**1-Bromobicyclo[3.3.1]nonan-9-one 2,4-dinitrophenylhydrazone** was prepared[13] from VIII and recrystallized from 95% ethanol; m. p. 185–186°.

*Anal.* Calcd. for $C_{15}H_{17}N_4O_4Br$: C, 45.35; H, 4.32; N, 14.10; Br, 20.12. Found: C, 45.55; H, 4.50; N, 14.23; Br, 20.13.

**Bicyclo[3.3.1]nonane (IX).**—Amalgamated zinc was prepared by stirring 100 g. of 20–30 mesh granulated zinc with 200 ml. of 10% mercuric chloride solution for one hour and washing with water. Amalgamated zinc (15 g.), 1 g. of VIII and 20 ml. of concentrated hydrochloric acid were heated under reflux for one-half hour, during which period the product (IX) sublimed and collected in the reflux condenser as a crystalline solid. The solid (0.4 g., 70%) was purified by sublimation at atmospheric pressure and 100° and by recrystallization from methanol, and then had m. p. 145–146° and was analytically pure. An authentic sample of IX prepared from bicyclo[3.3.1]nonan-2,6-dione[4,16] by Clemmensen reduction under the conditions described above did not depress the m. p. of IX prepared from VIII. The two samples also had identical infrared spectra.

**Reaction of VIII with Sodium in Liquid Ammonia and with Sodamide.**—Small pieces of sodium totaling 1.1 g. were added to a solution of 4.4 g. of VIII in 50 ml. of liquid ammonia. The blue color of the solution disappeared rapidly and, after the addition was completed, 2.6 g. of ammonium chloride was added and the ammonia was allowed to evaporate. The solid residue was extracted with acetone, which was then distilled under reduced pressure. The white crystalline residue (possibly X), 2.1 g. (68%) had m. p. 105–107° and was recrystallized from methylcyclohexane as glistening plates, m. p. 107–107.5°.

*Anal.* Calcd. for $C_9H_{15}NO$: C, 70.55; H, 9.86; N, 9.14. Found: C, 70.44; H, 9.96; N, 9.08.

(16) We are indebted to Edward C. Hermann for the tetramethyl bicyclo[3.3.1]nonan-2,6-dione-1,3,5,7-tetracarboxylate used in the preparation of this compound.

Properties observed for the compound which are in accord with its formulation as an amide include its failure to form a hydrochloride or benzoyl derivative, failure to react with semicarbazide and 2,4-dinitrophenylhydrazine, and reaction with boiling sodium hydroxide forming ammonia. The same product was obtained by addition of 1 g. of VIII to the sodamide prepared from 0.25 g. of sodium and a catalytic amount of iron oxide in 50 ml. of liquid ammonia. After thirty minutes, 1 g. of ammonium chloride was added and the product (0.5 g.) was isolated by the procedure described above.

## Summary

Bicyclo[3.3.1]non-3-en-9-one-1-carboxylic acid (V) has been prepared by the Michael addition of α-carbethoxycyclohexanone to acrolein at −70°, followed by cyclization of the resulting aldehyde III by treatment with concentrated sulfuric acid and saponification of the ester IV. Both the acid V and the corresponding saturated acid VII resist decarboxylation by heating. Bicyclo[3.3.1]nonan-9-one-1-carboxylic acid (VII) was decarboxylated by reaction of the silver salt with bromine. The carbon skeleton of the resulting bromoketone VIII has been established by reduction to the known solid hydrocarbon, bicyclo[3.3.1]nonane (IX). Although the halogen in VIII is located at a bridgehead, the compound formed silver bromide on treatment with alcoholic silver nitrate, and reacted with sodium or sodamide in liquid ammonia to give an amide (possibly X).

