The degradation of 1.7 g. (0.02 mole) of cyclopropanecarboxylic acid-X-^{14}C by similar procedures gave carbon dioxide and the benzamide of cyclopropylamine-X-^{14}C, m.p. 96–98° (lit.[43] 98.5°), prepared as described by Shriner, Fuson and Curtin.[42a]

Partial Degradation of Cyclopentanol-X-^{14}C.—In a 100-ml. flask equipped with a condenser, dropping funnel and magnetic stirrer was placed 2.7 g. (0.03 mole) of cyclopentanol-X-^{14}C. A solution of 4.8 g. of potassium dichromate, 6.1 g. of concentrated sulfuric acid and 32 ml. of water was added dropwise during 90 minutes in order that the temperature would not rise above 60°.[44] The acid solution was stirred for 1 hour, extracted with five 20-ml. portions of ether, and the combined ether extracts were dried over anhydrous magnesium sulfate and distilled. Crude cyclopentanone-X-^{14}C (b.p. 128–131°; lit.[31e] 130°), 2.3 g. (90% yield), was obtained.

In a 100-ml. flask equipped with a mechanical stirrer and condenser were placed 2.3 g. (0.028 mole) of cyclopentanone-X-^{14}C and 54 g. of polyphosphoric acid. Approximately 2 g. (0.03 mole) of sodium azide was added in small portions over a period of 1 hour. The temperature was slowly increased to 50° and maintained at this temperature for 9 hours. The reaction mixture was neutralized with 50% sodium hydroxide solution and extracted with ten 25-ml. portions of chloroform. The combined chloroform extracts were dried over anhydrous magnesium sulfate and distilled. Crude 5-aminovalerolactam-X^{14}C, 1.5 g. (50% yield) [b.p. 140° (15 mm.) (lit.[31d] 137°(14 mm.), for inactive material], was obtained.

In a 100-ml. flask containing 1.5 g. (0.015 mole) of 5-aminovalerolactam-X-^{14}C were added 1.5 ml. of concentrated hydrochloric acid and 5 ml. of water. The mixture was heated and magnetically stirred for 3 hours. The volume of solution was increased to 15 ml. with water and the solution was treated successively in the following manner: 0.75 g. of litharge powder, 0.4 g. of litharge powder, 0.075 g. of lead hydroxide, 0.75 g. of silver oxide and finally hydrogen sulfide. The solution was filtered and concentrated to approximately 2 ml. and placed in a desiccator overnight.

In a 50-ml. flask equipped with an addition tube and a magnetic stirrer was placed 1.5 g. (0.014 mole) of 5-aminovaleric acid-X-^{14}C and 2.8 ml. of concentrated sulfuric acid. Over a period of 10 minutes 0.65 g. (0.015 mole) of hydrazoic acid in 7.5 ml. of chloroform was added dropwise while the flask was heated at 50°. The evolved carbon dioxide was collected and the N,N′-dibenzamide derivative of 1,4-diaminobutane-X-^{14}C, 1.3 g. (33%), m.p. 175–176° (lit.[31e] 177°), was prepared.[42a]

1-Cyclopropylethanone-2-^{14}C.—In a 300-ml., three-necked flask equipped with a mechanical stirrer, condenser and dropping funnel were placed 4.8 g. (0.2 g. atom) of magnesium turnings which had been previously dried, 50 ml. of anhydrous ether and a crystal of iodine. A few drops of an ethereal solution of methyl-^{14}C iodide[38] (17.3 g., 0.12 mole, 0.25 mc.) in 50 ml. of anhydrous ether were added. After the reaction had been initiated the methyl-^{14}C iodide solution was added dropwise while the flask was cooled in an ice-bath over a period of 0.5 hour. When the exothermic reaction terminated, the mixture was stirred and refluxed for 2 hours. Approximately 8 g. (0.12 mole) of cyclopropyl cyanide in 50 ml. of ether was added dropwise over a period of 0.5 hour. The mixture was then stirred and refluxed for 18 hours, then 90 ml. of 3 *N* hydrochloric acid was added with stirring. After stirring for 1.5 hours, the ether layer was separated and the aqueous phase was extracted with three 25-ml. portions of ether. The combined ether solutions were dried over anhydrous magnesium sulfate overnight and distilled. Approximately 3.8 g. (38%) of 1-cyclopropylethanone-2-^{14}C, b.p. 112–113° (lit.[31f] b.p. 114°), was obtained.

