Table I. Chemical Shifts and Coupling Constants

Compd.	N-Methyl-L-glucosamine H-1 τ	N-Methyl-L-glucosamine H-1 J, c.p.s.	Streptose H-1 τ	Streptose H-1 J, c.p.s.	Streptose 3-Formyl τ	Streptose 3-Formyl J, c.p.s
I	4.80	3.0	4.73	Singlet		
I sulfate	4.46	3.0	4.68	Singlet		
II sulfate	4.43	3.5	4.69	Singlet	4.93	Singlet
III	4.99	3.0	4.73	Singlet		
IVa	4.96	2.6	5.01	1.5		
IVb	4.99	3.0	5.06	4.7		

α-L- configuration in streptomycin) to be reached on rotational grounds. Compound III was prepared by the following reaction sequence. Deguanylation[12] of dihydrostreptomycin sulfate gave dideguanyldihydrostreptomycin bicarbonate, m.p. 157°, $[\alpha]^{26}D$ −119° (*c* 2.0, water),[13,14] which was polyacetylated,[12,14] then de-O-acetylated by barium methoxide in dry methanol during 20 hr. at room temperature. Repeated recrystallization of the product from ethanol gave microcrystalline tri-N-acetyldideguanyldihydrostreptomycin (III)[15] hemiethanolate, m.p. 196–198°, $[\alpha]^{26}D$ −100° (*c* 2.0, water), R_{Gm} 0.5[16] [*Anal.* Calcd. for $C_{24}H_{43}N_3O_{15}\cdot 0.5C_2H_5OH$: C, 47.27; H, 7.28; N, 6.59. Found: C, 47.51; H, 7.31; N, 6.55], whose infrared spectrum (KBr pellet) showed amide (but no ester) carbonyl absorption at 1640 cm.$^{-1}$.

The requisite methyl N-acetyldihydrostreptobiosaminide anomers (IVa and IVb) were obtained by the following sequence. Dihydrostreptomycin sulfate was methanolyzed[17] and the mixture of methyl dihydrostreptobiosaminide anomers was acetylated and separated[18] into the ether-insoluble methyl pentaacetyl-α-L-dihydrostreptobiosaminide (Va), m.p. 197°, $[\alpha]^{25}D$ −120° (*c* 2.0, $CHCl_3$), and the ether-soluble methyl pentaacetyl-β-L-dihydrostreptobiosaminide (Vb), m.p. 155°, $[\alpha]^{25}D$ −37° (*c* 2.0, $CHCl_3$).[13,18] Treatment of the pentaacetyl methyl α-glycoside with barium methoxide at room temperature for 48 hr. gave methyl N-acetyl-α-L-dihydrostreptobiosaminide (IVa) hemihydrate, $[\alpha]^{27}D$ −160° (*c* 2.0, water), R_f 0.495 (*n*-BEW 415), R_{Gm} 3.5[16] [*Anal.* Found: C, 47.70; H, 7.47; N, 3.35], while treatment of the pentaacetyl methyl β-glycoside with ammonia-saturated anhydrous methanol for 48 hr. at room temperature gave methyl N-acetyl-β-L-dihydrostreptobiosaminide hemihydrate (IVb), $[\alpha]^{27}D$ −32° (*c* 2.0, water), R_f 0.432 (*n*-BEW 415), R_{Gm} 3.3[16] [*Anal.* Found: C, 47.82; H, 7.26; N, 2.89].[19]

(12) W. J. Polglase, *J. Org. Chem.*, 27, 1923 (1962).
(13) These physical properties are in excellent agreement with values in the cited reference.
(14) M. L. Wolfrom and W. L. Polglase, *J. Am. Chem. Soc.*, 70, 2835 (1948).
(15) This compound (III) was prepared earlier by direct N-acetylation of dideguanyldihydrostreptomycin [S. Tatsuoka and S. Horii, *Proc. Japan. Acad.*, 39, 314 (1963)] and reported (without crystallization, melting point, or microanalyses) to have $[\alpha]^{21}D$ −87.5° (*c* 1.0, water). N.m.r. values reported by Tatsuoka and Horii for chemical shifts of the methyl groups generally agree with those found for the present sample.
(16) The value R_{Gm} here refers to the mobility of a compound relative to glucosamine hydrochloride on silica gel thin layer chromatography. The solvent system employed (*n*-BEW 415) was the organic phase of the system *n*-butyl alcohol–ethyl alcohol–water, 4:1:5.
(17) J. Fried and D. Wintersteiner, *J. Am. Chem. Soc.*, 69, 79 (1947).
(18) N. G. Brink, F. A. Kuehl, Jr., E. H. Flynn, and K. Folkers, *ibid.*, 68, 2557 (1946).
(19) The anomeric configurations assigned the two glycosides from their rotational properties[16] are in agreement with those derived from their n.m.r. spectra (see Table I).

