Reactions of o- and p-cyanostyrene with thiols. These reactions were carried out as with the amines. Except in the case of the addition product of thioglycolic acid, ether solutions of the product mixtures were washed first with 5% sodium hydroxide to remove unchanged thiol, dried over calcium chloride and either distilled directly to give the addition product or stripped of ether and converted to a derivative for analysis. The ether solution of the thioglycolic acid adduct was washed repeatedly with water to remove unchanged thioglycolic acid. The crude product was then isolated by extraction from the ether by 10% sodium hydroxide solution, followed by reacidification, ether extraction, drying, and stripping of the ether. A part of this crude product was converted to a benzylisothiouronium salt derivative (see Table II).

Acknowledgment. This research was supported by a grant from the Petroleum Research Fund administered by the American Chemical Society. Grateful acknowledgment is hereby made to the donors of this fund.

MISSOULA, MONT.

[CONTRIBUTION FROM THE DEPARTMENTS OF CHEMISTRY OF STANFORD UNIVERSITY AND WAYNE STATE UNIVERSITY]

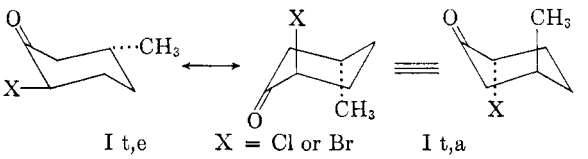
Optical Rotatory Dispersion Studies. XXXIII.[1] α-Haloketones (Part 6).[2] *trans*-2-Bromo-5-*t*-butylcyclohexanone[3]

CARL DJERASSI, E. J. WARAWA, ROBERT E. WOLFF,[4] AND E. J. EISENBRAUN

Received November 30, 1959

Resolution of *cis*-3-*t*-butylcyclohexanol was accomplished through the brucine salt of its acid phthalate, while *trans*-3-*t*-butylcyclohexanol (prepared by catalytic hydrogenation of *m*-*t*-butylphenol) was resolved *via* its 3β-acetoxy-Δ⁵-etienate. Oxidation of either resolved alcohol provided optically active 3-*t*-butylcyclohexanone, which was transformed into *trans*-2-bromo-5-*t*-butylcyclohexanone. Rotatory dispersion and ultraviolet and infrared measurements in different solvents indicated the complete absence of conformational mobility (due to the anchoring effect of the equatorial *t*-butyl group) in this system, in marked contrast to the behavior observed (ref. 5) with *trans*-2-halo-5-methylcyclohexanones.

In an earlier investigation,[5] we have demonstrated by the remarkable changes in the rotatory dispersion Cotton effect curves in solvents of different polarity that there exists a mobile equilibrium in the *trans*-2-halo-5-methylcyclohexanone system (I) between the two chair forms I, t,e and I t,a.[6] This was confirmed by dipole moment, infrared and ultraviolet measurements,[7] and quantitative calculations (in the case of I. X=Br) of the conformer composition (I, t,e *vs.* I t,a) in different solvents.



I t,e X = Cl or Br I t,a

A second, independent verification of these conclusions would involve the synthesis of a relative of *trans*-2-bromo-5-methylcyclohexanone (I, X=Br), where conformational mobility is inhibited on steric grounds, and to subject such a substance to the same physical measurements. In spite of recent comments,[8] the most straightforward approach appeared to be to replace the methyl group in I by a *t*-butyl function. Winstein and Holness[9] pointed out that such a bulky substituent would invariably anchor the cyclohexane ring in that conformation in which the *t*-butyl group occupies the equatorial orientation.[10]

---

(1) Paper XXXII, C. Djerassi, *Rec. Chem. Progress*, **20**, 101 (1959).

(2) Part 5, C. Djerassi, N. Finch, and R. Mauli, *J. Am. Chem. Soc.*, **81**, 4997 (1959).

(3) Grateful acknowledgment is made to the National Cancer Institute of the National Institutes of Health for financial support (grant No. CY-2919 at Wayne State University and grant No. CY-4818 at Stanford University). The major portion of the experimental work was carried out in the Department of Chemistry of Wayne State University.

(4) Present address: Institut de Biologie Physicochimique, Paris V.

(5) C. Djerassi and L. E. Geller, *Tetrahedron*, **3**, 319 (1958); C. Djerassi, L. E. Geller, and E. J. Eisenbraun, *J. Org. Chem.*, **25**, 1 (1960).