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[CONTRIBUTION FROM THE CHEMICAL LABORATORIES OF THE JOHNS HOPKINS UNIVERSITY]

# The Synthesis of 3,5-Di-*s*-butyl-1-cyclopentenealdehyde[1]

BY EVANS B. REID AND JOHN F. YOST[2,3]

For several years work in these laboratories has been directed toward the synthesis of the plant hormones, auxins a and b,[4] and an important intermediate in our projected synthesis is 3,5-di-*s*-butyl-1-cyclopentenealdehyde. Earlier attempts to approach this compound by alkylation of the cyclopentene ring were without success.[1] Our attention then turned to the exploration of methods of synthesizing the appropriately substituted 1,2-cyclohexanediol, which should yield the desired 1-cyclopentenealdehyde through ring splitting and cyclodehydration. While engaged in this work, the last steps of our projected method were utilized by English and Barber[5] in their novel synthesis of 3,5-di-*n*-propyl-1-cyclopentenealdehyde. These authors employed a Claisen rearrangement, followed by reduction to prepare 3,5-di-*n*-propylpyrocatechol, which was then further reduced to the corresponding cyclohexanediol. On cleavage of the diol with lead tetraacetate, their cyclopentenealdehyde formed spontaneously.

Our approach to the synthesis of the 3,5-di-*s*-butyl analog was, of necessity, a direct one, and involved nuclear alkylation of phenol in the 2- and 4-positions. *s*-Butyl alcohol and anhydrous hydrogen fluoride were used since earlier work had indicated that under such conditions,[6] (1) oxygen alkylation does not occur, (2) isomerizations (excluding partial racemization[7,8] within the alkyl group are absent, and (3) no meta substitution is induced. Further, from the vast amount of experimentation on alkylation

(1) This is the second paper describing synthetic work related to the auxin field. For the first, see Reid and Yost, THIS JOURNAL, **72**, 1807 (1950).

(2) From the doctoral dissertation of John F. Yost, The Johns Hopkins University.

(3) Standard Oil Company of Indiana Fellow, 1949–1950.

(4) Kögl, Erxleben, Michaelis and Visser, *Z. physiol. Chem.*, **235**, 181 (1935), and earlier papers.

(5) English and Barber, THIS JOURNAL, **71**, 3310 (1949).

(6) Calcott, Tinker and Weinmayr, *ibid.*, **61**, 1010 (1939).

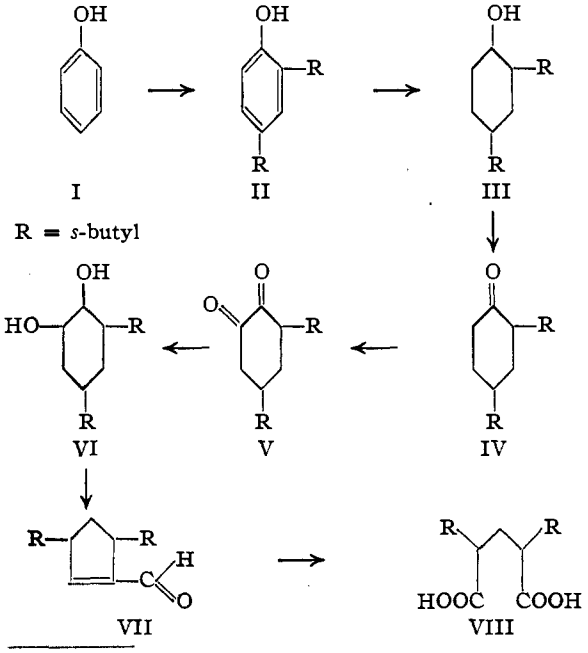
(7) Price and Lund, *ibid.*, **62**, 3105 (1940).

(8) Burwell and Archer, *ibid.*, **64**, 1032 (1942).

with catalysts of the Friedel and Craft type[9] it was to be anticipated that the 2,4-di-*s*-butylphenol would be obtained free from the 2,6-isomer.

In the sequence of reactions employed it will be noted that the initial alkylation reaction is cardinal, since the structure of the alkyl groups in the cyclopentenealdehyde (VII) is determined during this step. That alkyl isomerization was unlikely was indicated by the isolation of some *p*-*s*-butylphenol[10] from the reaction mixture, but, due to the refractory nature of the dialkylated phenol, which must consist of a mixture of diastereoisomers, an unequivocal demonstration of the presence of two *s*-butyl groups was impracticably difficult. The synthesis of mono-, di- and tri-*t*-butylphenols has been reported recently,[11] and it is apparent from the boiling point and solubility of 2,4-di-*t*-butylphenol that separation of this compound from the di-*s*-butyl isomer would be difficult, especially if the tertiary compound were present in relatively small amounts. However, at the dialkylcyclohexanone stage (IV) (*vide infra*), it became possible to prepare solid derivatives and to demonstrate the absence of skeletal rearrangement within the alkyl groups.

