of norbornadiene,[23] and the recently discovered olefin disproportionation reactions.[24]

Finally, we direct attention to a remarkable feature of the reactions described in this communication, namely the ability of the fully saturated cubane molecule to interact sufficiently strongly with a stable transition metal complex to experience the observed catalytic effects. Previous examples of the facile catalysis of hydrocarbon reactions by transition metals have involved molecules containing either unsaturated (*e.g.*, olefinic) bonds or cyclopropane rings which have been considered to play essential roles in the coordination of the substrates to the catalysts.[4,7,8,24a]

Acknowledgment. Support of this work by the National Science Foundation and by the Petroleum Research Fund, administered by the American Chemical Society, is gratefully acknowledged. We thank Dr. Steven A. Cerefice for valuable discussions and assistance. One of us (L. C.) also thanks Montecatini Edison S.p.A. for a leave of absence and a fellowship.

(23) T. J. Katz and N. Acton, *Tetrahedron Lett.*, 2601 (1967), and references therein. These authors have also interpreted the cycloaddition reactions of norbornadiene in terms of nonconcentrated mechanisms.

(24) N. Calderon, E. A. Ofstead, J. P. Ward, W. A. Judy, and K. W. Scott, *J. Amer. Chem. Soc.*, **90**, 4133 (1968); W. B. Hughes, *ibid.*, **92**, 532 (1970).

(24a) NOTE ADDED IN PROOF. Following submission of this manuscript two reports have appeared describing the silver(I)-catalyzed rearrangements of the homocubyl and 1,1′-bishomocubyl systems [W. G. Dauben, M. G. Buzzolini, C. H. Schallhorn, and D. L. Whalen, *Tetrahedron Lett.*, 787 (1970); L. A. Paquette and J. C. Stowell, *J. Amer. Chem. Soc.*, **92**, 2584 (1970)]. Following this we have found that silver salts also catalyze the analogous rearrangements of cubane and its derivatives. The difference between the behaviors of the silver and rhodium catalysts in these systems is most striking and is being further examined.

(25) On leave from Montecatini Edison S.p.A., Centro di Chimica Organica Esplorativa, Novara, Italy.

Luigi Cassar,[25] Philip E. Eaton, Jack Halpern
Department of Chemistry, University of Chicago
Chicago, Illinois 60637

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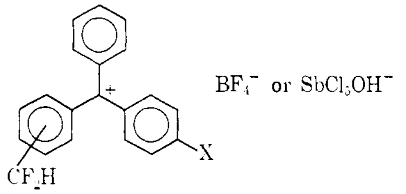
Nuclear Magnetic Resonance Studies of Chirality in Triarylmethyl Cations. Mechanism of Enantiomer and Diastereomer Interconversion

Sir:

The trityl cation, which derives its stability from charge delocalization to its equivalent phenyl rings, must assume a compromise conformation consistent with maximum coplanarity and minimum *ortho* steric interactions.[1] Evidence has accumulated that the ion has D_3 symmetry in solution[2] and the symmetrical propeller conformation in the solid state has been confirmed by an X-ray study.[3] Given a sufficiently high phenyl rotational barrier, suitably substituted trityl cations can give rise to both diastereomers and, as a consequence of the chirality inherent in the trityl propeller conformation, enantiomers. Interconversion of isomers must proceed *via* a transition state in which phenyl rings become either (a) perpendicular to or (b) coplanar with the trigonal plane.[4] Since the latter motion leads to increased steric interactions between neighboring *ortho* protons and the former leads to decreased charge stabilization by phenyl, studies of the energetics and mechanism for this exchange provide information on the relative importance of steric and electronic effects in this system.

The presence and magnitude of a barrier to the process which interconverts diastereomeric fluorines in di- and tri-*meta*-fluorotrityl cations have been elegantly demonstrated by the pioneering nmr study of Schuster, Colter, and Kurland (SCK).[5] However, such data in the absence of information on steric factors can be mechanistically compatible with a planar structure, and we have therefore chosen to detect the dissymmetry inherent in the trityl propeller by utilization of a *m*-difluoromethyl group as a diastereotopic[6] probe. The results, reported below, support a propeller conformation in which interconversion of enantiomeric propellers occurs *via* a two-ring flip (*i.e.*, two rings perpendicular) transition state, rather than the intuitively less satisfactory three-ring flip transition state proposed previously for a related system.[5]