(6) As proposed to us by Dr. W. Klyne, we are employing two suffixes, the first denoting the relationship between the halogen atom and the alkyl group (c = *cis*, t = *trans*) and the second the orientation of the halogen atom (e = equatorial, a = axial).

(7) N. L. Allinger, J. Allinger, L. E. Geller, and C. Djerassi, *J. Org. Chem.*, **25**, 6 (1960).

(8) W. Hückel and M. Hanack, *Ann.*, **616**, 18 (1958).

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

(10) For other examples where a *t*-butyl group was employed to fix the conformation of a cyclohexane ring see: H. L. Goering, R. L. Reeves, and H. H. Espy, *J. Am. Chem. Soc.*, **78**, 4926 (1956); E. L. Eliel and C. A. Lukach, *J. Am. Chem. Soc.*, **79**, 5986 (1957); R. A. Pickering and C. C. Price, *J. Am. Chem. Soc.*, **80**, 4931 (1958); N. L. Allinger and J. Allinger, *J. Am. Chem. Soc.*, **80**, 5476 (1958).

Because optical rotatory dispersion measurements played an important role in our arguments,[5,7] the hitherto undescribed optically active 3-*t*-butylcyclohexanone was required. Furthermore, in view of the complexity of the monobromination of 3-methylcyclohexanone,[5] it was necessary to demonstrate—and this could be done with the racemic ketone—that bromination of 3-*t*-butylcyclohexanone does, in fact, yield some of the required *trans*-2-bromo-5-*t*-butylcyclohexanone. The present report deals with the experimental answers to these problems.

Initially, we prepared 3-*t*-butylcyclohexanone (IV)[11] by the 1,4-addition of *t*-butyl magnesium chloride to Δ^2-cyclohexenone. In agreement with Winstein and Holness,[9] our yields (20–30%) were far below those (*ca.* 70%) reported in the original literature,[12] and an alternate procedure is described in the sequel. Attempts to resolve the ketone IV by means of D-tartramidic acid hydrazide[13] failed, as the amorphous tartramazone could not be purified successfully. Consequently the ketone was reduced with lithium aluminum hydride to *cis*-3-*t*-butylcyclohexanol (V), whose acid phthalate has already been described.[9] Resolution through the brucine salt and regeneration of the alcohol yielded the pure (+)-antipode V and this was oxidized to (+)-3-*t*-butylcyclohexanone (IV).

In view of the poor overall yield to the resolved ketone IV, the following alternate procedure was selected. Catalytic hydrogenation of *m*-*t*-butylphenol (II)[14] with a rhodium catalyst proceeded in excellent yield to furnish the known[9] *trans*-3-*t*-butylcyclohexanol (III), which upon oxidation led to 3-*t*-butylcyclohexanone (IV), thus representing by far the best method for the synthesis of the racemic ketone. The formation of the *trans* alcohol (III) implies that the hydrogenation of the phenol (II) proceeded either stepwise with possible detachment from the catalyst surface and readsorption at an intermediate stage on the opposite side of the molecule or through the intermediacy of the ketone IV.

In contrast to the behavior of *cis*-3-*t*-butylcyclohexanol (V), we were unable to effect resolution of the *trans* isomer III through alkaloid salts of its acid phthalate. Recourse was therefore taken of the long neglected employment of steroid acids for the resolution of alcohols, and 3β-acetoxy-Δ^5-etienic acid was selected because of its recent successful use[15] for a similar purpose. Fractional crystallization provided the pure levorotatory *trans*-3-*t*-butylcyclohexyl 3β-acetoxy-Δ^5-etienate (VI), which was cleaved by means of lithium aluminum hydride into an easily separable mixture of 17β-hydroxymethyl-Δ^5-androsten-3β-ol (VII) and (+)-*trans*-3-*t*-butylcyclohexanol (III). Oxidation of the latter gave the same dextrorotatory antipode of 3-*t*-butylcyclohexanone (IV) as had been obtained earlier from (+)-*cis*-3-*t*-butylcyclohexanol (V).