Employing Hudson's rules of isorotation for compounds IVa and IVb, one calculates the molecular rotational contribution of the N-acetyldihydrostreptobiosamino unit as $[M]_B = -38{,}800$, that of the anomeric glycosidic center as $[M]_A = \pm 25{,}900$ (− for the α-L-anomer). It follows then that the molecular rotation of III is constituted $[M]_{III} = [M]_S + [M]_A + [M]_B$, where $[M]_S$, the contribution of an asymmetrically substituted N-diacetylstreptamine, may be estimated from the rotation of N,N′-diacetyl-2,6-di-O-methylstreptamine,[2] $[\alpha]^{26}D$ +6.3° (*c* 3.5, water), which is of the opposite absolute configuration, since the streptamine portion of III is substituted at C-4 instead of C-6. Thus, $-64{,}600 = -1800 + [M]_A - 38{,}800$, and $[M]_A = -24{,}000$, clearly indicating the α-L- configuration for streptose.[20]

Similar conclusions regarding glycosidic bond stereochemistry can be reached for the closely related antibiotic bluensomycin,[22] which has the same structure as dihydrostreptomycin except that one of the guanidine groups is replaced by a carbamate group. In the n.m.r. spectrum of bluensomycin sulfate the values for the anomeric protons corresponding to the respective columns of Table I are: N-methyl-L-glucosamine H-1, τ 4.44, J = 3.0 c.p.s.; dihydrostreptose H-1, τ 4.66, singlet. These values are clearly in accord with an α-L-configurational assignment for both sugars.

Acknowledgments. We thank the Department of Scientific and Industrial Research (London) for a N.A.T.O. Postdoctoral Fellowship (to I. J. McG.). This investigation was supported in part by Public Health Service Research Grant No. AI-01278 from the National Institute of Allergy and Infectious Diseases.

(20) The same conclusion can be reached by still another route, essentially that of Lemieux, DeWalt, and Wolfrom.[7a] Thus, dodecaacetyldihydrostreptomycin (VI) has $[\alpha]^{22}D$ −67°,[7a] its hydrolysis product N-tetraacetyl-2,5,6-O-triacetylstreptidine (VII) dihydrobromide monohydrate has $[\alpha]^{19}D$ −5.4°,[21] methyl pentaacetyl-α-L-dihydrostreptobiosaminide (Va) has $[\alpha]^{25}D$ −117°,[18] and methyl pentaacetyl-β-L-dihydrostreptobiosaminide (Vb) has $[\alpha]^{25}D$ −34°,[18] from which $[M]_{VI} = [M]_{VII} + [M]_A + [M]_B$, and $[M]_A = -32{,}700$, indicating again the α-L-configuration.
(21) A. H. Comrie, H. C. Mital, and J. B. Stenlake, *J. Med. Pharm. Chem.*, 2, 153 (1960).
(22) B. Bannister and A. D. Argoudelis, *J. Am. Chem. Soc.*, 85, 234 (1963).

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Photoisomerization of Tri-*t*-butylbenzenes. Prismane and Benzvalene Isomers[1]

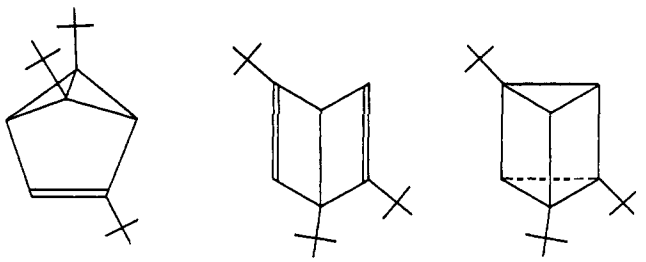
Sir:

The photoisomerization[2–4] of polyalkylbenzenes has been shown[4] to result from transposition of ring carbon atoms and has been explained[3,4] in terms of nonbenzenoid intermediates. We have now established

