadiene, and 10 mg of hydroquinone in 5 ml of benzene was heated in a sealed tube at 120° for 48 hr. Solvent was removed, and bulb-to-bulb distillation of the residue gave 465 mg (56%) of a mixture of **6** and **7** (63:37 by nmr). These were separated and purified on column B. Major isomer **6** showed the following properties: ir 3010, 2960, 1715, 1340, 1240, 1090, 1075, 1060, and 700 cm^{-1}; nmr δ 1.50 (d, J = 13 Hz, 1 H), 1.54 (d, J = 13 Hz, 1 H), 1.78 (m, 2 H), 2.09 (s, 3 H), 2.18 (d, J = 6 Hz, 1 H), 2.86 (d, J = 6 Hz, 1 H), 3.02 (s, 3 H), 5.80 (dd, J_1 = 3, J_2 = 6 Hz, 1 H), 6.08 (dd, J_1 = 3, J_2 = 6 Hz, 1 H); mass spectrum m/e 166.0989 (M$^+$, calcd for $C_{10}H_{14}O_2$, 166.0993). Minor isomer **7** showed the following properties: ir 3010, 1715, 1345, 1120, 1080, 1070, and 705 cm^{-1}; nmr δ 1.07 (dd, J_1 = 4, J_2 = 12 Hz, 1 H), 1.27 (m, 2 H), 1.43 (m, 1 H), 1.95 (dd, J_1 = 4, J_2 = 12 Hz, 1 H), 2.14 (s, 3 H), 2.72 (m, 1 H), 2.98 (s, 3 H), 5.93 (dd, J_1 = 4, J_2 = 5.5 Hz, 1 H), 6.23 (dd, J_1 = 4, J_2 = 5.5 Hz, 1 H); mass spectrum m/e 166.0947 (M$^+$, calcd for $C_{10}H_{14}O_2$, 166.0993).

Registry No.—**2a**, 51933-10-9; **2c**, 51933-11-0; **2d**, 51933-12-1; **3a**, 21983-72-2; **3b**, 51933-13-2; **3c**, 51933-14-3; **3d**, 51933-15-4; **3e**, 51933-16-5; **3f**, 51933-17-6; **4c**, 51933-18-7; **4d**, 51933-19-8; **4e**, 51933-20-1; **4f** isomer A, 51933-21-2; **4f** isomer B, 51933-22-3; **6**, 51933-23-4; **7**, 51933-24-5.

References and Notes

(1) R. A. Cormier, W. L. Schreiber, and W. C. Agosta, *J. Amer. Chem. Soc.*, **95**, 4873 (1973); R. A. Cormier and W. C. Agosta, *ibid.*, **96**, 618 (1974).
(2) E. A. Braude and C. J. Timmons, *J. Chem. Soc.*, 3131 (1953).
(3) For exchange reactions leading to ketals of simple open-chain and cyclic ketones, see N. B. Lorette and W. L. Howard, *J. Org. Chem.*, **25**, 521 (1960); W. L. Howard and N. B. Lorette, *ibid.*, **25**, 525 (1960).
(4) J. Sauer, *Angew. Chem.*, **79**, 76 (1967); *Angew. Chem., Int. Ed. Engl.*, **6**, 16 (1967), and references cited therein.
(5) J. M. Mellor and C. F. Webb, *J. Chem. Soc., Perkin Trans. 2*, 17 (1974).
(6) R. V. Moen and H. S. Makowski, *Anal. Chem.*, **39**, 1860 (1967); **43**, 1629 (1971). In all cases the nmr signal for a given substituent appears upfield for the endo compound relative to its position for the exo isomer.

(7) Grateful acknowledgment is made to the donors of the Petroleum Research Fund, administered by the American Chemical Society, for support of this research.