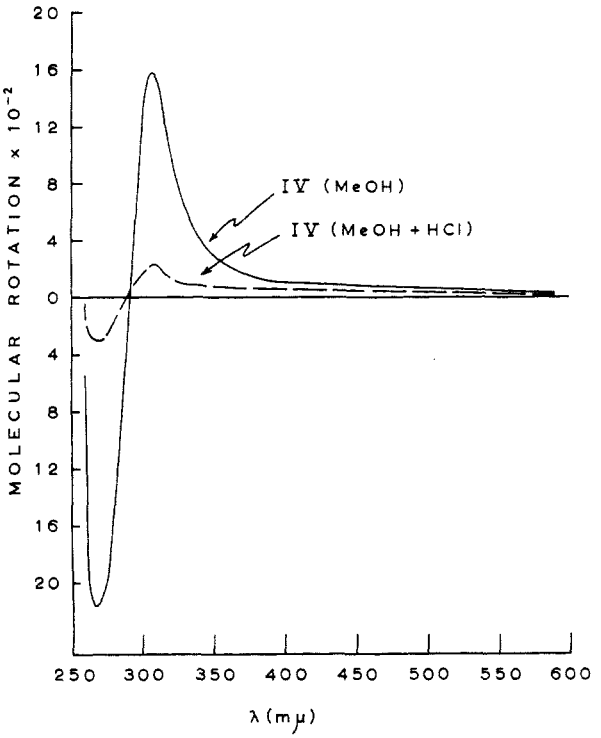


Fig. 1. Optical rotatory dispersion curve of (+)-3-*t*-butylcyclohexanone (IV) in methanol solution before and after the addition of one drop of concd. hydrochloric acid

The rotatory dispersion curve in methanol solution of (+)-3-*t*-butylcyclohexanone (IV) is reproduced in Fig. 1 and except for a somewhat increased amplitude[16,17] is identical with that of (+)-3-methylcyclohexanone measured[18] under similar conditions. It follows,[1,19] therefore, that the absolute configurations of (+)-3-*t*-butylcyclohexanone

(11) For all structural formulas, we are employing absolute configurational representations (steroid notation: solid line implying bond above the plane of the paper and dotted line referring to bond below that plane) corresponding to the resolved antipode employed in our work.

(12) F. C. Whitmore and G. W. Pedlow, *J. Am. Chem. Soc.*, **63**, 758 (1941).

(13) F. Nerdel and E. Henkel, *Ber.*, **85**, 1138 (1952); P. F. Wiley, K. Gerzon, E. H. Flynn, M. V. Sigal, O. Weaver, U. C. Quarck, R. R. Chauvette, and R. Monahan, *J. Am. Chem. Soc.*, **79**, 6062 (1957).

(14) Generously donated by Dow Chemical Company, Pittsburgh, California, and by Stepan Chemical Company, Chicago, Illinois.

(15) R. B. Woodward and T. J. Katz, *Tetrahedron*, **5**, 70 (1959).

(16) For nomenclature and recording of experimental data see C. Djerassi and W. Klyne, *Proc. Chem. Soc.*, **55** (1957) and Chapter 2 in ref. 19.

(17) The increased molecular amplitude can be ascribed to the more powerful dextrorotatory contribution of the *t*-butyl group as compared with the methyl group. These quantitative differences in the rotatory contribution of substituents of various size and polarity will be covered in a future paper.

(18) C. Djerassi and G. W. Krakower, *J. Am. Chem. Soc.*, **81**, 237 (1959).

(19) C. Djerassi, *Optical Rotatory Dispersion: Applications to Organic Chemistry*, McGraw Hill Book Co., New York, 1960. See especially chapter 10.

(IV) and (+)-3-methylcyclohexanone must be identical and, as this problem has already been solved for the latter ketone by classical means,[20] the stereoformulas III, IV, and V are correct in terms of absolute configuration.[11]

By employing the recently reported[1,19,21] rotatory dispersion technique for the determination of methyl ketal formation—measurement of the diminution of the Cotton effect amplitude upon addition of hydrochloric acid—the results shown in Fig. 1 were obtained. These show the formation of 85% of methyl ketal as compared with 93%[21] for (+)-3-methylcyclohexanone. This difference is probably just barely within experimental accuracy of the method and indicates that if the 3-*t*-butyl group has an effect upon the reactivity of the keto function—as has been suggested recently[10]—it is rather small.