Reduction of 2,4-di-*s*-butylphenol (II) was smoothly accomplished in acetic acid with Adams catalyst, to yield 2,4-di-*s*-butylcyclohexanol (III). The latter was a viscid liquid which underwent slight dehydration on distillation *in vacuo*. It may be noted that reduction of aromatic rings under the described conditions has been shown to involve predominantly *cis*-addition of hydrogen.[12] In the present instance the problem is complicated by the fact that our reduction product contains five asymmetric centers and must, therefore, consist of a very complex mixture of stereoisomers.




Oxidation of the dialkylcyclohexanol (III) to give 2,4-di-*s*-butylcyclohexanone (IV), was effected smoothly and in good yield by means of chromic-sulfuric acid mixture.[13] The ketone was a limpid oil, much less viscous than the parent alcohol. It formed two *isomeric* oximes, though in greatly different proportions. That these oximes were not merely syn- and anti- forms was shown by hydrolysis. Each oxime furnished an oil from which *only* the parent derivative could be regenerated, and since neither oxime was due to isomerized alkyl groups (*vide infra*), the formation of these isomers must be due either to stereoisomerism within the cyclohexyl ring, or within the *s*-butyl groups.

Since the yield of combined oximes was practically quantitative, the dialkylcyclohexanone stage represented a critical point in our synthesis where it became possible to demonstrate the absence of isomerization during the initial alkylation reaction. For this purpose, phenol was alkylated with *t*-butyl alcohol under the original conditions. 2,4-Di-*t*-butylphenol was reduced to the corresponding cyclohexanol, and the latter was oxidized to form 2,4-di-*t*-butylcyclohexanone. Unlike di-*s*-butylcyclohexanone, the di-*t*-butylcyclohexanone formed but *one* oxime, and this was much different from either of the isomeric oximes obtained from the di-*s*-butyl ketone. This we take as proof that the dialkylation of phenol with *s*-butyl alcohol and anhydrous hydrogen fluoride proceeds without skeletal rearrangement. Further, if it is assumed that the reduction of 2,4-dialkylphenols is completely stereospecific, regardless of the nature of the alkyl groups, it then follows that the isomerism of the oximes of 2,4-di-*s*-butylcyclohexanone is due to the two side-chain asymmetric centers. However, it is conceivable that the *s*-butyl groups being unsymmetrical, might exert directive influences during the reduction of the dialkylphenol, and hence render the reduction somewhat less than completely stereospecific. The isomerism of the oximes of 2,4-di-*s*-butylcyclohexanone would then be due to two isomeric ring structures. On this basis, the di-*t*-butylcyclohexanone should give only one oxime, since reduction of the parent phenol with its perfectly symmetrical groups, should be virtually stereospecific. In the absence of definitive evidence, the latter possibility appears the more likely.

It is of interest that the Oppenauer method, as

(9) Price, "Organic Reactions," Vol. III, John Wiley and Sons, Inc., New York, N. Y., 1946, Ch. I.

(10) Reilly and Hickinbottom, *J. Chem. Soc.*, **117**, 103 (1920).

(11) Stillson, Sawyer and Hunt, THIS JOURNAL, **67**, 303 (1945).

(12) Linstead and Doering, *ibid.*, **64**, 1985 (1942).

(13) The procedure was similar to that which has been used for the oxidation of menthol: Sandborn, "Organic Syntheses," Coll. Vol. I, John Wiley and Sons, Inc., New York, N. Y., 1941, p. 340.

applied to the oxidation of cholesterol[14] failed to oxidize 2,4-di-*s*-butylcyclohexanol.

The direct oxidation of menthone to buchucamphor (diosphenol) by ferric chloride has been reported,[15,16] but the reaction seems subject to steric effects, since tetrahydrocarvone is not oxidized.[11] Comparison of the structure of menthone with that of 2,4-di-*s*-butylcyclohexanone (IV), shows that the methylene group of the latter is less blocked than that of menthone. Further, the presence of *s*-butyl groups may be considered to induce a higher and favorable electron density on the ring. To these factors is ascribed the ready oxidation of our ketone to the diketone, and in superior yield.[16] The deep golden-yellow 3,5-di-*s*-butyl-1,2-cyclohexanedione (V) behaved, in general, similarly to buchucamphor in its strong enol test and inertia to carbonyl reagents.[17]

Attempts were made to prepare the diketone by mild hydrolysis of 2,6-dibromo-2,4-di-*s*-butylcyclohexanone,[18] but these were only partially successful since the product was contaminated with halogenated material that persisted throughout subsequent operations.