(1) Based on work performed under the auspices of the U. S. Atomic Energy Commission.
(2) K. E. Wilzbach and L. Kaplan, *J. Am. Chem. Soc.*, 86, 2307 (1964).
(3) A. W. Burgstahler and P. L. Chien, *ibid.*, 86, 2940, 5281 (1964). *Cf.* also E. M. Arnett and J. M. Bollinger, *Tetrahedron Letters*, 3803 (1964).
(4) L. Kaplan, K. E. Wilzbach, W. G. Brown, and S. S. Yang, *J. Am. Chem. Soc.*, 87, 675 (1965).

that a benzvalene[5] (I) is an intermediate in the photointerconversion of 1,2,4-tri-*t*-butylbenzene (IV) and the 1,3,5 isomer (V). We have also shown that irradiation of either IV or V at 2537 Å. leads to a photostationary mixture in which the principal component is a prismane (III). III is produced from the Dewar benzene II previously isolated by van Tamelen and Pappas.[6]

Like II, I and III are reasonably stable at room temperature, but rearomatize at higher temperature. I is converted exclusively to IV (50% in 7 hr. at 95° in isooctane); III gives a mixture of IV, V, and II (60% in 18 hr. at 115° in isohexane). I exhibits an ultraviolet absorption maximum at 2350 Å. (ϵ 3500) similar to that observed in the previously reported benzvalene.[5] The infrared spectrum has characteristic bands at 3088 cm.$^{-1}$ (cyclopropyl C–H stretching) and at 1603 and 1562 cm.$^{-1}$ in the double bond region. The n.m.r. spectrum[7] consists of two singlets for the *t*-butyl protons at τ 8.94 (18 H) and 8.99 (9 H), a quartet at 4.95 (1 H), and an octet centered at 8.3 (2 H). The multiplets are analyzed as an ABX system with X at τ 4.95, A at 8.27, B at 8.35, J_{AB} = 6.65 c.p.s., J_{AX} = 2.45 c.p.s., and J_{BX} = 1.25 c.p.s. The n.m.r. spectrum is fully consistent with that of a tri-*t*-butylbenzvalene with one *t*-butyl on the double bond. The two high field protons have τ values between those (τ 8.14 and 8.43) of the methine protons in 1-methyltricyclo-[2.1.1.0^{5,6}]hexane[8]; the olefinic proton is at too high field for a cyclopropene[6] or cyclobutene,[8] but is reasonable for a substituted cyclopentene. The failure to split the larger *t*-butyl peak at very high resolution, the large magnitude[8] of J_{AB}, and the formation of a single isomer on rearomatization lead us to favor structure I, the 2,5,6 isomer, over the 1,2,5 and 1,3,5 isomers.

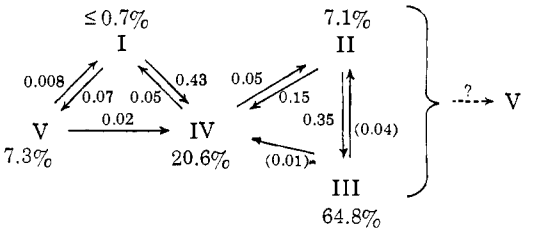


I II III

The prismane III has not yet been obtained free of II; the best sample had a purity of 82%. The infrared spectrum of this sample showed no absorption in the double bond region except for two very small peaks attributable to II.[9] In the ultraviolet III exhibits only end absorption: ϵ 1100 at 2200 Å. Its n.m.r. spectrum consists of two singlets at τ 9.07 (18 H) and 9.24 (9 H) and a seven-line multiplet centered at τ 7.94 (3 H). The latter corresponds to an AB_2 spectrum with A at τ 7.97, B at 7.92, and J_{AB} = 2.0 c.p.s. Structure III appears to be the only one consistent with the spectral and thermolytic results; it is the prismane isomer most similar to Dewar benzene (II).

Photochemical studies of the tri-*t*-butylbenzene system were carried out in isohexane solution at room temperature with light of 2537 Å. (Germicidal lamp, Corning No. 7910 filter). Mixtures of the products were analyzed, after removal of solvent at room temperature, by n.m.r. utilizing the characteristic[10] *t*-butyl peaks. Gas chromatography was also used for analysis, but its utility was limited by the anomalous behavior of III (*vide infra*). Initial rates and products of photolysis of I, II, IV, and V were determined on the separated isomers. The photochemical behavior of III was deduced from these results and the composition of the photostationary mixture.