With the resolution problem solved, it was necessary to turn to the preparation of the required bromo derivative. Most of the studies were conducted with the racemic 3-*t*-butylcyclohexanone (IV), as the optically active material was required only for the rotatory dispersion measurements (*vide infra*). Just as in the earlier recorded[5] bromination of (+)-3-methylcyclohexanone, a mixture was produced from which one pure, crystalline monobromo derivative (VIII) could be separated in poor yield. The *location* of the bromine atom was established by the course of the dehydrobromination with 2,4-dinitrophenylhydrazine[22] which led smoothly to a 2,4-dinitrophenylhydrazone of 3-*t*-butylcyclohexenone. Its ultraviolet absorption spectrum ($\lambda_{max}^{CHCl_3}$ 383 mμ) was most compatible[23] with the Δ^2-5-*t*-butylcyclohexenone formulation (IX) and complete confirmation came from a repetition of this dehydrobromination with the optically active bromo ketone VIII. The resulting 2,4-dinitrophenylhydrazone (IX) was optically active, which would not have been the case if the alternate 2-bromo-3-*t*-butylcyclohexanone formulation had obtained.

The *orientation* of the bromine atom in VIII was established as equatorial by ultraviolet and infrared spectral measurements (see Tables I and II) in a wide variety of solvents of different polarity. The ultraviolet spectral shift in going from 3-*t*-butylcyclohexanone (IV) to its monobromo derivative (VIII) ranged from 1–4 mμ (Table 1), which is consistent[24] only with an equatorial bromo substituent. Similarly, the infrared shift towards lower wave length of 0.05–0.07 μ in six different solvents (Table II) in going from the ketone IV to VIII again requires[25] an equatorial orientation for the halogen atom.

TABLE I

POSITIONS OF ULTRAVIOLET ABSORPTION CARBONYL MAXIMA

Solvent	3-*t*-Butylcyclohexanone (IV) λ_{max} (mμ)	log ε	*trans*-2-Bromo-5-*t*-butylcyclohexanone (VIII) λ_{max} (mμ)	log ε
Isoöctane	287	1.25	286	1.39
Carbon tetrachloride	290	1.28	290	1.42
Dioxane	285	1.30	281	1.40
Methanol	279	1.21	281	1.41

TABLE II

POSITIONS OF INFRARED ABSORPTION CARBONYL MAXIMA

Solvent	3-*t*-Butylcyclohexanone (IV) λ_{max} (μ)	*trans*-2-Bromo-5-*t*-butylcyclohexanone (VIII) λ_{max} (μ)
Isoöctane	5.80	5.75
Carbon tetrachloride	5.81	5.75
Dioxane	5.82	5.75
Chloroform	5.82	5.77
Methanol	5.82	5.77
Dimethyl sulfoxide	5.84	5.77

The optical rotatory dispersion results of (+)-*trans*-2-bromo-5-*t*-butylcyclohexanone (VIII) are collected in Fig. 2. In the 3-methylcyclohexanone series[5] a strongly negative Cotton effect is observed in a nonpolar medium (e.g. octane) because of the axial conformer I t,a, while a large shift towards positive rotation is encountered in a polar solvent (methanol) because of an increased proportion of the conformer I t,e, with an equatorial halogen atom. As shown in Fig. 2, (+)-*trans*-2-bromo-5-*t*-butylcyclohexanone (VIII) exhibits in both methanol and isoöctane solution a positive Cotton effect, which according to the axial haloketone rule (or its extension, the octant rule)[1,19] is only consistent with the conformation VIII.[26] Even more important is the observation that within the limit of experimental error, the molecular amplitudes of the Cotton effect curves of VIII in two solvents of widely differing polarity (methanol *vs.* isoöctane) are identical. These results do not only

(20) For pertinent references see E. J. Eisenbraun and S. M. McElvain, *J. Am. Chem. Soc.*, **77**, 3383 (1955).

(21) C. Djerassi, L. A. Mitscher, and B. J. Mitscher, *J. Am. Chem. Soc.*, **81**, 947 (1959).

(22) V. R. Mattox and E. C. Kendall, *J. Am. Chem. Soc.*, **70**, 882 (1948); C. Djerassi, *J. Am. Chem. Soc.*, **71**, 1003 (1949).

