AN ABSTRACT OF THE THESIS OF

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(Major) (Date)

Title: Attempts to Prepare cis-1, 2-dicyclohexenylethylene.

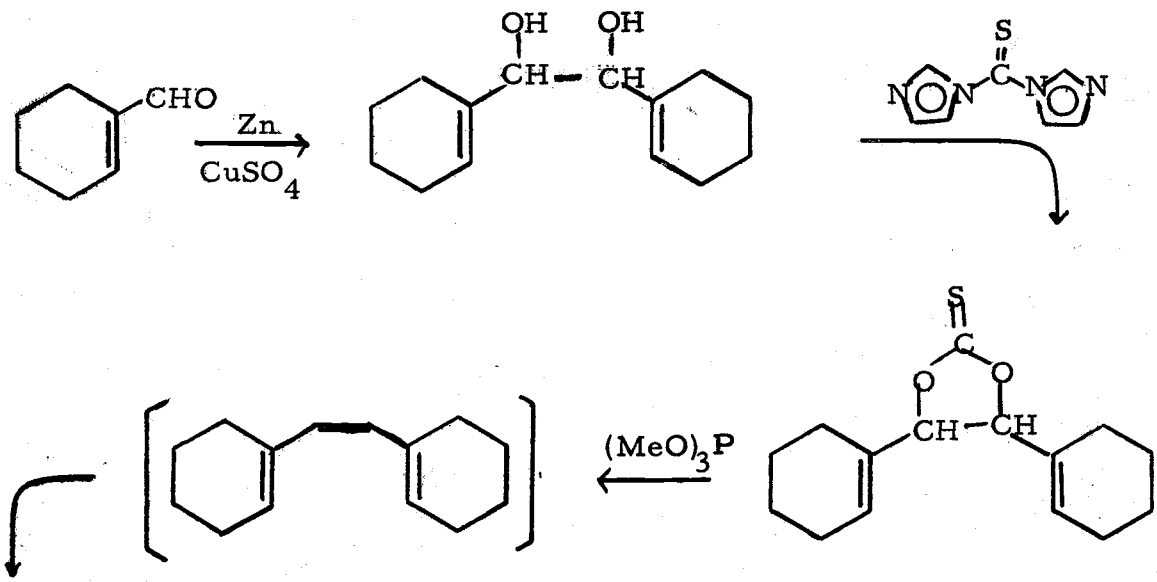
Abstract approved: Redacted for privacy
Dr. Elliot N. Marvell

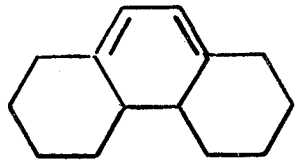
Inhoffen and Quinkert (13) reported the preparation of cis-1, 2-dicyclohexenylethylene via semihydrogenation of 1, 2-dicyclohexenylacetylene. They attributed a λ_{max} 249 nm to this triene. An attempt to repeat the synthesis (21) showed that the reduction was not highly selective and a mixture was obtained. This thesis reports two attempts to synthesize the cis-triene.