Reduction of the diketone (V) to 3,5-di-*s*-butyl-1,2-cyclohexanediol (VI), was accomplished in glacial acetic acid with Adams catalyst. The diol was an exceedingly viscous oil, colorless when first obtained, but becoming yellow on distillation. Oxidation of the diol with lead tetraacetate proceeded smoothly. The product was 3,5-di-*s*-butyl-1-cyclopentenealdehyde (VII), which had formed by cyclodehydration during the oxidation.[5] Evidence in favor of the assigned structure (VII) was obtained through oxidation. The product, after distillation in high vacuum, gave analytical figures and neutral equivalents which accorded with those calculated for $\alpha,\alpha'$-di-*s*-butylglutaric acid (VIII), in preponderantly anhydride form.

**Acknowledgment.**—One of the authors (J. F. Y.) wishes to express his appreciation of a grant-in-aid from the Hynson, Westcott and Dunning Fund in the pursuance of this research.

## Experimental

**2,4-Di-*s*-butylphenol.**—The general alkylation procedure of Calcott, Tinker and Weinmayr[6] was used. Experimentation showed that the best yields of dialkylated product were obtained when 2.1 moles of freshly distilled *s*-butyl alcohol, in which was dissolved 1.0 mole of phenol (commercial but not discolored), were added to 6.25 moles of chilled anhydrous hydrogen fluoride. The product was fractionally distilled from a short Claisen column in a nitrogen atmosphere at 1.0 mm. Fourteen grams of material containing monoalkylated phenol was obtained, b. p. 80–100°, with the main fraction distilling from 100–112°. A higher fraction, 14 g., had b. p. 112–120°, and probably consisted of trialkylated material. The crude stereoisomeric mixture of 2,4-di-*s*-butylphenols was sufficiently pure to be used directly. The yield was 152 g., or 73.8%, $n^{23}D$ 1.5022. For analysis, this material was refractionated under nitrogen at 4.0 mm., and a cut with b. p. 123–125° was taken.

*Anal.* Calcd. for $C_{14}H_{22}O$: C, 81.53; H, 10.75. Found: C, 81.79; H, 10.93.

The substance darkened appreciably on standing at room temperature, but could be kept indefinitely in a refrigerator.

When the lower fraction, b. p. 80–100°, was kept for several weeks at refrigerator temperature, it partly solidified. After recrystallization from aqueous alcohol, the solid had m. p. 58.5–59.5°. The reported[10] m. p. for *p*-*s*-butylphenol is 59°.

**Tests on 2,4-Di-*s*-butylphenol.**—The usual ferric chloride test[19] for enols was negative[20] for the dialkyl compound; for *p*-*s*-butylphenol it was only feebly positive. In 50% dioxane–water solution, however, heat was evolved as the solution became turbid. Under the same conditions *p*-*s*-butylphenol gave an exothermic reaction and a pale green color. The dialkylphenol reacted with acetyl, benzoyl, and 3,5-dinitrobenzoyl chlorides, but the products were highly viscous yellow oils that failed to crystallize. Attempts to form the phenylurethan produced only a trace of crystalline material after keeping for several months. The phenol appeared to react with chloroacetic acid in the normal manner,[21] but again crystalline material did not form. With metallic sodium at room temperature, hydrogen was evolved slowly; at 60–70° the evolution was vigorous, and the residue darkened. When treated with neutral or basic permanganate, the phenol was immediately oxidized, but only yellow glassy polymers resulted. With diazomethane a very slow and incomplete reaction ensued. After treatment for two days, Zeisel determinations[22] (in which heating with hydriodic acid for three hours was required for complete ether cleavage) showed less than 5% alkylation. Refluxing the phenol for eighteen hours with dimethyl sulfate and sodium hydroxide produced an oil whose b. p. was not materially different from that of the original, but which contained 29.2% of methylated material. Additional treatment with the same reagents for forty-eight hours increased the alkylated material to 35.5%. This product had b. p. 87–94° under nitrogen at 0.5 mm., $n^{27}D$ 1.4930.