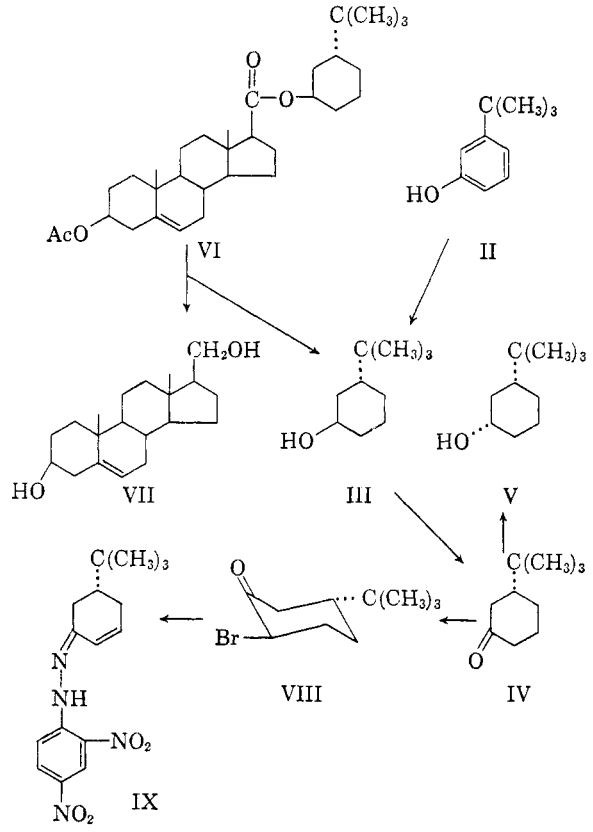
(23) See C. Djerassi and E. Ryan, *J. Am. Chem. Soc.*, **71**, 1000 (1949).

(24) R. C. Cookson, *J. Chem. Soc.*, 282 (1954).

(25) R. N. Jones, D. A. Ramsay, F. Herling, and K. Dobriner, *J. Am. Chem. Soc.*, **74**, 2828 (1952); E. J. Corey, *J. Am. Chem. Soc.*, **75**, 2301, 3297 (1953).

(26) There is practically no wave length shift (in any given solvent) in the position of the rotatory dispersion extrema in going from the ketone IV to its bromo derivative (VIII), which again represents an important criterion (see Chapter 9 in ref. 19) of an equatorially oriented halogen atom.

confirm fully our earlier conclusions[5,7] about conformational mobility in the 2-bromo-5-methylcyclohexanone series (I t,e ⟷ I t,a), but they also demonstrate the complete absence of such mobility in the *t*-butyl analog. Fig. 2 represents a clear-cut graphic illustration of the validity of using[9] a bulky *t*-butyl substituent as an effective anchoring device to achieve a frozen conformation.



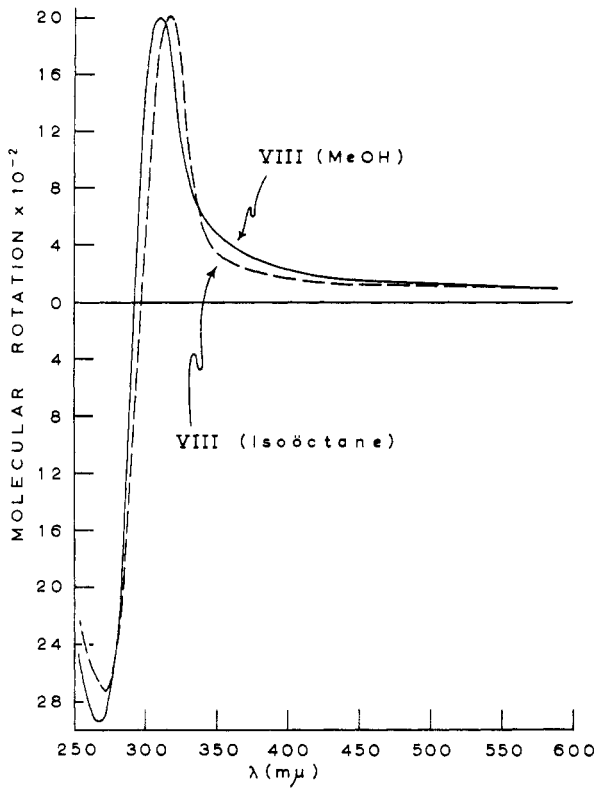


Fig. 2. Optical rotatory dispersion curve of (+)-*trans*-2-bromo-5-*t*-butylcyclohexanone (VIII) in methanol and in isoöctane solution

EXPERIMENTAL[27]

Resolution of cis-3-t-butylcyclohexanol (V). Reduction[9] of 21.5 g. of 3-*t*-butylcyclohexanone (IV) with lithium aluminum hydride provided 20 g. of the crude alcohol which was converted directly into its acid phthalate. Two recrystallizations from 66% aqueous methanol led to 24 g. of *cis*-3-*t*-butylcyclohexyl acid phthalate, m.p. 134–136° (lit.,[9] m.p. 136–136.8°).