The limiting ^{19}F nmr spectra of the *m*-difluoromethyltrityl cation are reproduced in Figure 1. The change from equivalent fluorines at ambient temperature (A_2X doublet, $J_{HF} = 56$ Hz) to nonequivalent fluorines at temperatures below $-30°$ (ABX octet, $\Delta\nu_{FF} = 140$ Hz, $J_{FF} = 301.5$ Hz) can be unambiguously attributed to the generation of diastereotopism in the CF_2H group as interconversion of the chiral trityl propellers becomes slow on the nmr time scale. Complete line shape analysis[7a] over the entire temperature range yields the activation data listed in Table I, the value $\Delta G^{\ddagger} = 12.7$ kcal/mol being in reasonable agreement with the data of SCK,[5] as expected for these similar cations. Analogous data obtained with the $-CF_2H$ probe in a *para* position are also listed in Table I and confirm the trends exhibited by the *m*-CF_2H ions.



To obtain information on the mechanism of propeller interconversion, the effect of *para′*-donating substituents was examined. The reduced symmetry of these *m*-CF_2H,*p′*-X (X = CH_3 or OCH_3) trityl cations adds an additional element of complexity to the ^{19}F spectra; slow rotation now results in the formation of two equal energy diastereomers (*syn* and *anti* of Figure

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(1) G. N. Lewis and M. Calvin, *Chem. Rev.*, **25**, 273 (1939); G. N. Lewis, T. T. Magel, and D. Lipkin, *J. Amer. Chem. Soc.*, **64**, 1774 (1942).

(2) R. B. Moodie, T. M. Connor, and R. Stewart, *Can. J. Chem.*, **37**, 1402 (1959); R. Dehl, W. R. Vaughn, and R. S. Berry, *J. Org. Chem.*, **24**, 1616 (1959).

(3) A. H. Gomes de Mesquita, C. H. MacGillavry, and K. Eriks, *Acta, Crystallogr.*, **18**, 437 (1965).

(4) Four transition states are possible and have been referred to as zero-, one-, two-, and three-ring flip processes by SCK,[5] indicating the number of rings which become perpendicular. Their terminology has been adopted here.

(5) A. K. Colter, I. I. Schuster, and R. J. Kurland, *J. Amer. Chem. Soc.*, **87**, 2278 (1965); R. J. Kurland, I. I. Schuster, and A. K. Colter, *ibid.*, **87**, 2279 (1965); I. I. Schuster, A. K. Colter, and R. J. Kurland, *ibid.*, **90**, 4679 (1968).

(6) For nomenclature and background of nmr spectroscopy of chiral compounds see: (a) M. van Gorkom and G. E. Hall, *Quart. Rev. Chem. Soc.*, **32**, 14 (1968); (b) K. Mislow and M. Raban, *Top. Stereochem.*, **1**, 22 (1967).

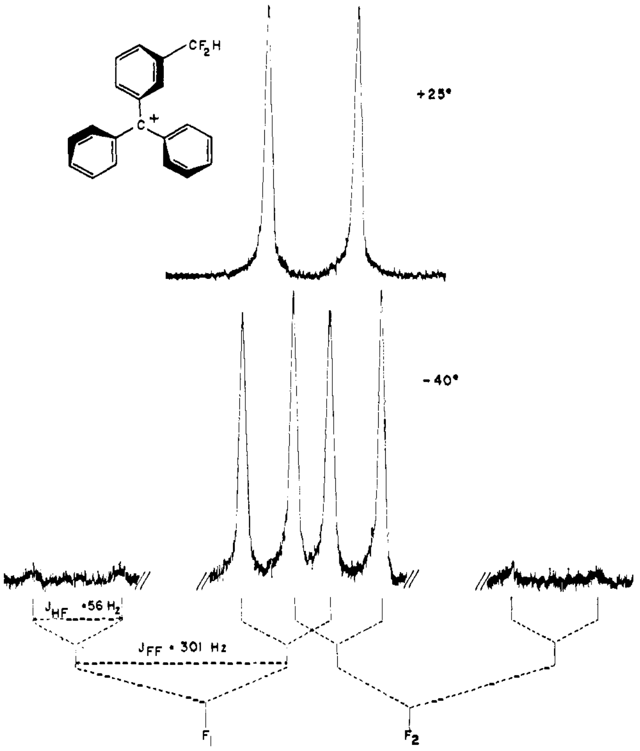

Figure 1. Fluorine nmr spectra of *m*-CF_2H-trityl$^+$ $SbCl_5OH^-$ in acetonitrile at 94.1 MHz showing limits of slow (−40°) and fast (25°) exchange.