The quantum yields[11] of the individual reactions and the percentages of the components of the photostationary mixture are shown.[12]



The benzvalene I accounts for nearly one-third of the isomerization V → IV and for the major part of the reverse isomerization. There is an indication that either II or III may be involved to some extent in the isomerization IV → V, but the details are not yet clear.[13]

As indicated by the composition of the photostationary mixture, useful quantities of II, III, and IV can be formed by irradiation of V at 2537 Å. The high extinction coefficient[14] of I at this wave length precludes its accumulation in significant quantity, but greater than 50% conversion of IV to an equimolar mixture of I and II has been attained by irradiation at 2800 Å. (Bausch and Lomb high intensity monochromator with SP-200 lamp).

The separation of I, II, IV, and V is readily accomplished by gas chromatography[15] using a Chromosorb G support coated with QF-1 or Carbowax. On such columns III is converted, almost instantaneously, to a mixture of the other isomers from which useful quantities of I and II can be obtained. III has been chromatographed unchanged at 60° on Fluorpak-80 coated

(5) The name "benzvalene" has been given to tricyclo[2.1.1.0^{5,6}]hex-2-ene: H. G. Viehe, R. Merényi, J. F. M. Oth, J. R. Senders, and P. Valange, *Angew. Chem.*, **76**, 922 (1964).

(6) E. E. van Tamelen and S. P. Pappas, *J. Am. Chem. Soc.*, **84**, 3789 (1962).

(7) N.m.r. spectra were taken in CCl_4 solution at 100 Mc. with a Varian HA-100 spectrometer. We are greatly indebted to Dr. R. C. Dougherty and Miss Gail Norman for these spectra.

(8) G. L. Closs and R. B. Larrabee, *Tetrahedron Letters*, 287 (1965). *Cf.* D. M. Lemal and K. S. Shim, *ibid.*, 3231 (1964); 952 (1965).

(9) Although the n.m.r. and ultraviolet spectra of the Dewar benzene isolated by us agree with those reported by van Tamelen and Pappas (ref. 6), its infrared spectrum exhibits peaks at 6.18 and 6.28 μ instead of at 6.26 and 6.46 μ.

(10) The τ values for the *t*-butyl peaks are as follows: I, 8.94, 8.99; II, 8.96, 9.04; III, 9.07, 9.24; IV, 8.47, 8.49, 8.72; V, 8.69.

(11) Based on comparisons with previously measured reactions (ref. 2). There is no indication that photosensitization plays a significant role in these reactions.

(12) In the photolysis of V, two fulvenes are also produced in low yield. The intense absorption of these products prevents the attainment of the steady state unless the initial optical density is less than 0.1.

(13) V is formed in the photolysis of II. Its quantity appears to be too large to have arisen from the IV initially formed.

(14) The molar extinction coefficients at 2537 Å. are: I, 1500; II, 100; III, 80; IV, 140; V, 120.

(15) Retention volumes of I, II, and IV relative to V: On QF-1, 90°: 0.56, 0.68, 3.1; on Carbowax 20M, 80°: 0.24, 0.30, 5.4.

with a mixture of Carbowax and KOH, but separation from II was precluded by the inefficiency of the column.

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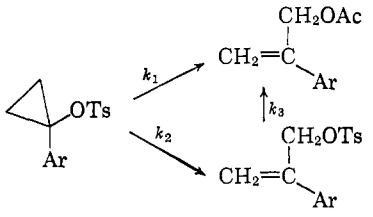
Chemistry of Cyclopropanols. III. The Mechanism of the Solvolysis of Cyclopropyl Tosylates

Sir:

Cyclopropyl tosylate undergoes solvolysis reactions at an exceedingly slow rate, 175° being required for its acetolysis.[1] The product of the solvolysis is allyl acetate, resulting from ring opening. In this communication we wish to report on various unusual aspects of this type of transformation.

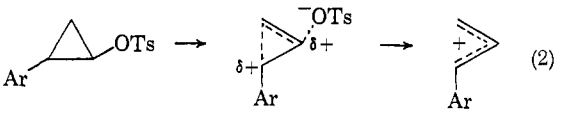
As expected, 1-arylcyclopropyl tosylates[2] solvolyze much more rapidly than cyclopropyl tosylate itself, although the reactions are complicated by internal return. The relevant transformations are shown in



(1)

eq. 1. At 108° in acetic acid–sodium acetate the first-order rate constants for the unsubstituted case (Ar = C_6H_5) are $k_1 = 1.9 \times 10^{-3}$ sec.$^{-1}$, $k_2 = 8.2 \times 10^{-3}$ sec.$^{-1}$, and $k_3 = 4.0 \times 10^{-4}$ sec.$^{-1}$. The Hammett[3] ρ values for the two pertinent reactions are -4.4 ($r = 0.996$)[3] for the process corresponding to k_1 and -4.0 ($r = 0.999$)[3] for the process corresponding to k_2.[4] No 1-phenylcyclopropyl acetate is formed, although it is stable to the reaction conditions.

