integration with the aid of an internal standard reveals the presence of 8.0 ± 0.5 fluorines. The position of this peak is in complete accord with that expected for the fluoroborate anion: thus, triphenylmethyl fluoroborate in methylene chloride appears at $+71.7$ p.p.m. and aqueous fluoroboric acid is at 71.3 p.p.m.[7]

For this data to be consistent with the presence of V as the major species, a rapid time-averaged exchange of the ring fluorine, boron trifluoride, and fluoroborate anion is required. Since the boron trifluoride resonance is found at $+47.8$ p.p.m. in methylene chloride, the fortuitous appearance of the exchange-averaged resonance at the exact chemical shift of authentic fluoroborate dictates that the ring fluorine of V, in the absence of exchange, appear at $+140$ p.p.m., a region in which apparently only aliphatic primary fluorine has been observed.[8] The absence of $F^{19}-B^{11}$ splitting[9] in the spectrum of IV could be interpreted as evidence for the presence of exchange averaging. However, this splitting is also absent in the trityl fluoroborate spectrum in which rapid equilibration of chemically different fluorines (as required for V) does not occur. At low temperatures the peak in question does broaden, perhaps due to a restoration of the $F^{19}-B^{11}$ splitting.

It now appears that differentiation between mono- and dication, as for example I and II, by its proton n.m.r. spectrum cannot be accomplished on an *a priori* basis, and details of these investigations will be reported in due course.

Acknowledgment.—We are particularly indebted to Dr. V. R. Sandel for many helpful discussions.

(7) G. A. Olah, et al., J. Am. Chem. Soc., **84**, 2733 (1962).

(8) W. D. Phillips, "Determinations of Organic Structures by Physical Methods," Academic Press, New York, N. Y., 1962, p. 406.

(9) $F^{19}-B^{11}$ splitting of the BF_4^- resonance into a poorly resolved quartet has been observed in a concentrated aqueous solution of $NaBF_4$ by R. D. Chambers, et al., Can. J. Chem., **39**, 258 (1961).

EASTERN RESEARCH LABORATORY   H. H. FREEDMAN
THE DOW CHEMICAL COMPANY   A. E. YOUNG
FRAMINGHAM, MASSACHUSETTS

Strained Systems. I. The Tricyclo[1.1.1.0⁴,⁵]pentane System

Sir:

It is well known that the photolysis of an α-diazomethyl ketone effects a reaction analogous to the Wolff rearrangement.[1] We have found, however, that an α-ketocarbene generated by ultraviolet irradiation undergoes an intramolecular addition to a double bond at a greater rate than the rearrangement.[2] Thus, the photolysis of 1,2-diphenyl-3-diazomethylketocyclopropene (I) has led to the formation of a hitherto unknown ring system. We now wish to report the synthesis and properties of this extremely strained tricyclo[1.1.1.0⁴,⁵]pentane system.

Compound I, m.p. 115° dec., was prepared from the corresponding acid chloride, m.p. 101–102°. A 0.5% solution of I in tetrahydrofuran was irradiated at room temperature with a Hanovia 450-w. mercury lamp, using a Pyrex filter.[3,4] Evolution of nitrogen sub-

(1) P. de Mayo, "Advances in Organic Chemistry, Methods and Results," Vol. II, Interscience Publishers, Inc., New York, N. Y., 1960, p. 407. For comparison with the silver-catalyzed rearrangement, see K. B. Wiberg and T. W. Hutton, J. Am. Chem. Soc., **78**, 1640 (1956).

(2) Addition of an α-ketocarbene to a double bond is also effected with copper-catalyzed thermal decomposition of the diazomethyl ketone. For instance, see G. Stork and J. Ficini, ibid., **83**, 4678 (1961). However, in cases where the products are thermally unstable, this method is not applicable.

(3) Treatment of I with silver benzoate in triethylamine effected the Wolff rearrangement and provided the methyl ester of the homologated acid in good yield.