**2,4-Di-*s*-butylcyclohexanol.**—Reduction was best carried out using 50 ml. of glacial acetic acid and 2.0 g. of Adams catalyst for each 0.2 mole of phenol. The initial hydrogen pressure was 45 p. s. i. g., and the uptake was rapid at first. The reaction became progressively slower, and continuous shaking for twenty-four hours was necessary to approach quantitative reduction.

On fractional distillation under nitrogen through a short Claisen column, 2,4-di-*s*-butylcyclohexanol was obtained as a colorless viscous liquid with an odor reminiscent of commercial insect-repellents, b. p. 103–105° at 1.0 mm., $n^{20}D$ 1.4782. During the distillation some frothing was noted as the product seemed to be undergoing slight dehydration. At refrigerator temperature the alcohol was stable.

*Anal.* Calcd. for $C_{14}H_{28}O$: C, 79.18; H, 13.29. Found: C, 79.50; H, 12.98.

The alcohol decolorized potassium permanganate and bromine solutions. With acetyl and benzoyl chlorides hydrogen chloride was evolved, but no solid derivative formed. The reaction with sodium at room temperature was slow, but at 60–70° hydrogen was evolved vigorously.

(14) Adkins and Cox, THIS JOURNAL, **60**, 1151 (1938).

(15) Asahina and Mituhori, *J. Pharm. Soc. Japan*, **484**, 255 (1922); *C. A.*, **16**, 2502 (1922).

(16) Walker and Read, *J. Chem. Soc.*, 238 (1934).

(17) Simonsen, "The Terpenes," 2nd ed., Vol. I, Cambridge University Press, 1947, p. 413

(18) Compare Wallach, *Ann.*, **414**, 271 (1918), who synthesized buchucamphor by hydrolysis of dibromomenthone.

(19) Shriner and Fuson, "The Systematic Identification of Organic Compounds," 3rd ed., John Wiley and Sons, Inc., New York, N. Y., 1948, p. 98.

(20) Compare Jannasch and Rathjen, *Ber.*, **32**, 2391 (1899), who report a negative test with 3,5-diethylphenol.

(21) Pokorny, THIS JOURNAL, **63**, 1768 (1941).

(22) Viebock and Brecher, *Ber.*, **63**, 3207 (1930).

**2,4-Di-*s*-butylcyclohexanone.**—Forty grams (0.19 mole) of the alcohol was oxidized with 38.3 g. (0.13 mole) of potassium dichromate in 195 ml. of water containing 17.5 ml. of concentrated sulfuric acid. The procedure was essentially that given for the oxidation of menthol.[13] This gave 34 g. of pale yellow oil with a camphoraceous odor, b. p. under nitrogen, 105–107° at 2.0 mm., $n^{23}D$ 1.4646. The yield was 86%. The product did not form a bisulfite addition compound, and it gave no enol test with ferric chloride solution. It decolorized Baeyer reagent, and formed hydrogen bromide when treated with bromine in carbon tetrachloride solution. Reduction with Adams catalyst in glacial acetic acid reformed the parent alcohol with absorption of the theoretical amount of hydrogen.

An almost quantitative yield of oxime was obtained, with m. p. 74–77° after recrystallization from alcohol. After several recrystallizations from alcohol the crude oxime was split into two fractions. The smaller of these had m. p. 73–74° while the main portion melted at 118–118.5°. These fractions, and an intermediate one whose m. p. range was 75–77°, were analyzed.

*Anal.* Calcd. for $C_{14}H_{27}NO$: C, 74.67; H, 11.87. Found for lower-melting oxime: C, 74.60; H, 12.11. Found for higher-melting oxime: C, 74.73; H, 12.11. Found for intermediate fraction: C, 74.78; H, 11.85.

In order to ascertain whether the isomerism of the oximes was due to *syn* and *anti* forms, or to the presence of two isomeric ketones, recourse was had to hydrolysis. A portion of each oxime was hydrolyzed by boiling with dilute sulfuric acid, and the resultant oil was collected and treated with hydroxylamine reagent. In each case only the parent oxime formed.

When an oxidation of the dialkylcyclohexanol was attempted using the Oppenauer method,[14] the alcohol was recovered in almost quantitative yield.