2), each of which exists as an enantiomeric propeller pair. The low-temperature ^{19}F spectra now consist of two equal intensity ABX octets, each octet representing the diastereotopic fluorines of one diastereomer. This is illustrated in Figure 2 for the *m*-CF_2H,*p*′-CH_3-trityl cation, only the inner eight lines of which are reproduced.[7b]

Table I. Activation Parameters for Substituted Trityl Cation Propeller Interconversion[a]

-CF_2H	X	$\Delta F_{25°}^{\ddagger}$	$\Delta S_{25°}^{\ddagger}$	T_c, °C	$\nu_{F1} - \nu_{F2}$ (−40°)[b]
meta	H	12.7	−6.2	0	140
meta	CH_3	11.6	−0.7	−14, −48[c]	127, 14[d]
meta	OCH_3			∼−80	
para	H	12.3	13.3	−2	62
para	CH_3	(10.4)[e]		−30	47
para	OCH_3	(8.7)[e]		−85	

[a] $\Delta F^{\ddagger}$ is in kilocalories per mole and $\Delta S^{\ddagger}$ in entropy units. [b] Chemical shift between diastereotopic fluorines in hertz at 94.1 MHz at −40°. Chemical shift increases with decreasing temperature with rate 1.0 and 0.3 Hz/deg for the *m*-CF_2H and *p*-CF_2H derivatives, respectively. This temperature dependence was taken into account in the line-shape calculations. [c] Coalescence temperature for diastereomer interconversion process. [d] Chemical shift between diastereomers. [e] Calculated from rate observed at T_c and $\Delta S^{\ddagger}$ calculated for *p*-CF_2H, *p*′-H compound.

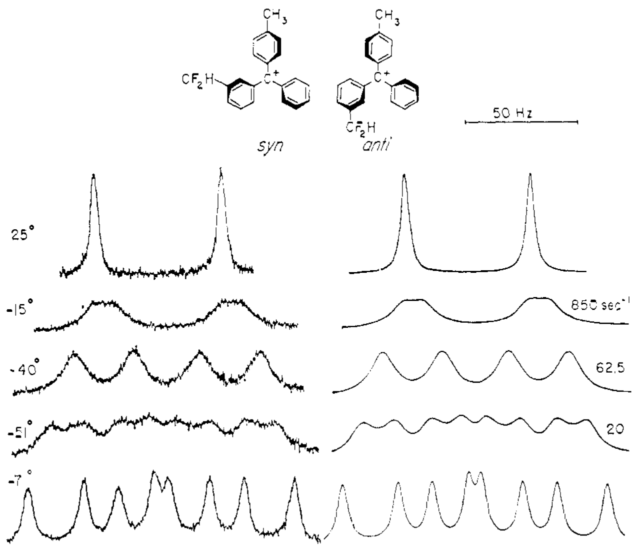

Figure 2. Temperature dependence of fluorine nmr spectra of *m*-CF_2H,*p*′-CH_3-trityl$^+$ BF_4^- in propionitrile along with calculated spectra and corresponding rate constants. The low intensity outer eight lines of both calculated and experimental spectra are not reproduced, but are included in the line-shape calculations.

Although these spectra are more complicated than those in Figure 1 they are also more informative concerning the enantiomer exchange mechanism. Since diastereomers exchange only when a *m*-CF_2H-phenyl ring flips, while any combination of coplanar and perpendicular rings exchanges enantiomeric propellers, the relative rates of exchange for diastereomers and diastereotopic fluorines, and consequently the overall appearance of the variable temperature spectra, depend on the exchange mechanisms. It can thus be demonstrated that the computer-calculated curves shown in Figure 2 are in agreement with a mechanism involving either a two- or three-ring flip, but, as expected on the basis of arguments advanced by SCK,[5] do not support a process in which two or all three rings become coplanar in the transition state (one- or zero-ring flip, respectively).