(4) The photolysis of 1,2-di-n-propyl-3-diazomethylketocyclopropene provided a ketone which corresponds to II. The n.m.r. spectrum of this
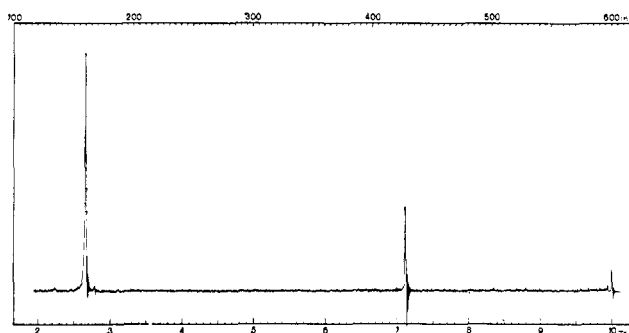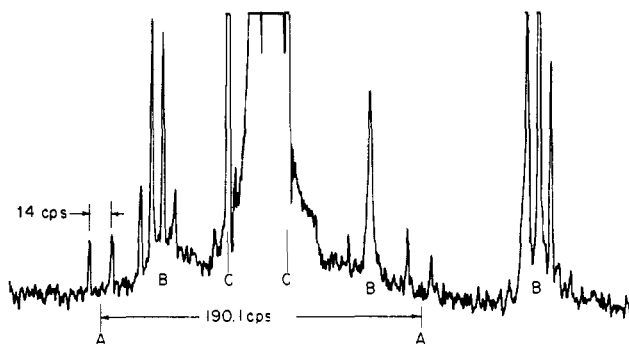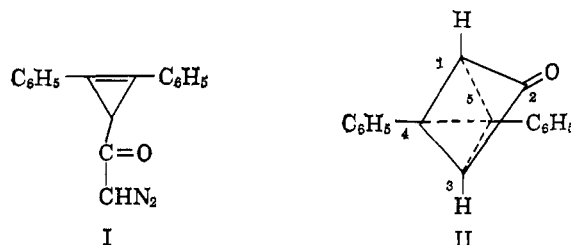

Fig. 1.—The n.m.r. spectrum of II.

Fig. 2.—The n.m.r. spectrum of the $^{13}C_1$ satellite of II (A); added ethanol (B); spinning side bands (C).

sided within 2 hr. and silicic acid chromatography of the photolysate easily separated a new ketone (II), m.p. 139–140° dec. (*Anal.* Calcd. for $C_{17}H_{12}O$: C, 87.90; H, 5.21; mol. wt., 232. Found: C, 87.88; H, 5.39; mol. wt., 230 (thermoelectric osmometer)).

I   II

While the infrared spectrum indicated the presence of a four-membered ketone (1785 cm.$^{-1}$), the n.m.r. spectrum in $CDCl_3$ (Fig. 1) showed two equivalent aliphatic protons at 7.12 τ and a phenyl absorption at 2.65 τ (10 protons). These analytical and spectral results are in complete agreement with the structure shown in II.

Catalytic hydrogenation of II proceeded with the uptake of two moles of hydrogen and provided in excellent yield *cis*-3,4-diphenylcyclopentanone (III),[5] m.p. 106–107°, identified by direct comparison with an authentic sample. Since the bicyclobutane system is

III
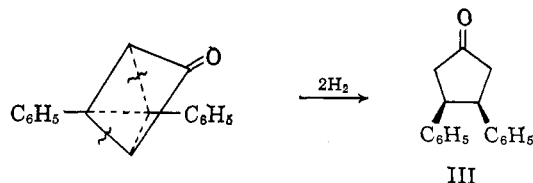
known to undergo hydrogenolysis,[6] the formation of

di-n-propyl derivative showed a singlet (2 protons) at 8.13 τ in addition to a typical n-propyl absorption. This experiment was carried out by Mr. N. T. Castellucci.

(5) D. Y. Curtin, et al., J. Am. Chem. Soc., **83**, 4838 (1961), and references cited therein.

(6) K. B. Wiberg and R. P. Ciula, ibid., **81**, 5261 (1959); J. Meinwald, C. Swithenbank, and A. Lewis, ibid., **85**, 1880 (1963). The course of hydrogenolysis of II is somewhat different from those of 1-carboethoxybicyclo-

III from II presents strong evidence in support of assigned structure II.