A mixture of 15.0 g. of the above acid phthalate and 19.7 g. of brucine was dissolved in 30 cc. of acetone and heated for 40 min. at 40°. After cooling, scratching, and standing overnight in the refrigerator the precipitated brucine salt was collected and recrystallized by triangular fractional crystallization using benzene as the solvent. The separation was followed by the melting point of the brucine salt (purest specimen, m.p. 117–120°) and by the rotation (maximum $[\alpha]_D$ +14°) of the derived acid phthalate obtained upon acid treatment of the salt. In this manner, 6.4 g. of pure brucine salt was secured and this was dissolved in methanol and treated with 10 cc. of 2*N* hydrochloric acid. After heating for 5 min., water was added, the mixture was left overnight in the refrigerator, and the crystals were filtered and washed well with water, the absence of brucine being demonstrated by a negative nitric acid-acetic acid color reaction. The constants (m.p. 104.5–107°, $[\alpha]_D^{30}$ +14°, c = 1.7 in chloroform) of dried solid (86% yield based on brucine salt) were not altered upon recrystallization from aqueous methanol and the infrared spectrum in chloroform solution was identical with that of the racemic acid phthalate.

A 1.78-g. sample of the resolved acid phthalate was steam distilled in the presence of 50 cc. of 50% potassium hydroxide solution, water being added continuously to maintain a constant volume. Ether extraction of the distillate and distillation at 25 mm. and a bath temperature of 130–150° afforded 0.87 g. of (+)-*cis*-3-*t*-butylcyclohexanol (V) $[\alpha]_D^{30}$ +7.9° (c = 3.1 in chloroform), which crystallized in the ice box but melted at room temperature; the infrared spectrum in chloroform solution was identical with that of the racemic material.[9]

Anal. Calcd. for $C_{10}H_{20}O$: C, 76.86; H, 12.90. Found: C, 76.38; H, 12.49.

trans-3-t-Butylcyclohexanol (III). Hydrogen uptake ceased after 14 hr. when a solution of 10.68 g. of *m*-*t*-butylphenol (II)[14] in 75 cc. of methanol was shaken at 14° and atmospheric pressure in the presence of hydrogen with 1.78 g. of a 10% rhodium sesquioxide on carbon catalyst.[28] After filtration of the catalyst, the solvent was removed by distillation through a Vigreux column and the residue was taken up in ether and washed well with 10% sodium hydroxide solution and then with water. The dried ether solution was evaporated to dryness and the residue (9.40 g.) crystallized completely upon cooling in Dry Ice; m.p. 56–59° (with sublimation at 53°). Vapor phase chromatography at 150° on a silicone grease-firebrick support showed the material to be homogeneous and it was used directly for the oxidation and

(27) Melting points were determined on the Kofler block. The infrared (Beckman spectrophotometer model IR 4) and ultraviolet (Perkin Elmer spectrophotometer model 4000A) spectral determinations were performed by Miss B. Bach.

(28) We are indebted to Mr. William Pearlman of Parke, Davis and Co., Detroit, for a gift of this catalyst.

resolution experiments described below. Sublimation of a 100 mg. sample at 0.1 mm. yielded 82 mg. of colorless solid with m.p. 59–60°; its infrared spectrum in chloroform solution was identical with that of the unsublimed specimen. A small amount of the alcohol was converted to the acid phthalate and recrystallized from acetic acid–hexane (1:5), whereupon it exhibited m.p. 152–153°, undepressed upon admixture with an authentic specimen (lit.,[9] m.p. 154.5–155.5°) of *trans*-3-*t*-butylcyclohexyl acid phthalate which was kindly supplied by Prof. S. Winstein.[9]