A decision in favor of the two-ring, rather than three-ring flip mechanism can be made on the basis of the effect of substituents on the magnitude of the barrier. The observation (see Table I) that the carbonium ion stabilizing groups, *p*-CH_3 and *p*-OCH_3, result in a significant decrease in $\Delta G^{\ddagger}$ is inconsistent with a three-ring flip. Inasmuch as donor substituents can lower the barrier only in conjunction with an aryl ring which is coplanar in the transition state, while a trend in the opposite direction is required by a transition state involving three perpendicular (nonconjugated) rings, we can eliminate the three-ring flip mechanism. We thus conclude that these trityl propellers racemize most readily by a two-ring flip process in which steric interactions are minimized while simultaneously maintaining the maximum delocalization of one ring.[8]

Finally, studies in progress suggest that an additional element of chirality, independent of any propeller-induced dissymmetry, is present in *meta,para*′-disubstituted trityl and similarly constituted carbonium ions.

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(7) (a) Theoretical spectra for the *m*-CF_2H–trityl compound were calculated using the computer program EXCH10 written by G. Whitesides; its application to an ABX spin system is discussed in G. M. Whitesides, B. A. Pawson, and A. C. Cope, *J. Amer. Chem. Soc.*, 90, 639 (1968), and G. M. Whitesides and J. D. Roberts, *ibid.*, 87, 4878 (1965). (b) For calculations such as shown in Figure 2 this program was modified so that the terms of the 16 × 16 kinetic transfer matrix contained the appropriate exchange contributions from both the diastereomer and enantiomer interconversion processes.

(8) It is conceivable that the mechanistic pathway for trityl isomer interconversion is substituent dependent. This possibility will be evaluated in a later publication.

This previously unrecognized phenomenon in no way influences our present conclusions and will be discussed in a full paper.

J. W. Rakshys, Jr., S. V. McKinley, H. H. Freedman
The Dow Chemical Company, Eastern Research Laboratory
Wayland, Massachusetts 01778

Received February 9, 1970

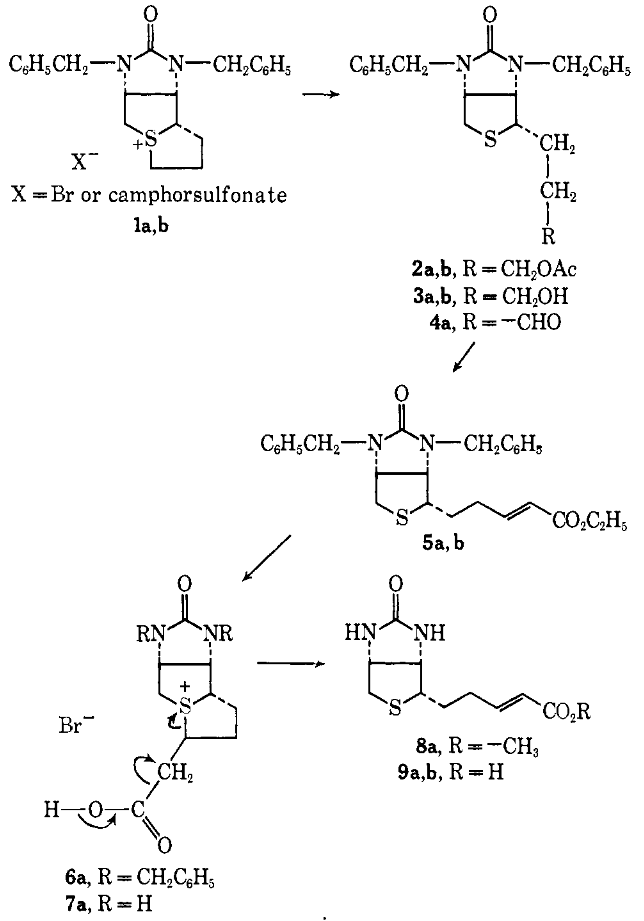
Synthesis of α-Dehydrobiotin

Sir:

The isolation and characterization of *d*-α-dehydrobiotin as a natural antimetabolite of the cofactor biotin with antibiotic properties against a number of microorganisms have been reported.[1] It is the most effective antimetabolite of biotin known, having about five times the potency of *d*-biotin sulfone and 80 times that of *d*-homobiotin in one assay.[1a]

This substance, which may facilitate the study of the biochemistry of biotin, was synthesized as follows. First, as a model, racemic α-dehydrobiotin was prepared by treatment of the racemic sulfonium bromide[2] **1a** with sodium acetate to give the open acetate **2** [mp 100-103°;[3] ir (CHCl$_3$) 1735 (ester C=O) and 1695 cm^{-1} (urea C=O)], which was hydrolyzed with alkali to the alcohol **3a** [mp 105-108°; ir (CHCl$_3$) 3630 (OH) and 1690 cm^{-1} (urea C=O)]. Oxidation of this alcohol to the aldehyde **4a** [mp 110-113°; ir (CHCl$_3$) 1720 (CH=O) and 1690 cm^{-1} (urea C=O); nmr (CDCl$_3$) δ 9.74 ppm (s, 1, -C*H*O)] without concomitant oxidation of the sulfide group was achieved with dicyclohexylcarbodiimide and dimethyl sulfoxide.[4] The additional two carbon atoms were attached by treatment of the aldehyde **4a** with the sodium salt of the triethylphosphonoacetate[5] to give **5a**, mp 96-100°.