1-Cyclopropylethanol-2-^{14}C.—A mixture of 7.6 g. (0.2 mole) of lithium aluminum hydride in 200 ml. of anhydrous ether was stirred at room temperature while 20 g. (0.23 mole) of 1-cyclopropylethanone-2-^{14}C dissolved in 75 ml. of anhydrous ether was added dropwise over a period of 45 minutes. The white precipitate was stirred and refluxed for 2 hours. The remaining lithium aluminum hydride and precipitate were decomposed by the careful addition of 30 ml. of ice-water and, after stirring for an additional 3 hours, the solution was filtered, dried over sodium hydroxide flakes, and distilled. Approximately 15.3 g. (77% yield, 2.1% radioactive yield), b.p. 122.5° (lit.[8] 120.5–121.0°), of 1-cyclopropylethanol-2-^{14}C was obtained. The phenylurethan derivative was prepared,[42b] m.p. 67.9–68.2°, and analyzed for radioactivity.

Degradation of 1-cyclopropylethanol-2-^{14}C was conducted as described for the isotopically labeled cyclopropylmethylcarbinol from the rearrangement reaction, and carbon dioxide from the permanganate oxidation and from the Schmidt degradation of cyclopropanecarboxylic acid was isolated and counted.

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[44] J. E. Nickels and W. Heintzelman, *J. Org. Chem.*, **15**, 1142 (1950).

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, PURDUE UNIVERSITY, LAFAYETTE, IND.]

Preparation of (−)-*cis*-2,4-Dimethylcyclohexanone from (+)-Pulegone

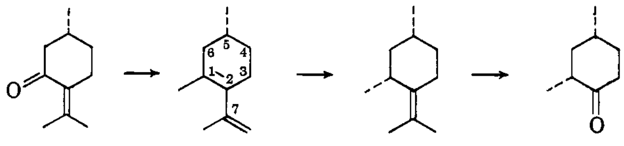
BY JOSEPH WOLINSKY AND DAVID CHAN

RECEIVED JULY 23, 1962

A novel and convenient preparation of (−)-*cis*-2,4-dimethylcyclohexanone from (+)-pulegone is described. The action of methylmagnesium iodide with (+)-pulegone affords 2-isopropenyl-1,5-dimethyl-1-cyclohexene (methylisopulegene) contaminated by 5% of 1-isopropylidene-2-methylene-4-methylcyclohexane. Although methylisopulegene does not absorb ultraviolet light above 210 mμ, it is smoothly reduced by use of sodium in liquid ammonia to give *cis*-1-isopropylidene-2,4-dimethylcyclohexane. Ozonolysis of the latter olefin affords (−)-*cis*-2,4-dimethylcyclohexanone.

Lawes[1] has shown that the thermal degradation of cycloheximide[2] (known also as actidione[3] and naramycin A[4]), an antibiotic which finds application in agriculture and is reported to possess anti-tumor activity,[5] affords (+)-*trans*-2,4-dimethylcyclohexanone (I), whereas alkaline degradation[3] yields (−)-*cis*-2,4-dimethylcyclohexanone (II). Djerassi[6] has related the absolute configuration of the asymmetric center at C-4 in ketone II to R-glyceraldehyde. In this report we wish to describe a novel and convenient method, outlined in Chart I, for the preparation of (−)-*cis*-II from (+)-pulegone. This conversion independently confirms the absolute configuration at C-4 in ketone II and cycloheximide.

CHART I



III IV II

Our interest in non-planar dienes[7,8] originally directed our attention to "methylpulegene,"[9–11] a diene produced by the reaction of pulegone with methylmagnesium iodide. Grignard[12] suggested the diene was a mixture of 2-isopropenyl-1,5-dimethyl-1-cyclohexene

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[1] B. C. Lawes, *J. Am. Chem. Soc.*, **84**, 239 (1962).

[2] B. E. Leach, J. H. Ford and A. J. Whiffen, *ibid.*, **69**, 474 (1947).

[3] E. C. Kornfeld, R. G. Jones and T. V. Parke, *ibid.*, **71**, 150 (1949).

[4] T. Okuda, M. Suzucki, Y. Egawa and K. Ashino, *Chem. Pharm. Bull.*, **7**, 27 (1959).