The n.m.r. spectrum[7] (Fig. 2) of the $^{13}C_1$ satellite of compound II revealed remarkably high coupling constants both for $^{13}C_1-H$ and H_1-H_3 ($^{13}C_1-H = 190.1$ c.p.s., $H_1-H_3 = 14$ c.p.s.). Using an equation to correlate coupling constants with the extent of sp hybridization of the carbon atomic orbitals used in the bonds,[8] we obtain 38% s-character for the exocyclic orbital of the C_1 atom. This high degree of s-character is a clear demonstration of the great strain involved in this ring system.[9]

In view of the fact that long-range proton spin–spin coupling constants are in the order of 0.3–0.5 c.p.s. with methyl ketones,[10] the size of the coupling constant observed for H_1-H_3 of II is remarkable. Although the theoretical aspect of the long-range spin–spin interaction still remains unclear, this large coupling evidently arises from the unique geometrical arrangement of the two hydrogens and two carbon atoms, i.e., these four atoms lie in a straight line and the distance of the carbon atoms is considerably shorter than 2.7 Å. Under these circumstances, an appreciable interaction of the two C–H orbitals (in particular, because of their large s-character) seems reasonable.

The ultraviolet spectrum of II in methanol showed a maximum at 242 mμ (ϵ 1.46 $\times$ 10^4). Thus a distinctive conjugation effect of cyclopropanes is observable in the case of the bicyclobutane system.

We are observing unique reactions intrinsic to the bicyclobutane system as well as unusual solvolytic behaviors of the tosylate of 4,5-diphenyltricyclo-[1.1.1.0^{4,5}]pentan-2-ol. These results will be reported in a separate paper.

Acknowledgment.—The author is grateful to Dr. A. A. Bothner-By for helpful discussions and Mr. N. T. Castellucci for his skillful assistance.

[1.1.0]butane and tricyclo[2.1.1.0^{5,6}]hexane-5-t-butylcarboxamide. However, this difference is easily rationalized by the steric hindrance of the two phenyl groups of II.

(7) The author is grateful to Mr. Joey Holcombe for determining this n.m.r. spectrum with a Varian Associates HR-100 spectrometer.

(8) N. Muller and D. E. Pritchard, J. Chem. Phys., **31**, 1471 (1959).

(9) G. L. Closs and L. E. Closs, J. Am. Chem. Soc., **85**, 2022 (1963).

(10) N. van Meurs, Spectrochim. Acta, **19**, 1695 (1963), and references cited therein, B. L. Shapiro, unpublished.

MELLON INSTITUTE   SATORU MASAMUNE
PITTSBURGH, PENNSYLVANIA

Microbiological 9α,12α- and 9α,18-Dihydroxylations of Androst-4-ene-3,17-dione

Sir:

Although a large number of papers dealing with the microbiological hydroxylation of steroids have appeared in recent years, the 18-hydroxylation has not been reported so far. We wish to report here the successful hydroxylation at the 9α-, 12α-, 14α-, 15β-, and 18-positions of androst-4-ene-3,17-dione (I). Among these, the 18-hydroxylation is believed to be the most important reaction because of its usefulness in preparing such 18-oxygenated steroids as aldosterone.

Transformation of I with the use of *Cercospora melonis* [*Corynespora melonis* (Cke) Lindau][1] produced four dihydroxylated compounds (II, III, IV, and V) by the method previously described.[4] These four products were obtained also when 9α-hydroxyandrost-4-

(1) By the use of this microorganism, Reichstein's substance S is converted into its 8β- and 15β-hydroxyl derivatives (see ref. 2 and 3, respectively).

(2) K. Tori and E. Kondo, Tetrahedron Letters, No. **10**, 645 (1963).

(3) E. Kondo, to be published.

(4) E. Kondo, K. Morihara, Y. Nozaki, and E. Masuo, J. Agr. Chem. Soc. Japan, **34**, 844 (1960).

ene-3,17-dione (VI)[5,6] was incubated with the same microorganism (see Scheme I, arabic numbers indicate the chemical shifts (τ) in deuteriochloroform solutions). Therefore, one of the two hydroxyl groups in each compound should be situated at the 9α-position.