**2,4-Di-*t*-butylcyclohexanol.**—Reduction of di-*t*-butylphenol[23] under the conditions used for the *s*-butyl isomer, was very slow. After seven hours, 1.0 g. of fresh catalyst was required, and again after seventeen hours it was necessary to add a further 1.0 g. of platinum oxide. A total of twenty-eight hours was necessary for the absorption of 77% of the theoretical amount of hydrogen. The product was isolated as an extraordinarily viscid and colorless oil, b. p. under nitrogen at 2.0 mm., 120–130°. Some dehydration appeared to take place during the distillation, and this was also indicated by the analysis, which was done on a cut, b. p. at 2.0 mm., 128°, $n^{25}D$ 1.4812.

*Anal.* Calcd. for $C_{14}H_{28}O$: C, 79.18; H, 13.29. Found: C, 81.06; H, 13.15.

An indication of the extremely high viscosity of this liquid is afforded by the fact that approximately thirty-six hours were required for 20 g. to pass through a 2-mm. capillary tube in a standard stopcock.

**2,4-Di-*t*-butylcyclohexanone.**—The oxidation of the di-*t*-butylcyclohexanol and the isolation of the product were accomplished by the conditions already described for the *s*-butyl isomer. The crude ketone was obtained as a pale yellow oil, b. p. under nitrogen at 2.0 mm., 90–115° (55% yield). On careful fractional distillation of this material under nitrogen at 2.0 mm., three fractions were obtained: (1) b. p. 90–100°, $n^{22}D$ 1.4644, 28.5% of the crude product; (2) b. p. 100–110°, $n^{22}D$ 1.4668, 50% of the crude product; (3) b. p. 100–115°, $n^{22}D$ 1.4726, 21% of the crude product. The preparation of oximes from these fractions revealed the fact that fraction (1) was rich in 2,4-di-*t*-butylcyclohexanone, and that fraction (2) contained less of the ketone, and fraction (3) less still. The oximes had m. p. 187–188°, and gave no depression in mixed m. p. determinations.

*Anal.* Calcd. for $C_{14}H_{27}NO$: C, 74.67; H, 11.87; N, 6.21. Found: C, 74.86; H, 11.78; N, 5.83.[24]

The oxime obtained from fraction (3) was greatly contaminated with viscous oil, presumed to be 2,4,6-tri-*t*-butylcyclohexanone.

**3,5-Di-*s*-butyl-1,2-cyclohexanedione.**—A solution of 43 g. (0.21 mole) of 2,4-di-*s*-butylcyclohexanone in 326 g. of 50% aqueous acetic acid containing 182 g. (0.67 mole) of ferric chloride hexahydrate, was stirred under gentle reflux for two hours. The initially yellow solution gradually turned greenish-brown as slight tar formation occurred. The product was isolated from the oxidation mixture by distillation with superheated steam at 150–160°. It was taken up in ether and dried over anhydrous sodium sulfate. The ether was removed by distillation, which occasioned the loss of some of the deep yellow product through co-distillation.[25] The residue was distilled under nitrogen, and had b. p. 117–127° at 2.0 mm., $n^{29}D$ 1.4812. The yield of crude material was 29 g., or 63.5%, which compares very favorably with the reported[16] yield of 13% for the analogous oxidation of menthone. For analysis the product was fractionally distilled under nitrogen through a short Claisen column, and a cut was taken with b. p. 110–110.5° at 1.0 mm., $n^{23}D$ 1.4894.

*Anal.* Calcd. for $C_{14}H_{24}O_2$: C, 74.95; H, 10.87. Found: C, 75.02; H, 10.86.

The product possessed a deep golden-yellow color. With ferric chloride solution a deep blue-green coloration developed, and with Fehling solution reduction proceeded readily. Attempts to prepare an oxime were unsuccessful.[26] The diketone was stable at refrigerator temperature.

Attempts were made to prepare the diketone by hydrolysis of the dibromoketone according to the procedure of Wallach.[18] 2,4-Di-*s*-butylcyclohexanone readily reacted with two equivalents of bromine, but the dibromide failed to undergo complete hydrolysis, even after prolonged treatment with base. A yellow oil was obtained, b. p. 117–127° at 1.0 mm., $n^{27}D$ 1.4888, which gave a strong Beilstein test. Reduction of this product to the diol (see below) likewise produced halogen-containing material. When the diol was split with lead tetraacetate the aldehydic product was contaminated with halogenated material that was not removed by several fractional distillations.