[5] H. C. Reilly, C. C. Stock, S. M. Buckley and D. A. Clark, *Cancer Research*, **13**, 684 (1953).

[6] E. J. Eisenbraun, J. Osiecki and C. Djerassi, *J. Am. Chem. Soc.*, **80**, 1261 (1958).

[7] E. E. van Tamelen, S. Levin, G. Brenner, J. Wolinsky and P. Aldrich, *ibid.*, **81**, 1666 (1959).

[8] H. H. Inhoffen, G. Quinkert, H. Hess and H. Erdmann, *Ber.*, **89**, 2273 (1956); H. H. Inhoffen, K. Brückner, K. Irmscher and G. Quinkert, *ibid.*, **88**, 1424 (1955).

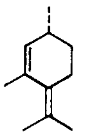
[9] V. Grignard, *Chem. Zentr.*, **72**, 624 (1901).

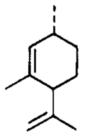
[10] K. Auwers and F. Eisenlohr, *Ber.*, **43**, 830 (1910).

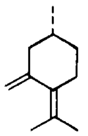
[11] H. Rupe and F. Emmerich, *ibid.*, **41**, 1750 (1908).

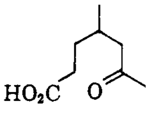
[12] V. Grignard and J. Savard, *Compt. rend.*, **181**, 589 (1925); for divergent views see J. Simonsen and L. N. Owen, "The Terpenes," The University Press, Cambridge, 1947, Vol. I, 2nd Edition, p. 379.

(III) and 6-isopropylidene-1,3-dimethyl-1-cyclohexene (V); however, more recently Duluo[13] postulated structure VI for the diene on the basis of the fact that it did not absorb ultraviolet light above 210 mμ. We have re-examined this matter and have found that "methylpulegene" is diene III contaminated by *ca.* 5% of 1-isopropylidene-2-methylene-4-methylcyclohexane (VII) and should be properly referred to as "methylisopulgene."


V


VI


VII



VIII

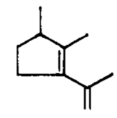
The presence of a terminal methylene group in methylisopulegene was suggested by peaks at 6.1 and 11.25 μ in its infrared spectrum and confirmed by the formation of formaldehyde on reductive ozonolysis. Oxidative ozonolysis gave the keto-acid VIII[14] which can only arise in a logical manner from diene III. The n.m.r. spectrum of methylisopulegene, measured at 60 Mc. with reference to tetramethylsilane, exhibited signals at 53.2 and 57.8 c.p.s. (one methyl group spin coupled with an adjacent proton), 93.8 and 101 superimposed upon a broad peak beginning at *ca.* 112 c.p.s. (two methyl groups attached to unsaturated carbon atoms, superimposed upon methylene and methine hydrogens) and a symmetrical doublet at 279 c.p.s., J 14.6 c.p.s. (two protons of a terminal methylene group). The absence of signals from other olefinic hydrogens clearly eliminates structure VI and establishes the fact that methylisopulegene has the constitution represented by formula III.

Vapor phase chromatography of methylisopulegene indicated the presence of *ca.* 5% of another hydrocarbon. This substance was isolated and its infrared spectrum proved to be identical with that of diene VII prepared by the reaction of pulegone with triphenylmethylenephosphorane. The structure of VII was confirmed by the formation of acetone and formaldehyde on ozonolysis and by its n.m.r. and infrared spectra (see Experimental).

In addition to methylisopulegene, the reaction of pulegone with methylmagnesium iodide afforded a higher boiling fraction composed largely of pulegone and 2-*t*-butyl-5-methylcyclohexanone.[14,15] The latter ketone was isolated following the destruction of pulegone with hot formic acid[16] and its identity was established by comparison with an authentic sample of *trans*-2-*t*-butyl-5-methylcyclohexanone.[17,18]

Methylisopulegene, as noted earlier by Duluo,[13] does not absorb in the ultraviolet above 210 mμ; its behavior, therefore, is analogous to that of a diene whose carbon–carbon double bonds are separated by at least two carbon atoms. This phenomenon appears even more unusual when compared with the normal ultraviolet absorption spectrum λ_{max} 238 and 243 mμ, ϵ 9,470 and 9,300, exhibited by 2-isopropenyl-1,5-dimethyl-1-cyclopentene (IX).[19]

Examination of Stuart–Briegleb and Fischer–Hirschfelder–Taylor molecular models of diene III indicate


IX

restricted rotation about the C-2–C-7 bond arising from steric interaction between the methyl group at C-1 and the terminal methylene and methyl groups at C-7. Diene III must assume a configuration in which an appreciable angle (50–90°) exists between the two double bonds; π-orbital overlap and delocalization of electrons in the excited state is therefore prohibited since electron transitions occur many times faster than the movement of nuclei (Franck–Condon principle). By contrast, the greater external bond angles of the cyclopentane ring in diene IX result in a considerable spread of the adjacent methyl and methylene groups; the isopropenyl group rotates freely to permit coplanarity and orbital overlap in both the ground and excited states.