Removal of the protecting benzyl groups presented unexpected problems due to the juxtaposition of the double bond and the electron-rich sulfide linkage. Heating of **5a** with 48% hydrobromic acid for 0.5 hr under reflux gave the cyclic sulfonium acid **6a** (mp 214-216°; nmr (DMSO) no band at δ 5-7 ppm); further heating under reflux for 4 hr then gave the debenzylated acid **7a**. Since it was anticipated that treatment of this intermediate with base would cause fragmentation[6] as shown by the arrows, the carboxyl group was esterified by treatment with methanol and hydrogen bromide, and then treated with sodium bicarbonate to give the methyl ester **8a**, mp 169.5-172°, which on alkaline hydrolysis gave *d,l*-α-dehydrobiotin (**9a**), mp 238-240°.



a = racemic
b = optically active

Repetition of this sequence of reactions starting from the *l*-thiophanium *d*-camphorsulfonate (**1b**) with characterization of the following optically active intermediates [**2b**, mp 98-100°, $[\alpha]^{25}$D −50.3° (*c* 1, CHCl$_3$); **3b**, mp 85-87°, $[\alpha]^{25}$D −54° (*c* 1, CHCl$_3$); and **5b**, mp 90-92°, nmr (DMSO) δ 5.78 (d, 1, J = 16 Hz, =C*H*—CO$_2$Et), 6.89 ppm (m, 1, -C*H*=CH—CO$_2$Et)] led to *d*-α-dehydrobiotin (**9b**), mp 256-257.5°, undepressed on addition of authentic material,[7] $[\alpha]^{25}$D +105.7 (*c* 1.2, 0.1 *N* NaOH) [lit.[1] mp 238-240°, $[\alpha]^{25}$D +92° (0.1 *N* NaOH)]. The antimicrobial properties of the synthetic material are also essentially identical with those reported[1] for the natural product.

Acknowledgment. We wish to thank Dr. T. C. Demny and Mr. J. Scheiner for the biological results. We also wish to thank our Physical Chemistry Department under the direction of Dr. P. Bommer for the nmr spectra (Dr. T. Williams), ir spectra (Mr. S. Traiman), and the microanalyses (Dr. F. Scheidel), and the skillful chemical assistance of Mr. T. Flynn is greatly appreciated.

George F. Field, William J. Zally, Leo H. Sternbach
Chemical Research Department, Hoffmann-La Roche Inc.
Nutley, New Jersey 07110

Received March 4, 1970

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(1) L. J. Hanka, M. B. Bergy, and R. B. Kelly, *Science*, **154**, 1667 (1967); L. J. Hanka, L. M. Reineke, and D. G. Martin, *J. Bacteriol.*, 100, 42 (1969); (a) S. H. Rubin and J. Scheiner, *Arch. Biochem.*, 23, 400 (1949).

(2) M. W. Goldberg and L. H. Sternbach, U. S. Patent 2,489,235 (1949).

(3) Compounds characterized by melting point gave satisfactory combustion analyses.

(4) K. E. Pfitzner and S. G. Moffatt, *J. Amer. Chem. Soc.*, 87, 5661, 5670 (1965).

(5) W. S. Wadsworth and W. D. Emmons, *ibid.*, **83**, 1733 (1961).

(6) See C. A. Grob and P. W. Schiess, *Angew. Chem.*, **79**, 1 (1967).

(7) We thank Dr. J. Berger of our Microbiology Department for making available a small amount of this material which he had obtained from the Upjohn Co. for his own use.

Thallium in Organic Synthesis. XV. Synthesis of Phenols and Aromatic Nitriles[1,2]

Sir:

We have recently reported[3] a simple, one-step synthesis of aromatic iodides which utilizes the *in situ*

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(1) We gratefully acknowledge partial support of this work by the