Compound II [m.p. 224–226°, $[\alpha]^{24}D$ +144.2° (dioxane), λ_{max} 242 mμ (ϵ 15,400), ν_{max}^{Nujol} 3441, 1724, 1659, and 1617 cm.$^{-1}$][7] and its monoacetate (VII, sirup, $\nu_{max}^{CCl_4}$ 3466, 1745, 1674, 1622, and 1240 cm.$^{-1}$) show no signal corresponding to the 18-methyl group in their n.m.r. spectra.[8] Instead, oxygen-bearing methylene signals (about 6.28 τ in II and about 5.73 τ in VII) are observed. The 19-methyl signal of II appears at 8.66 τ shifted by −0.12 p.p.m. from that of I, owing to the 9α-hydroxyl group.[9,10] Chromium trioxide oxidation of II afforded an aldehyde [VIII, m.p. 208–211°, $[\alpha]^{25}D$ −7.3°, λ_{max} 240.5 mμ (ϵ 15,800), ν_{max}^{Nujol} 3400, 1747, 1692, 1646, and 1616 cm.$^{-1}$], which was verified by the appearance of the n.m.r. signal of an aldehydic proton at 0.47 τ. These results suggest that II is the 18-hydroxyl derivative of VI. Confirmatory evidence that II has an 18-hydroxyl group, not a 19-hydroxyl group, was obtained by the following degradation of II with *Bacillus sphaericus* (ATCC 7055) having the ability to 1-dehydrogenate various steroids.[11–13] Microbiological dehydrogenation of II afforded an expected 9,10-seco compound [IX, m.p. 148–150°, $[\alpha]^{27.5}D$ +91°, λ_{max} 279.5 mμ (ϵ 2350), ν_{max}^{Nujol} 3452, 1727, 1693, 1611, and 1512 cm.$^{-1}$]. The n.m.r. spectra of IX and its diacetate (X, sirup, $\nu_{max}^{CCl_4}$ 1751, 1713, 1612, 1591, 1502, and 1213 cm.$^{-1}$) show the signal of a methyl group attached to the benzene ring at 7.76 and 7.68 τ, respectively, and an AB-type quartet due to the oxygen-bearing methylene group. The angular methyl signal that appears in II is not observed in IX and X. For the purpose of comparison, 9,10-seco-3-hydroxyandrosta-1,3,5(10)-triene-9,17-dione[6,14] (XI, m.p. 122–123°, $[\alpha]^{27}D$ +96°) and its acetate (XII, m.p. 145–146°, $[\alpha]^{27.5}D$ +83°) were prepared by the same method. The main n.m.r. features of XI and XII resemble those of IX and X, respectively, except that the 18-methyl signals in XI and XII are replaced by a doublet of doublets in IX and X. Thus the structure of II was established to be 9α,18-dihydroxyandrost-4-ene-3,17-dione.

Compound III [m.p. 253–257°, $[\alpha]^{23.5}D$ +213.8°, λ_{max} 241 mμ, (ϵ 16,200), ν_{max}^{Nujol} 3434, 3359, 1720, 1678, and 1625 cm.$^{-1}$] was converted into its monoacetate [XIII, m.p. 254–256°, $[\alpha]^{24}D$ +201.3°, λ_{max} 241 mμ (ϵ 16,000), ν_{max}^{Nujol} 3565, 1740, 1661, 1617, and 1240 cm.$^{-1}$] by the usual acetylation. Chromium trioxide oxida-

(5) E. Kondo and T. Mitsugi, ibid., **35**, 521 (1961).

(6) R. M. Dodson and R. D. Muir, J. Am. Chem. Soc., **80**, 6148 (1958).

(7) Elementary analyses of the compounds described here gave satisfactory values. Unless otherwise noted, optical rotations were determined in chloroform containing 1% ethanol, and ultraviolet absorption spectra were observed on the solutions in 95% ethanol.

(8) All n.m.r. spectra were taken with a Varian A-60 spectrometer on 2–5% solutions in deuteriochloroform containing tetramethylsilane as an internal reference at room temperature. Chemical shifts are expressed in τ-values.

(9) The additivity rule for signal shifts of the angular methyl groups due to shielding by various functional groups has been well established [for example, see R. F. Zürcher, Helv. Chim. Acta, **44**, 1380 (1961)].

(10) The shift value of the 19-methyl due to a 9α-hydroxyl group was reported to be about −0.14 p.p.m.[2] It should be noted that the signal shift of the 4-proton by about −0.15 p.p.m. is characteristic for the introduction of a 9α-hydroxyl group into a Δ^4-3-keto steroid.

(11) T. H. Stoudt, W. J. McAleer, J. M. Chemerda, M. A. Kozlowski, R. F. Hirschmann, V. Marlatt, and R. Miller, Arch. Biochem. Biophys., **59**, 304 (1955).

(12) E. Kondo and E. Masuo, Ann. Rept. Shionogi Res. Lab., **10**, 103 (1960).

(13) It has been well known that 9α-hydroxy-Δ^4-3-keto steroids are transformed to their 9,10-secophenol derivatives by microorganisms capable of introducing a Δ^1-double bond.[8,14]

(14) C. J. Sih, Biochim. Biophys. Acta, **62**, 541 (1962).