Diene VII also displays an abnormal ultraviolet maximum: λ_{max} 220 mμ, ϵ 5,000. In this case the shift to lower wave length can be attributed to non-planarity which is a consequence of the chair conformation of the cyclohexane ring.[20] The normal spectra of the planar dienes 1,2-dimethylene-cyclopentane (λ_{max} 246–248 mμ, ϵ 10,000),[21] 3-isopropylidene-2-methylene-1-methylcyclopentane (λ_{max} 249 mμ, ϵ 10,850)[19] and tetramethyl fulgide (1,2-diisopropylidenesuccinic anhydride),[22] (λ_{max} 271 mμ, ϵ 9,200)[23] appears to support this argument.

Whereas methylisopulegene does not absorb ultraviolet light above 210 mμ, its behavior as a conjugated 1,3-diene was demonstrated by the facile formation of a 1:1 adduct with tetracyanoethylene and by chemical reduction with sodium in liquid ammonia. *These observations provide an impressive example of the lack of correlation between the electronic transitions which occur on absorbtion of electromagnetic radiation and the electronic transitions and concurrent nuclear movement which produce a transition state and products during a chemical transformation.*

Chemical reduction of methylisopulegene proceeded exclusively in a 1,4-fashion to give *cis*-1-isopropylidene-2,4-dimethylcyclohexane (IV) contaminated by a small amount of the corresponding *trans* isomer and *ca.* 1% of three unidentified olefins.

Ozonolysis of the crude olefin IV, followed by preparative scale vapor phase chromatography, afforded (−)-*cis*-2,4-dimethyl-cyclohexanone (II) (molecular amplitude, *a* −1499) and a small amount of (+)-*trans*-2,4-dimethyl-cyclohexanone (I) (*a* +2287). These ketones were identical in every respect with *pure* (−)-*cis*-II and (+)-*trans*-I derived from cycloheximide.

Application of the octant rule[24] predicts a negligible Cotton effect for Ia and IIa, a strong positive effect for Ib and a strong negative effect for IIb. The observed optical rotatory dispersion curves are in qualitative agreement with the configurational assignments; however, the magnitude of these Cotton effects is surprising. If it is accepted that molecular amplitudes

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[13] R. Duluo, P. Crabbé and G. Dupont, *Bull. soc. chim. France*, 1548 (1955).

[14] H. Rupe, H. Schobel and E. Abegg, *Ber.*, **46**, 1528 (1912).

[15] C. Djerassi, E. J. Warawa, J. M. Berdahl and E. J. Eisenbraun, *J. Am. Chem. Soc.*, **83**, 3335 (1961).

[16] O. Wallach, *Ann.*, **289**, 337 (1896).

[17] J. H. Brewster and G. Asato, unpublished work.

[18] We wish to express our appreciation to Dr. Asato for making this comparison.

[19] J. Wolinsky, B. Choller and M. D. Baird, *J. Am. Chem. Soc.*, **84**, 2775 (1962).

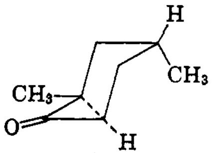
[20] A. T. Blomquist and D. T. Longone, *ibid.*, **79**, 3916 (1957).

[21] A. T. Blomquist, J. Wolinsky, Y. C. Meinwald and D. T. Longone, *ibid.*, **78**, 6057 (1956).

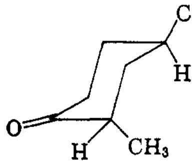
[22] H. Stobbe, *Ber.*, **38**, 3673 (1905).

[23] The structure of tetramethyl fulgide was confirmed by its n.m.r. spectrum which exhibited two signals characteristic of methyl groups. It is instructive to note that tetramethylfulgenic acid, λ_{max} 218 mμ, ϵ 14,600, provides another example of a non-planar diene.