Resolution of trans-3-t-butylcyclohexanol (III). Addition of 200 g. of thionyl chloride to 25 g. of 3β-acetoxy-Δ^5-etienic acid[29] resulted in complete solution. After 6 hr. at room temperature the excess thionyl chloride was removed *in vacuo* and the acid chloride, dissolved in 210 cc. of pyridine, was added to 11.8 g. of *trans*-3-*t*-butylcyclohexanol (III) in 25 cc. of pyridine. The mixture was stirred for 18 hr. and was then poured into a solution of 265 cc. of concd. hydrochloric acid in 1.4 l. of water. The precipitated solid was filtered (yield of air dried material, 32.7 g.) and freed from adhering alcohol by steam distillation. The residual, crude (28.2 g.) *trans*-3-*t*-butylcyclohexyl 3β-acetoxy-Δ^5-etienate (VI) was extracted with benzene, leaving *ca.* 5 g. of unchanged acid as a residue. The benzene solution was chromatographed on Merck acid-washed alumina and eluted with benzene-ether mixtures, ether, and finally ether containing some methanol. A total of 18 g. of colorless, solid material was obtained, the various fractions ranging in m.p. from 60–140° to 127–141°. Each fraction was purified separately by repeated recrystallization from acetone, leading eventually to a total of 2.30 g. of the pure diasteroisomer VI, m.p. 157–158.5°, $[\alpha]_D^{24}$ −30.4° (c = 0.093 in chloroform), $\lambda_{max}^{CHCl_3}$ 5.80 and 7.90 μ.

Anal. Calcd. for $C_{32}H_{50}O_4$: C, 77.06; H, 10.11; O, 12.83. Found: C, 76.65; H, 9.89; O, 13.52.

The above ester VI (0.44 g.) in ether solution was heated under reflux for 2 hr. with an excess of lithium aluminum hydride. After processing in the usual manner, the reduction product was leached with pentane which left undissolved 0.24 g. of the steroid diol VII. Removal of the pentane by careful distillation and sublimation of the residue (0.16 g.) at 50°/0.1 mm. furnished 0.1 g. of (+)-*trans*-3-*t*-butylcyclohexanol (III), m.p. 61.5–63°, $[\alpha]_D^{28}$ +19.8° (c = 0.85 in chloroform).

Anal. Calcd. for $C_{10}H_{20}O$: C, 76.86; H, 12.90; O, 10.24. Found: C, 76.70; H, 12.97; O, 10.03.

3-t-Butylcyclohexanone (IV). To an ice cold solution of 240 mg. of *trans*-3-*t*-butylcyclohexanol (III) in 25 cc. of pure acetone was added dropwise, with stirring, a standard chromium trioxide–sulfuric acid solution,[30] small quantities of anhydrous magnesium sulfate being added during the titration. Upon formation of a permanent orange coloration, the solution was stirred for an additional 30 min., excess acid was neutralized with sodium bicarbonate, and the solution was filtered and then dried with magnesium sulfate. The acetone was distilled off carefully, the last traces being removed by codistillation with hexane until the distillate failed to respond to Brady's solution. Distillation of the residue gave 208 mg. of 3-*t*-butylcyclohexanone, b.p. 75–80°/3.5–3.7 mm. The substance was homogeneous by vapor phase chromatography and the relevant ultraviolet and infrared spectral properties are listed in Table I and II.

The 2,4-dinitrophenylhydrazone was recrystallized from ethanol, m.p. 161–162.5°, $\lambda_{max}^{CHCl_3}$ 366 mμ, log ε 4.40.

Anal. Calcd. for $C_{16}H_{22}N_4O_4$: C, 57.48; H, 6.63; N, 16.76. Found: C, 56.98; H, 6.52; N, 16.25.

Similar oxidation of 442 mg. of the (+)-antipode of III (or V) yielded 427 mg. of (+)-3-*t*-butylcyclohexanone, $[\alpha]_D^{24.5}$ +25° (c = 0.489 in chloroform); its infrared spectrum (chloroform solution) was identical with that of the racemic ketone. Rotatory dispersion (see Fig. 1) in methanol (c, 0.115): $[\alpha]_{700}$ +6.9°, $[\alpha]_{589}$ +24°, $[\alpha]_{305}$ +1010°, $[\alpha]_{267.5}$ −1400°, $[\alpha]_{255}$ −337°; after addition of one drop of concd. hydrochloride acid: $[\alpha]_{589}$ +10°, $[\alpha]_{315}$ +116°, $[\alpha]_{272.5}$ −210°, $[\alpha]_{260}$ −29°. Rotatory dispersion in isoöctane (c, 0.130): $[\alpha]_{700}$ +30°, $[\alpha]_{589}$ +16°, $[\alpha]_{320}$ +902°, $[\alpha]_{315}$ +726°, $[\alpha]_{310}$ +768°, $[\alpha]_{275}$ −1010°, $[\alpha]_{252.5}$ −740°.

Anal. Calcd. for $C_{10}H_{18}O$: C, 77.86; H, 11.76. Found: C, 77.33; H, 11.60.