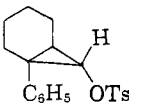
A more interesting observation is that both *cis*- and *trans*-2-arylcyclopropyl tosylates[2] solvolyze *faster* than cyclopropyl tosylate itself, although the inductive effect of the phenyl group might have been expected to decrease the rate. Thus, at 108° the first-order rate constant for acetolysis of *trans*-2-phenylcyclopropyl tosylate is 3.2×10^{-5} sec.$^{-1}$, and the *cis* isomer reacts at one-fifteenth of this rate. The Hammett ρ value for the solvolysis of a series of *trans*-2-arylcyclopropyl tosylates is -1.8 ($r = 0.95$).[4] The product of the solvolysis is cinnamyl acetate and no 2-phenylcyclopropyl acetate could be detected, although it was shown to be stable to the reaction conditions. These results indicate that the solvolysis of cyclopropyl tosylates is a concerted process, with ring opening occurring in the transition state of the reaction (eq. 2). The aryl group thus exerts its influence by stabilizing the positive charge being generated on the benzyl carbon.[5]



(2)

The transformation of a 2-substituted cyclopropyl tosylate into the proposed transition state and thence into the cinnamyl cation involves the rotation of the aryl group through approximately 90°. Woodward and Hoffmann[6] have recently proposed that groups in the cyclopropyl cation would rotate in opposite directions (both inward or both outward) in going to the allyl cation. Our results indicate that the cyclopropyl cation is not an intermediate in the solvolysis and led us independently to the conclusion that *the direction of rotation is dependent upon the stereochemistry of the leaving group.* Combined with the theory of Woodward and Hoffmann our results suggest that an R group *trans* to the leaving group rotates outward.[7] The slower rate of solvolysis of *cis*- than *trans*-2-phenylcyclopropyl tosylate is in agreement with this hypothesis since inward rotation of the *cis*-phenyl group would lead to a less stable, sterically hindered cation.[8]

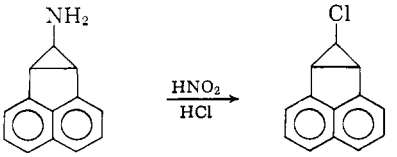
In agreement with this hypothesis, we have prepared the *exo*-phenylnorcaranyl tosylate shown and find it to be very unreactive under conditions where 2-phenylcyclopropyl tosylate solvolyzes readily. Rotation of the *trans* groups *outward* in such a system is



obviously impossible. In order for solvolysis to occur a true cyclopropyl cation may have to be formed. The possibility of using this technique to generate these previously unknown ions is currently being explored.[9]

Acknowledgment. This investigation was supported by the National Science Foundation and the Alfred P. Sloan Foundation.

(1) J. D. Roberts and V. C. Chambers, *J. Am. Chem. Soc.*, 73, 5034 (1951).
(2) C. H. DePuy, G. M. Dappen, K. L. Eilers, and R. A. Klein, *J. Org. Chem.*, 29, 2813 (1964).
(3) H. Jaffé, *Chem. Rev.*, 53, 191 (1953).
(4) The correlation is with σ^+.
(5) Cyclopropyl tosylate itself undoubtedly also undergoes ring opening simultaneously with solvolysis since, as slow as its solvolysis rate is, it is appreciably faster than that calculated on the basis of angle strain. See C. S. Foote, *J. Am. Chem. Soc.*, **86**, 1853 (1964); P. von R. Schleyer, *ibid.*, **86**, 1856 (1964).
(6) R. B. Woodward and R. Hoffmann, *ibid.*, **87**, 395 (1965).
(7) Hoffmann has shown by molecular orbital calculations that such a hypothesis is reasonable.[6] We are grateful to Dr. Hoffmann for stimulating discussions.
(8) The cinnamyl acetates equilibrate under the reaction conditions: E. A. Braude, D. W. Turner, and E. S. Waight, *J. Chem. Soc.*, 2404 (1958), and earlier papers.
(9) R. Pettit, *J. Am. Chem. Soc.*, **82**, 1972 (1960), has reported one of the very few cases where a cyclopropyl cation was generated without rearrangement. Judging by the method of synthesis, the amine is *trans* to the fused ring. Ring opening cannot be simultaneous with loss of nitrogen and a cyclopropyl cation may be formed, which is captured



by chloride ion. Other examples of the application of this hypothesis are reported in the following communication.
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