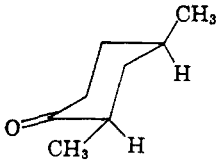
[24] W. Moffitt, R. B. Woodward, A. Moscowitz, W. Klyne and C. Djerassi, *J. Am. Chem. Soc.*, **83**, 4013 (1961).



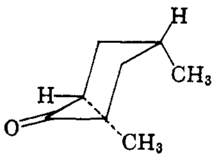
Ia



Ib



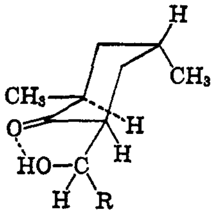
IIa



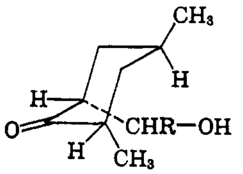
IIb

are additive, and values of *a* 5560 and 0[25] are taken for 2-axial and 2-equatorial substituents, respectively, then one obtains a calculated equilibrium value of 73.1% IIa and 26.9% IIb for *cis*-II and 58.9% Ia and 41.1% Ib for *trans*-I. The high percentage calculated for IIb is difficult to reconcile with normal configurational considerations and suggests its partial existence in a twist form.[26]

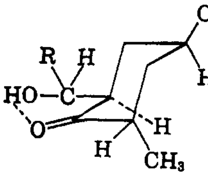
Okuda[27] has represented cycloheximide and naramycin B as XI and XII on the basis of their respective small negative and large positive Cotton effects. A divergent view has been expressed by Lawes.[1] Of the two possible configurations XI and XII for cycloheximide, Lawes suggested that an epimerization at C-2 in XII should readily afford the stable isocycloheximide[28] (XIII) having all ring substituents equatorial, *whereas XI should be resistant to epimerization.* The following reasons were offered for the latter conclusions:



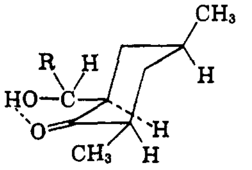
XIa



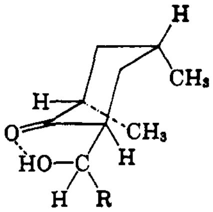
XIb



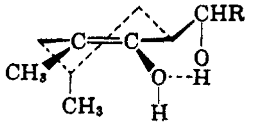
XII



XIII



XIV



XV

(1) An epimerization at C-2 or C-6 in XI would be unlikely since it would yield a less stable conformation because of the added 1,3-diaxial opposition between groups at C-4 and C-2 or C-4 and C-6. (2) Configurational isomer XIa should be greatly stabilized over isomer XIb; consequently, epimerization at both C-2 and C-6 would not be likely since it would involve a highly unstable intermediary conformation XIb. These assumptions appear to be unwarranted on the basis that: (1) equilibration with a 1,3-diaxial isomer such as XIV is not unlikely since an appreciable 1,3-diaxial conformation, or modified twist form, is indicated for *cis*-II and (2) the epimerization of cycloheximide presumedly involves a thermodynamically controlled acid-catalyzed process which probably involves the enol form of the carbonyl group (*e.g.*, XV); consequently, conformation XIb need not be involved in the epimerization of cycloheximide. It is plausible to assume that either XI or XII could isomerize to XIII; in the case of XI epimerization at C-2 or C-6 would yield XII or XIV which could then transform into XIII. We conclude that a choice between XI and XII for cycloheximide cannot be made on the basis of its reported conversion to isocycloheximide.

Experimental[29]

Methylisopulegene, 2-Isopropenyl-1,5-dimethyl-1-cyclohexene (III).—Pulegone (39.95 g.) was added to an excess of methylmagnesium iodide in ether. After heating for 1 hour, dilute hydrochloric acid was added and the ether layer was separated and dried. Distillation gave *ca.* 25 g. of methylisopulegene, b.p. 53–61° (5 mm.), and *ca.* 10 g. of a ketonic mixture, b.p. 80–91° (5 mm.).

A redistilled sample of methylisopulegene showed b.p. 65–68° (10 mm.), n^{14}D 1.4737, $[\alpha]^{28}$D +96° (*c* 1.723, EtOH); λ_{max} 3.26, 3.45, 5.63, 6.15, 6.95, 7.0, 7.33, 7.88, 8.19, 8.35, 8.67, 8.82, 8.99, 9.32, 9.66, 10.0, 10.36, 10.48, 11.26 and 11.66 μ.