The semicarbazone of the (+)-ketone IV exhibited m.p. 179–182°, $[\alpha]_D$ +4° (chloroform).

Anal. Calcd. for $C_{11}H_{21}ON_3$: C, 62.52; H, 10.02. Found: C, 62.93; H, 10.41.

trans-2-Bromo-5-t-butylcyclohexanone (VIII). To a cold (10°) solution of 1.015 g. of 3-*t*-butylcyclohexanone (IV) in 7 cc. of anhydrous ether containing 3 drops of 10% hydrogen bromide–acetic acid solution was added dropwise with stirring 1.058 g. of bromine dissolved in 0.26 cc. of glacial acetic acid. The rate of addition was adjusted to the rate of decolorization and the entire reaction was complete in 5 min., whereupon the colorless solution was poured into saturated salt solution and the bromoketone extracted with ether. After thorough washing and drying, the ether was removed at room temperature by bubbling nitrogen gas through the solution under a slight vacuum. The liquid, lachrymatory residue (1.43 g.) was treated with 1 cc. of dry pentane and cooled in a Dry Ice–acetone bath, crystallization being promoted by scratching. The resulting crystals were filtered rapidly after about 5–10 min. and this process was repeated 10 times until no more crystals formed. The total solid material (140 mg.) melted at 54–57° with prior sublimation at 48°. When sublimed at 70°/0.1 mm., 70 mg. of colorless crystals, m.p. 71.5–72.5°, were obtained and these were unchanged upon repeated sublimation. This material was used for the spectral studies (Tables I and II) as well as for the dehydrobromination described below.

Anal. Calcd. for $C_{10}H_{17}BrO$: C, 51.48; H, 7.35; O, 6.86; Br, 34.30. Found: C, 51.21; H, 7.32; O, 6.98; Br, 34.22.

When the bromination was repeated with 310 mg. of (+)-3-*t*-butylcyclohexanone, there was isolated 48 mg. of solid bromoketone with m.p. 64–68°. Sublimation at 70°/0.1 mm. afforded 25 mg. of the pure bromoketone VIII, m.p. 82–83°, whose infrared spectrum in chloroform solution was identical with that of the racemic bromoketone. Rotatory dispersion (Fig. 2) in methanol (c, 0.099): $[\alpha]_{700}$ +8°, $[\alpha]_{589}$ +42°, $[\alpha]_{310}$ +856°, $[\alpha]_{265}$ −1265°, $[\alpha]_{250}$ −1055°. Rotatory dispersion in isoöctane (c, 0.0975): $[\alpha]_{700}$ +29°, $[\alpha]_{589}$ +45°, $[\alpha]_{317.5}$ +862°, $[\alpha]_{272.5}$ −1168°, $[\alpha]_{255}$ −964°.

Δ^2-5-t-Butylcyclohexenone 2,4-dinitrophenylhydrazone (IX). To a solution of 22 mg. of *trans*-2-bromo-5-*t*-butylcyclohexanone (VIII) in 5 cc. of glacial acetic acid[22] was added 20 mg. of 2,4-dinitrophenylhydrazine; the mixture was warmed for 15 min. in a current of nitrogen and then poured into water. The product was extracted with benzene, dried, and passed through a column of Fischer activated alumina to yield 30 mg. of bright red dinitrophenylhydrazone. Two recrystallizations from ethanol gave the analytical specimen of IX, m.p. 155.5–156.5°, $\lambda_{max}^{CHCl_3}$ 383 mμ, log ε 4.35.

Anal. Calcd. for $C_{16}H_{20}N_4O_4$: C, 57.82; H, 6.07; N, 16.86. Found: C, 57.76; H, 6.07; N, 16.20.

Repetition of this reaction with 10 mg. of (+)-*trans*-2-bromo-5-*t*-butylcyclohexanone (VIII) furnished the optically active form of the 2,4-dinitrophenylhydrazone IX, m.p. 150.5–151°, $[\alpha]_D^{25}$ −111° (c = 0.235 in chloroform), $\lambda_{max}^{CHCl_3}$ 382 mμ, log ε 4.34.

STANFORD, CALIF.

(29) Grateful acknowledgment is made to Dr. H. L. Herzog and Dr. A. L. Nussbaum of Schering Corporation, Bloomfield, N. J., for a supply of this acid.

(30) See K. Bowden, I. M. Heilbron, E. R. H. Jones, and B. C. L. Weedon, *J. Chem. Soc.*, 39 (1946).