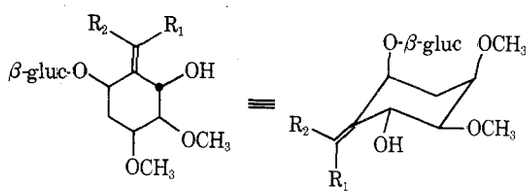
Structure and Stereochemistry of Simmondsin

Carl A. Elliger,* A. C. Waiss, Jr., and R. E. Lundin

Western Regional Research Laboratory, Agricultural Research Service, U. S. Department of Agriculture, Berkeley, California 94710

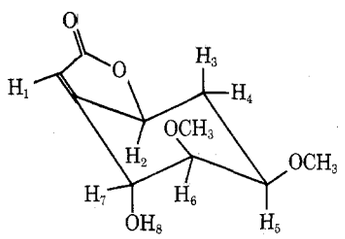
Received April 17, 1974

We recently[1] reported the isolation of a naturally occurring toxicant from *Simmondsia californica* and tentatively characterized its structure as **1a**. We now wish to report the definite establishment of structure **1b** in which the configuration of the cyano group is syn to the axial β-glucosyl substituent.



1a, R_1 = CN; R_2 = H
b, R_1 = H; R_2 = CN

Acid hydrolysis of the parent glucoside in boiling 1 *N* HCl for 1.5 hr produces, in addition to the previously reported phenolic derivatives, an α,β-unsaturated lactone, mp 138–140°, whose structure (**2**) is very closely related to



2

the starting glucoside. Satisfactory elemental analysis was obtained, and its infrared absorptions at 1665 and 1755 cm^{-1} are consistent with the proposed structure.[2] The nmr spectrum (Table I) permits unequivocal assignment of

Table I
Nmr Spectrum of 2 [$(CD_3)_2CO$]

H_1 δ 5.98, d, $J_{1,2}$ = 2 Hz
H_2 δ 5.12, 8 lines, $J_{1,2}$ = 2, $J_{2,3}$ = 11, $J_{2,4}$ = 6.5 Hz
H_3 δ 1.58, q, $J_{2,3} = J_{3,4} = J_{3,5}$ = 11 Hz
H_4 δ 2.52, complex, $J_{3,4}$ = 11, $J_{2,4}$ = 6, $J_{4,5}$ = 4 Hz
H_5 δ 3.90 (d), d, d (upfield half concealed by H_6), $J_{4,5}$ = 4, $J_{5,6}$ = 2 Hz
H_6 δ 3.83, complex (partially obscured by upfield half of H_5), $J_{5,6}$ = 3, $J_{6,7}$ = 3 Hz
H_7 δ 4.90, t, $J_{6,7} = J_{7,8}$ = 3, $J_{1,7}$ = 0 Hz
H_8 δ 5.03, d, $J_{7,8}$ = 3 Hz (31°)
$-OCH_3$'s (6 H) δ 3.40, 3.44

stereochemistry (spin-decoupling techniques were used for proton assignment). Protons H_{2-5} neatly reveal their orientation by the quartet exhibited by H_3 in which coupling of the adjacent axial hydrogens as well as the geminal coupling constant is 11 Hz. The observation that H_1 and H_2 possess a coupling of 2 Hz while that of H_1 and H_7 is zero is consistent with approximate 90° orientation of the C–H_2 bond with respect to the plane of the lactone ring. The orientation of H_7 nearly within the same plane would result in minimal coupling to H_1, as is found.[3] Hydrogens 6 and 7 are equatorially located.

The formation of lactone **2** must occur *via* initial hydrolysis of the glucosyl residue as in Scheme I followed by ring inversion to place the now equatorial hydroxyl group extremely close to the nitrile function. Under acid catalysis ring closure may occur easily to give lactone from the initially formed imino ester.

The proximity of the nitrile function to any adjacently located equatorial substituent no doubt is the cause of the rather unusual stereochemistry in simmondsin (**1b**) itself. To minimize the interaction of the glucosyl portion of the molecule with the cyano group, the glycosidic linkage assumes axial geometry even though this introduces 1,3-diax-