Vapor phase chromatography of the diene on a Ucon polar column demonstrated the presence of *ca.* 5% of a second hydrocarbon. This impurity was collected and its infrared spectrum proved to be identical with that of 1-isopropylidene-2-methylene-4-methylcyclohexane (VII).

The tetracyanoethylene adduct of methylisopulegene showed m.p. 160–161° after three recrystallizations from ether.

Anal. Calcd. for $C_{17}H_{18}N_4$: C, 73.35; H, 6.52. Found: C, 73.68; H, 6.40.

Ozonolysis of Methylisopulegene. A. Reductive.—A solution of 200 mg. of methylisopulegene in 15 ml. of acetic anhydride was ozonized at −78° for 1 hour. The ozonide solution was stirred with zinc dust and water and then distilled directly into a solution containing 2,4-dinitrophenylhydrazine. The resulting solid was collected, dried and chromatographed using silica gel and 4% ether–petroleum ether as an eluent. There was obtained: a, *ca.* 20 mg. of red oil which could not be crystallized; b, 15 mg. (5%) of acetone 2,4-DNP, m.p. 124–125°; and c, 80 mg. (28%) of formaldehyde 2,4-DNP, m.p. 163–165°.

B. Oxidative.—A solution of 10.44 g. (0.066 mole) of methylisopulegene in 30 ml. of methylene chloride was ozonized at −78° for 8 hours. The ozonide solution was added to water containing 7.50 g. of 30% hydrogen peroxide. The methylene chloride was then removed *in vacuo* and the resulting mixture was vigorously stirred at room temperature for 64 hours. The mixture was extracted with ether and the combined ether extracts were extracted with aqueous sodium carbonate solution. The basic solution was acidified with 6 *N* hydrochloric acid and extracted with ether. Removal of the ether afforded 5.85 g. of crude keto-acid VIII. Distillation gave the pure acid, b.p. 116–118° (0.3 mm.), n^{25}D 1.4475, λ_{max} 5.80 and 5.87 μ; n.m.r. 52 and 58 ($CH_3\overset{|}{\underset{|}{C}}$-H), multiplets at 96 and 139 (-CH_2- and -$\overset{|}{C}$H-) 123 (CH_3CO-) and 660.2 c.p.s. (-CO_2H); lit. b.p. 171° (14 mm.),[14] b.p. 101° (0.02 mm.).[6]

Anal. Calcd. for $C_8H_{14}O_3$: C, 60.74; H, 8.92. Found: C, 60.86; H, 8.86.

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[25] C. Beard, C. Djerasiott si, T. Elland R. C. C. Tao, *J. Am. Chem. Soc.*, **84**, 874 (1962).

[26] W. S. Johnson, V. J. Bauer, J. L. Margrave, M. A. Frisch, L. H. Dreger and W. N. Hubbard, *ibid.*, **83**, 606 (1961).

[27] T. Okuda and M. Suzuki, *Chem. Pharm. Bull.*, **9**, 1014 (1961).

[28] A. J. Lemin and J. H. Ford, *J. Org. Chem.*, **25**, 344 (1960), have reported that cycloheximide can be isomerized to isocycloheximide with acetic acid-washed alumina.

[29] All boiling and melting points are uncorrected. Ultraviolet spectra were measured with a Cary recording spectrophotometer, model 10-11M. Nuclear magnetic resonance spectra were recorded by Mr. W. E. Baitinger with a Varian Associates V-4300-B high resolution n.m.r. spectrometer with associated 12 in. electromagnet equipped with a super stabilizer. The microanalyses were performed by Dr. C. S. Yeh and Mrs. V. Keblys.

The semicarbazone derivative of VII melted at 148–150° after several recrystallizations from water (lit. m.p. 150°[14]).

The action of an ethereal solution of diazomethane on the keto-acid VIII afforded the corresponding methyl ester, b.p. 54–56° (0.5 mm.), n^{25}D 1.4334. The n.m.r. spectrum of the ester was identical with that of acid VIII except for the absence of the carboxylate proton band at 660 and the presence of a new methoxyl signal at 215.9 c.p.s.

Anal. Calcd. for $C_9H_{16}O_3$: C, 62.76; H, 9.37. Found: C, 62.69; H, 9.56.

