in paper electrophoresis and ion-exchange chromatography. Analysis of the acid hydrolysate of the synthetic heptadecapeptide by both microbiological means[21] and the chromatographic method of Spackman, *et al.*,[22] disclosed an amino acid composition consistent with the theoretically calculated values (microbiological: $Lys_{2.8}His_{0.9}Arg_{1.7}Ser_{2.3}Glu_{1.0}Gly_{2.0}Val_{1.1}Met_{0.9}Tyr_{0.9}Phe_{1.0}Pro_{1.0}$; chromatographic: $Lys_{3.2}His_{1.0}Arg_{2.1}Ser_{1.9}Glu_{1.1}Gly_{2.1}Val_{1.2}Met_{0.9}Tyr_{1.0}Phe_{1.0}Pro_{0.9}$). The intact heptadecapeptide was found to contain tyrosine and tryptophan in a molar ratio of one to one, as determined spectrophotometrically.[23]

[21] The microbiological assay was carried out by the Shankman Laboratories, Los Angeles.

[22] D. H. Spackman, W. H. Stein and S. Moore, *Anal. Chem.*, **30**, 1190 (1958).

[23] T. W. Goodwin and R. A. Morton, *Biochem. J.*, **40**, 628 (1946).

[24] We wish to acknowledge the generous support of the National Institutes of Health of the United States Public Health Service (G 2907) and the Albert and Mary Lasker Foundation.

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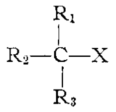
## REACTIONS OF TRICYCLOPROPYLCARBINOL DERIVATIVES[1,2]

*Sir:*

Some time ago we reported[3] that a second cyclopropyl group was nearly as effective as the first in accelerating the solvolysis of cyclopropylcarbinyl derivatives. Thus, the ratios of the solvolysis rates $I_0:I_1:I_2$ (X = *p*-nitrobenzoate) in 80% aqueous dioxane at 60° were 1:246:23,500. At the time, we were unsuccessful in attempts to

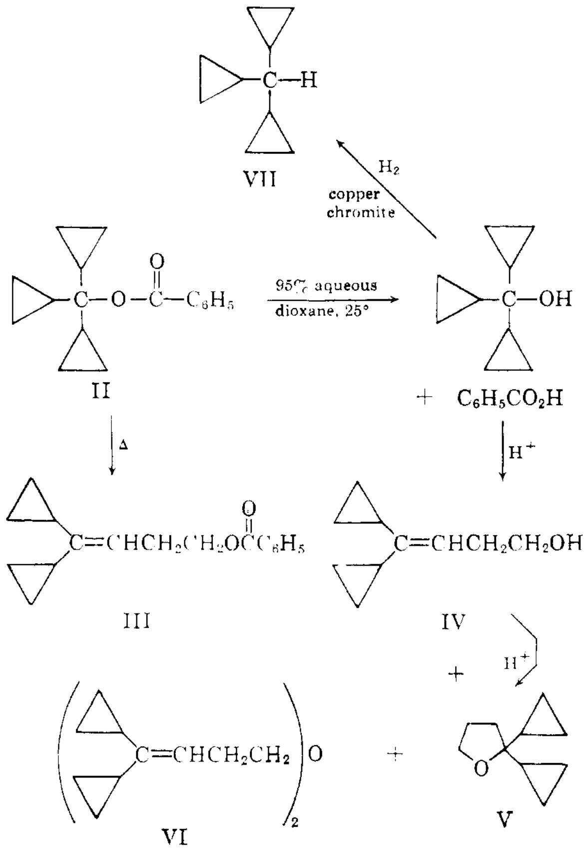


$$R_2-\overset{\displaystyle R_1}{\underset{\displaystyle R_3}{C}}-X$$

$I_0$[4]: $R_1 = R_2 = R_3$ = isopropyl
$I_1$: $R_1 = R_2$ = isopropyl; $R_3$ = cyclopropyl
$I_2$: $R_1$ = isopropyl; $R_2 = R_3$ = cyclopropyl
$I_3$: $R_1 = R_2 = R_3$ = cyclopropyl

prepare the *p*-nitrobenzoate of tricyclopropylcarbinol ($I_3$, X = PNB) but we have now prepared a solvolyzable derivative, the unsubstituted benzoate (II), which solvolyzes with alkyl–oxygen fission. The ester was obtained in quantitative yield[5] from the reaction of the potassium salt of the alcohol with benzoyl chloride in pentane at 0°.[6] The n.m.r. spectrum of the benzoate showed only the five aromatic protons (ortho, 2.18 τ; meta and para, 2.60 τ) and fifteen cyclopropane protons (methine, 8.6 τ; methylene, 9.2–9.7 τ).