**3,5-Di-*s*-butyl-1,2-cyclohexanediol.**—The optimum conditions for the reduction of the dione consisted in shaking 0.13 mole of the latter in 50 ml. of glacial acetic acid with 0.8 g. of Adams catalyst under hydrogen at 40 p. s. i. g. Under these circumstances the initial phase of the reduction was only moderately exothermic, and 96–100% hydrogen absorption was accomplished in about six hours. When a larger proportion of catalyst was used, considerable heat was engendered, which occasioned some dehydration of the diol formed, since hydrogen absorption proceeded beyond the theoretical amount. Under these conditions the product was contaminated with material whose analytical figures approximated those of a monoalcohol, presumed to be 3,5-di-*s*-butylcyclohexanol (b. p. 105° at 1.0 mm., $n^{28}D$ 1.4688).

The diol was obtained as a colorless and exceedingly viscid liquid, which developed a yellow color during distillation. After two distillations under nitrogen the main product was separated into two fractions, (a) b. p. 125–136° at 1.0 mm., $n^{30}D$ 1.4762, and (b) b. p. 136° at 1.0 mm., $n^{30}D$ 1.4798. The latter fraction was analyzed.

*Anal.* Calcd. for $C_{14}H_{28}O_2$: C, 73.68; H, 12.36. Found: C, 73.85; H, 12.14.

For the preparation of the cyclopentenealdehyde it was later found advantageous merely to remove the lower-boiling products formed during the reduction of the diketone (up to 118° under nitrogen at 0.05 mm.), and to oxidize the nearly colorless residue, which had $n^{25}D$ 1.4878.

**3,5-Di-*s*-butyl-1-cyclopentenealdehyde.**—Oxidation of the impure distillates of diol with lead tetraacetate according to the procedure of English and Barber,[5] gave alde-

(23) This compound was prepared by the method used for the *s*-butyl isomer. The yield (17%) is much inferior to that reported by Stillson, Sawyer and Hunt, ref. 11.

(24) We wish to thank Mrs. J. E. Buck for this microanalysis.

(25) Compare von Pechmann, *Ber.*, **24**, 3956 (1891).

(26) Simonson, ref. 17, reports the oxime to be the only carbonyl derivative of buchucamphor that has been prepared.

hydic material boiling, under nitrogen, at 112–120° at 2.0 mm. A fraction with b. p. 112° at 2.0 mm., $n^{28}D$ 1.4676, was analyzed.

*Anal.* Calcd. for $C_{14}H_{24}O$: C, 80.71; H, 11.61. Found: C, 80.34; H, 12.47.

The 2,4-dinitrophenylhydrazone was prepared, and had m. p. 183–184° after recrystallization from alcohol.

*Anal.* Calcd. for $C_{20}H_{28}N_2O_4$: C, 61.83; H, 7.27. Found: C, 61.65; H, 7.28.

Using undistilled 3,5-di-*s*-butyl-1,2-cyclohexanediol (above), a 63.5% yield of 3,5-di-*s*-butyl-1-cyclopentenealdehyde was obtained, b. p. 120–123° under nitrogen at 3.0 mm., $n^{25}D$ 1.4770.

In contradistinction to the parent glycol, the cyclopentenealdehyde was a limpid liquid with a pale yellow color and an odor reminiscent of acrolein. It was stable under nitrogen at refrigerator temperature.