The Reaction of Pulegone with Triphenylmethylenephosphorane.—The slow addition of 16.5 g. of pulegone to a stirred ethereal solution of triphenylmethylenephosphorane, prepared from triphenylmethylphosphonium bromide and phenyllithium, afforded a white precipitate. The mixture was heated for 2 days and then the solid was removed by filtration. The ether solution was washed with water, dried and distilled to yield: a, 2.0 g. of crude hydrocarbons, b.p. 54–59° (5.4 mm.); b, 1.0 g. of a ketonic mixture which was largely pulegone contaminated by a small amount of isopulegone and three lesser unidentified impurities; and c, 6.0 g. of a viscous unidentified yellow oil, b.p. 139–143° (0.7 mm.).

1-Isopropylidene-2-methylene-4-methylcyclohexane (VII), comprising *ca.* 75% of fraction a, was purified by v.p.c. using a Ucon polar column and showed n^{20}D 1.4792, $\lambda_{\max}^{\mathrm{EtOH}}$ 220 mμ, ε 5,000; $\lambda_{\max}^{\mathrm{isoöctane}}$ 216-217 mμ ε 5,700 and $\gamma_{\max}$ 3.27, 3.47, 5.6, 6.16, 6.92, 7.32, 7.54, 7.78, 8.24, 8.88, 9.02, 9.14, 9.40, 10.02, 11.24, 11.50 and 12.70. The n.m.r. spectrum of VII displayed signals at 54.7, 59.5, 102.8, 106.1, 272.5 and 290.6 c.p.s.

Anal. Calcd. for $C_{11}H_{18}$: C, 87.92; H, 12.07. Found: C, 88.04; H, 12.23.

The tetracyanoethylene adduct of diene VII appeared to be unstable. The adduct was obtained as a white crystalline solid, m.p. 66–67.5°. Several recrystallizations from petroleum ether afforded a solid, m.p. 62–78°, whose analytical data were not in accord with that expected for a 1:1 adduct. This material was not investigated further.

Ozonolysis of diene VII in the usual fashion afforded equal quantities of acetone and formaldehyde 2,4-dinitrophenylhydrazones.

A second hydrocarbon, presumedly **1-methylene-2-isopropyl-4-methylcyclohexane**, accounted for the remaining 25% of fraction a. This olefin had a lower retention time than diene VII and showed n^{20}D 1.4578, ε 112 at 215 mμ and maxima at 6.10 and 11.25 μ. The n.m.r. spectrum of this olefin was consistent with its structural assignment, 51.1, 52.6 and 58.0 ($3CH_3$ groups), 103.7 ($-CH_2-$ and $-CH$) and 270.6 and 275.7 ($>C{=}CH_2$).

Anal. Calcd. for $C_{11}H_{20}$: C, 86.76; H, 13.24. Found: C, 86.56; H, 12.84.

1-Isopropylidene-2,4-dimethylcyclohexane (IV).—Methylisopulegene was recovered unchanged after heating with sodium in ethanol or propanol. Chemical reduction proceeded smoothly under the following conditions. To a solution of 6.13 g. (0.266 g. atom) of sodium in 100 ml. of liquid ammonia was gradually added an ether solution of 4.2 g. (27.95 mmoles) of methylisopulegene. The reaction mixture was stirred for 30 minutes and then solid ammonium chloride was added cautiously until the deep blue color disappeared. The ammonia was evaporated and ether and water added. The ether layer was separated, dried and the ether removed under diminished pressure. The residue was analyzed by v.p.c.; one major component, *ca.* 94%, and one minor component 3–4%, in addition to traces of three unidentified materials were present. A pure sample of olefin IV was obtained by preparative scale v.p.c. by use of a Carbowax 20M column and displayed $[\alpha]^{27}$D −182°, 53.6, 55.8, 57.9, 61.1 ($2\ CH_3{-}CH{-}$) and 77.2, 80.4, c.p.s. ($(CH_3)_2C{=}C<$).

Anal. Calcd. for $C_{11}H_{20}$: C, 86.76; H, 13.24. Found: C, 87.03; H, 13.36.

The minor component from reduction appeared to be *trans*-1-isopropylidene-2,4-dimethylcyclohexane on the basis of the similarity of its n.m.r. spectrum with that of olefin IV.