II solvolyzes at an extraordinarily rapid rate, as seen from the data in the table.[7]



The acceleration for replacement of isopropyl ($I_2$) by a third cyclopropyl is about 1080-fold in 95% dioxane at 25°; the comparison is perhaps made more vivid by noting the half-lives (II 9.4 minutes, $I_2$ (X-benzoate) = 169 hours). This rate enhancement for the third cyclopropyl group, comparable (or greater) in magnitude than for the first or second, implies that each cyclopropyl group is involved in stabilizing the charge on the tricyclopropylcarbonium ion; the truly unusual solvolysis rate for a benzoate ester implies unusual stability for this carbonium ion. The exclusive hydrolysis product was tricyclopropylcarbinol (no rearranged alcohol, no olefin).[8] In accord with each ring being involved in positive charge stabilization, the n.m.r. spectrum of tricyclopropylcarbinol in 98% sulfuric acid shows a single peak[9] at 7.79 $\tau_m$.[10]

TABLE I

SOLVOLYSIS RATES

| Ester | % Aqueous dioxane | *t*, °C. | $k_1 \times 10^4$, sec.$^{-1}$ |
|---|---|---|---|
| II | 95 | 25.0 | 12.3 |
| | | 15.5 | 4.37 |
| | | 7.9 | 2.52 |
| | 90 | 7.9 | 22.9 |
| $I_2$ (X-Benzoate) | 95 | 25.0 | 0.0114 |

[1] This research was supported in part by grant 488-C from the Petroleum Research Fund of the American Chemical Society. Grateful acknowledgment is hereby made to the donors of this fund. This research was also supported in part by grant G-14289 from the National Science Foundation, for which we are also grateful.

[2] Paper X in a series on Cyclopropane Chemistry. For the previous paper see *J. Am. Chem. Soc.*, **82**, 6362 (1960).

[3] H. Hart and J. M. Sandri, *ibid.*, **81**, 320 (1959).

[4] The subscript indicates the number of cyclopropyl groups.

[5] All compounds reported gave satisfactory analyses.

[6] A similar procedure, and many variations of it, were totally unsuccessful with *p*-nitrobenzoyl chloride.

[7] Rates were followed by quenching samples in anhydrous acetone at −10°, then rapid titration in a nitrogen atmosphere with dilute base in aqueous dioxane at −5 to 0°. Values in the table are mean values for at least three separate determinations, often on different samples of ester, and are accurate to ± 10%.

[8] Methanolysis gives the corresponding methyl ether.

[9] See communication by N. C. Deno, H. G. Richey, Jr., J. S. Liu, H. D. Hodge, J. D. Houser and M. J. Wisotsky, *J. Am. Chem. Soc.*, **84**, 2016 (1962).

Attempts to dehydrate tricyclopropylcarbinol by distillation *in vacuo* from small amounts of sulfuric acid or phosphorus pentoxide lead to rearranged alcohol IV, 2,2-dicyclopropyltetrahydrofuran V, identified by analysis, n.m.r. and independent synthesis from $\gamma$-butyrolactone and cyclopropyllithium, and the bis-ether VI, in varying proportions depending on reaction conditions.[11] No methylenecyclopropane type product was observed, but polymer, possibly arising from 1,1-dicyclopropylbutadiene, was obtained in varying amounts.[12]

II must be stored in a refrigerator or it rearranges to the allylcarbinyl benzoate III. The rearrangement is slow at 50° but complete in 30 minutes at 100°. In contrast, $I_2$ (X-benzoate) shows only slight rearrangement after 70 minutes at 100°. These rearrangements are being investigated with $O^{18}$.[13]

Tricyclopropylcarbinol is hydrogenolyzed readily (*cf.* arylcarbinols[14]) to tricyclopropylmethane (VII) by hydrogen over copper chromite at 175°, the structure of the product being clear from its analysis, n.m.r. and integrated near infrared spectrum. Overhydrogenation results in some hydrogenolysis of one cyclopropane ring.

Extensions to solvolyses of related aryl and vinyl (for example, dicyclopropylvinylcarbinol) derivatives are in progress.

(10) $\tau_m$ is the $\tau$-value using the methyl protons of methanesulfonic acid as an internal reference. The value 6.76 $\tau$ is assigned to the methyl group, the latter having been measured by Dr. C-Y. Wu directly against tetramethylsilane in trifluoroacetic acid, a mutual solvent. We have found this internal reference particularly useful in n.m.r. studies of stable mono- and dicarbonium ions in sulfuric acid.

(11) *Cf.* N. Zelinsky, *Ber.*, **34**, 3887 (1901); N. V. Keersbilck, *Bull. Soc. Chim. Belg.*, **38**, 205 (1929); T. A. Favorskaya, N. V. Scherbinskaya and E. S. Golovacheva, *Zhur. Obshcheĭ Khim.*, **23**, 1878 (1953).

(12) *Cf.* M. Hanack and H. Eggensperger, *Angew. Chem.*, **74**, 116 (1962).

(13) For an $O^{18}$ study of cyclopropylcarbinyl benzenesulfonate, see D. B. Denney and E. J. Kupchik, *J. Am. Chem. Soc.*, **82**, 859 (1960).