**Oxidation of 3,5-Di-*s*-butyl-1-cyclopentenealdehyde.**—The oxidation method was adapted from that used by Kögl, *et al.*, in their work with auxin a.[27] Three g. (0.0135 mole) of the cyclopentenealdehyde was dissolved in 900 ml. of 50% aqueous ethanol. To this was added, with rapid stirring but no external cooling, 2700 ml. of 0.05 *N* potassium permanganate solution containing 15.5 g. of sodium carbonate. The time required for the addition was five hours. The color of the permanganate solution was immediately discharged as each drop engaged the aldehydic solution, and slight warming occurred spontaneously. After the addition was complete, the mixture was stirred an additional four hours, allowed to settle, and then filtered. The filtrate was evaporated on the steam-bath to small bulk, and extracted with ten portions of ether. These were discarded. The aqueous residue was then acidified with dilute hydrochloric acid, and again extracted with ten portions of ether. The ether extracts were dried over sodium sulfate, and evaporated. The residual acidic oil was fractionally distilled through a small Claisen column, under nitrogen, at a pressure of $10^{-4}$ mm. Three fractions were collected: (1) 0.5 g., b. p. 110–113°; (2) 0.5 g., b. p. 113°; (3) 0.5 g., b. p. 113–127°. All fractions were slightly brownish in color, indicating slight decomposition. It may be noted that the reported b. p.[4] for the analogous product obtained from auxin a (but in which both *s*-butyl groups possess the *d*-configuration), is 100–115° in "hochvacuum." This term very probably indicates a pressure close to that used in our distillation, since the boiling ranges of the two products are very similar. Although the Dutch workers were finally able to obtain their product in solid form (as the dibasic acid), our fractions remained liquid. Fraction (2) was analyzed.

*Anal.* Calcd. for the dicarboxylic acid, $C_{13}H_{24}O_4$: C, 63.90; H, 9.90. Calcd. for the anhydride, $C_{13}H_{22}O_3$: C, 68.99; H, 9.80. Found: C, 67.28; H, 9.76. That the main portion of our product was preponderantly the anhydride of $\alpha,\alpha'$-di-*s*-butylglutaric acid was demonstrated by its behavior in neutral equivalent determinations. The compound was insoluble in water, and reacted only slowly with dilute alkali. When a sample was first dissolved in ethanol, and then a titration performed, the neutral equivalent was 274. The calculated neutral equivalent for the mono-ethyl ester of $\alpha,\alpha'$-di-*s*-butylglutaric acid is 272. On the other hand, when samples were dissolved in water–acetone and treated with excess standard base, the neutral equivalents determined by back titration were 125 and 129. Phenolphthalein indicator was used, and blanks were determined in all cases. The calculated neutral equivalent for $\alpha,\alpha'$-di-*s*-butylglutaric acid is 122; that for the anhydride is 132.

(27) Kögl, Erxleben and Haagen-Smit, *Z. physiol. Chem.*, **225**, 215 (1934).


## Summary

The synthesis of 3,5-di-*s*-butyl-1-cyclopentenealdehyde from phenol has been described. The method is of general application.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# The Maleic Anhydride Adduct of N-Phenyl-3,5-diethyl-2-propyl-1,4-dihydropyridine

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The reaction of N-phenyl-3,5-diethyl-2-propyl-1,4-dihydropyridine I with maleic anhydride[1] forms a one to one adduct in spite of the fact that the double bonds in the dihydropyridine ring of I are not conjugated with each other.

The structure of the adduct, an anhydride, m. p. 120°, can be inferred from its behavior toward a variety of reagents. It is exactly dibasic and the careful addition of a strong acid to an aqueous solution of the sodium salt forms the corresponding acid, m. p. 153°, which as previously reported reforms the anhydride by loss of water. Reversion to the adduct also occurs in water. On the other hand, the adduct is soluble in concentrated hydrochloric acid and after standing a hydrochloride, m. p. 187°, crystallizes out. This salt contains two carboxyl groups. Since I contains methylenic hydrogen, reaction by a "substitution" mechanism to form a new dihydropyridine might be expected. However, the adduct is stable toward mild oxidizing agents such as iodine.[1] This and the fact that there is no tendency for the compound to disproportionate or polymerize in the presence of acid indicates that it cannot be a dihydropyridine.

The presence of methylenic hydrogen in I and the mechanism for a related diene synthesis already elucidated by Snyder, Hasbrouck and Richardson[2] suggest that the adduct is III formed by reaction (1).

Adequate support for structure III is found in the alkaline degradation of the adduct which forms aniline and the salts of butyric acid, 3,5-diethylbenzoic acid and an acid believed to be 3,5-diethylphthalic acid. The formation of these salts shows that the dienophile attaches itself to positions three and six of I. Only one crystalline modification of the adduct is formed in the reaction, though theory predicts that III should exist in many stereo forms. Since II, due to the asymmetry of carbon atom 2, must exist, if at all, as a racemic modification it might be predicted that at

(1) Craig, Schaefgen and Tyler, THIS JOURNAL, **70**, 1624 (1948).

(2) Snyder and others, *ibid.*, **61**, 3558 (1939).