Ozonolysis of 1-Isopropylidene-2,4-dimethylcyclohexane (IV).—A solution of 0.49 g. of 1-isopropylidene-2,4-dimethylcyclohexane (IV) in acetic anhydride was ozonized at −78° and the resulting solution was poured into a stirred slurry of 15 g. of zinc dust and 200 ml. of water. The mixture was distilled into a solution of 2,4-dinitrophenylhydrazine reagent to afford 1.20 g. of a yellow solid. Chromatography of 200 mg. of this solid on silica gel and employing 4% ether–petroleum ether as an eluent afforded 91 mg. of *cis*-2,4-dimethylcyclohexanone 2,4-DNP, m.p. 155–162°, and 62.9 mg. of acetone 2,4-DNP, m.p. 124–126° after several recrystallizations from ethanol.

The 2,4-DNP derivative of ***cis*****-2,4-dimethylcyclohexanone** melted at 163.5–166° after several recrystallizations from ethanol; reported[3] m.p. 169–172°.

Anal. Calcd. for $C_{14}H_{18}N_4O_4$: C, 54.89; H, 5.92. Found: C, 55.45; H, 6.07.

(−)-*cis*-**2,4-Dimethylcyclohexanone**.—A solution of 1.04 g. of crude 1-isopropylidene-2,4-dimethylcyclohexane in 25 ml. of acetic anhydride was ozonized as described above. After working up the reaction in the usual fashion, the zinc dust was removed by filtration and the filtrate was extracted with ether. The ether extract was washed with water, 5% sodium bicarbonate solution and saturated salt solution and then dried. The ether was removed under diminished pressure and the residue was purified by v.p.c. using a Carbowax 20M column at 115°. Two fractions, *cis*-II and *trans*-I, were isolated and amounted to 85% and 5% of the crude product, respectively. *cis*-II (purity greater than 99.5%) showed $n^{13.5}$D 1.4478, $[\alpha]^{30}$D −1.46° (*c* 0.056, EtOH); R.D. in ethanol (*c* 0.3975): $[\alpha]_{580}$ 0.0°, $[\alpha]_{546}$ −3.37°, $[\alpha]_{405}$ −25.2°, $[\alpha]_{334}$ −153°, $[\alpha]_{310}$ −504°, $[\alpha]_{305}$ −569°, $[\alpha]_{300}$ −480°, $[\alpha]_{290}$ −108°, $[\alpha]_{285}$ +101°, $[\alpha]_{275}$ +440°, $[\alpha]_{270}$ +621°, $[\alpha]_{265}$ +534°. Djerassi[6] reported a trough at 297.5 mμ (−278°) and a peak at 275 mμ (−57°) for a sample of *cis*-II which was probably contaminated by 10–20% of *trans*-I. The infrared spectrum of this *cis*-II was identical with that of a pure sample of (±)-*cis*-2,4-dimethylcyclohexanone[30] and that of (−)-*cis*-II obtained by alkaline degradation of actidione.[30]

(+)-*trans*-**2,4-Dimethylcyclohexanone** (greater than 99.5% purity after isolation by v.p.c.) showed n^{24}D 1.4481; R.D. in ethanol (*c* 0.0144): $[\alpha]_{579}$ +31.3°, $[\alpha]_{546}$ +50.6°, $[\alpha]_{404}$ +160°, $[\alpha]_{334}$ +504°, $[\alpha]_{315}$ +925°, $[\alpha]_{312.5}$ +959°, $[\alpha]_{305}$ +801°, $[\alpha]_{300}$-+570°, $[\alpha]_{295}$ +243°, $[\alpha]_{290}$ −146°, $[\alpha]_{285}$ −469°, $[\alpha]_{275}$ −845°, $[\alpha]_{270}$ −856°, $[\alpha]_{265}$ −855°. Lawes reported a peak at 315–320 mμ (+770°) for a sample of *trans*-I which contained 7.2% of (−)-*cis*-II.

Acknowledgment.—This work was supported in part by a grant from the Purdue Research Foundation.

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(30) The authors wish to express their appreciation to Dr. W. Gurowitz, Dow Chemical Co., for a generous sample of (±)-2,4-dimethylcyclohexanone, to Dr. Allan J. Lemin, the Upjohn Co., for a supply of actidione and to Dr. W. T. Sumerford and B. Lawes for actidione and a sample of (+)-*trans*-2,4-dimethylcyclohexanone.