(14) H. Adkins, "Reactions of Hydrogen with Organic Compounds over Copper–Chromium Oxide and Nickel Catalyst," The University of Wisconsin Press, Madison, 1937, p. 69.

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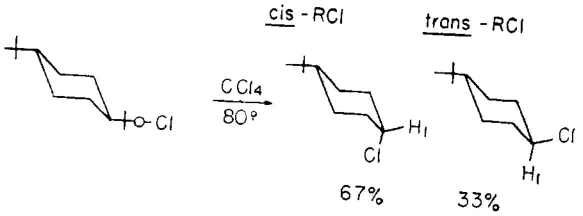
## ON THE NATURE OF THE CYCLOHEXYL RADICAL[1]

*Sir:*

We wish to report results of interest in the general problem of the geometry of carbon radicals, and to call attention to the suitability of the decomposition of hypochlorites[2] for the study of radicals.

Decomposition of dimethyl-(*trans*-4-*t*-butylcyclohexyl)-carbinyl hypochlorite[3] in carbon tetrachloride (*cis*-initial concn., 0.3–0.5 *M*) afforded acetone and and *trans*-4-*t*-butylcyclohexyl chloride (79–94% yields). *The ratio of* **cis**-*chloride to* **trans**-*chloride is two to one.*



These chlorides were identical in all respects with samples prepared by the action of thionyl chloride on a *cis–trans* mixture of 4-*t*-butylcyclohexanol in ether containing tri-*n*-butylamine. The chlorides were separated by vapor phase chromatography on a nitrile silicone column at 97° (*cis*-chloride, Calcd.: C, 68.74; H, 10.96; Cl, 20.30. Found: C, 68.91; H, 10.97; Cl, 20.40. *trans*-chloride, found: C, 68.62; H, 10.88; Cl, 20.28). Assignment of *cis*-stereochemistry to the chloride of shorter retention time is based on: (1) its enhanced ease (in comparison with the *trans*-isomer) of conversion by base to 4-*t*-butylcyclohexene[4]; (2) location of the C-1 hydrogen at 5.63 $\tau$ (*vs.* 6.36 $\tau$ for the *trans*-isomer[5]; (3) the marked similarity in infrared spectra with the corresponding *cis*- and *trans*-bromides of known configuration.[6]

Decomposition of dimethyl-(*cis*-4-*t*-butylcyclohexyl)-carbinyl hypochlorite[3] in carbon tetrachloride affords exactly the same product composition as that obtained from the *trans*-isomer described above. Both hypochlorites are stable in the dark, are readily decomposed by weak irradiation or heating, and in agreement with other tertiary alkyl hypochlorites,[2] decompose by a free radical chain reaction of long chain length.

$$R—C(CH_3)_2—O—Cl + R\cdot \longrightarrow R—C(CH_3)_2—O\cdot + Cl—R$$

$$R—C(CH_3)_2—O\cdot \longrightarrow R\cdot + (CH_3)_2C{=}O$$

That the observed two-to-one ratio of *cis*-chloride to *trans*-chloride is the result of kinetic control is established by: (1) the stability of the products to the reaction conditions (in separate control experiments) and (2) the thermodynamic preference of *trans* (equatorial) over *cis* (axial) chloride.[5]

Decomposition of the hypochlorites in carbon tetrachloride shows a small *decrease* in the ratio of *cis* to *trans* chloride with decreasing temperature (67/33 at +80°; 65/35 at 0°, 62/38 at −30°). The *cis*-hypochlorite affords exactly the same product ratio as the *trans* at all temperatures measured (+80°, 0°, −30°). This exact correspondence is strong evidence for the intermediacy of the 4-*t*-butylcyclohexyl radical in the two decompositions.

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[1] This work was supported by the National Science Foundation and by the Atomic Energy Commission.

(2) (a) C. Walling and A. Padwa, *J. Am. Chem. Soc.*, **82**, 2207 (1961); (b) F. D. Greene, M. L. Savitz, H. H. Lau, F. D. Osterholtz and W. N. Smith, *ibid.*, **83**, 2196 (1961).

(3) The hypochlorite was prepared from the corresponding alcohol by the action of hypochlorous acid [see F. D. Greene, *J. Am. Chem. Soc.*, **81**, 2688 (1959), and references cited therein]. The dimethyl-(*trans*- and *cis*-4-*t*-butylcyclohexyl)-carbinols employed in this study were prepared by the procedures of R. D. Stolow and C. B. Boyce, *J. Org. Chem.*, **26**, 4726 (1961).

(4) S. Winstein and N. J. Holness, *J. Am. Chem. Soc.*, **77**, 5562 (1955).

(5) A. J. Berlin and F. R. Jensen, *Chem. and Ind.*, 998 (1960); L. W. Reeves and K. O. Strømme, *Can. J. Chem.*, **38**, 1241 (1960).

(6) E. L. Eliel and R. G. Haber, *J. Org. Chem.*, **24**, 143 (1959). We wish to thank Professor Eliel for infrared spectra of the *cis* and *trans*-bromides.