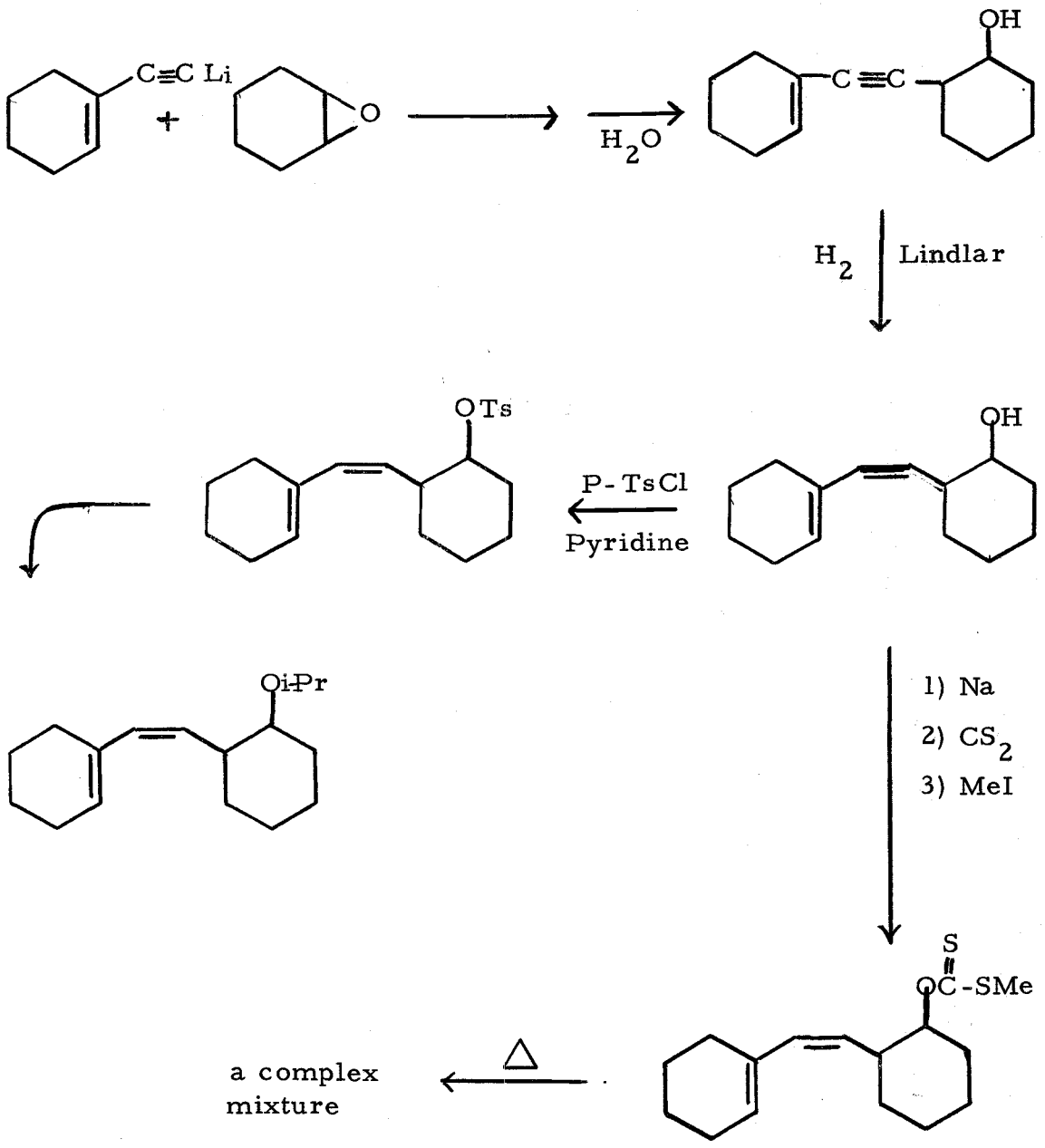
Cyclohexenecarboxaldehyde was reduced by Thiele's method (26) to a mixture of meso and racemic forms of 1, 2-dicyclohexenyl-1, 2-ethanediol. The two forms were separated by thin layer chromatography and a thioncarbonate was synthesized from the higher melting isomer by the procedure of Corey and Winter (8). Thermal decomposition of this thioncarbonate proceeded slowly in trimethylphosphite. Under the conditions of the reaction cis-1, 2-dicyclohexenylethylene apparently was formed but was cyclized to give 1, 2, 3, 4, 4a, 5, 5a, 6, 7, 8-decahydrophenanthrene.

Further attempts to prepare the desired triene involved

elimination reactions of cis-1-cyclohexenyl-2-(2-substituted cyclohexenyl) ethylenes. The basic substrate cis-1-cyclohexenyl-2-(2-hydroxycyclohexyl) ethylene was prepared by treating the lithium salt of cyclohexenylacetylene with cyclohexene oxide followed by semi-hydrogenation of the initial product. Reaction of the tosylate of that alcohol with isopropoxide ion gave mainly substitution product. In order to invert the stereochemistry at the tosylate-bearing carbon, the tosylate was treated with tetra-n-butylammonium bromide in acetone, but the unreacted starting material was recovered. Finally a methyl xanthate was prepared from the alcohol. Thermal decomposition of the xanthate gave a complex mixture from which no pure product was isolated.






C≡C Li
+
O
H2O
OH
C≡C
H2
Lindlar
OTs
P-TsCl
Pyridine
OH
OiPr
1) Na
2) CS2
3) MeI
S
OC-SMe
a complex
mixture
△

Attempts to Prepare cis-1, 2-dicyclohexenylethylene

by

Somkid Kaesornsomboon

A THESIS

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ATTEMPTS TO PREPARE CIS-1, 2-DICYCLOHEXENYLETHYLENE

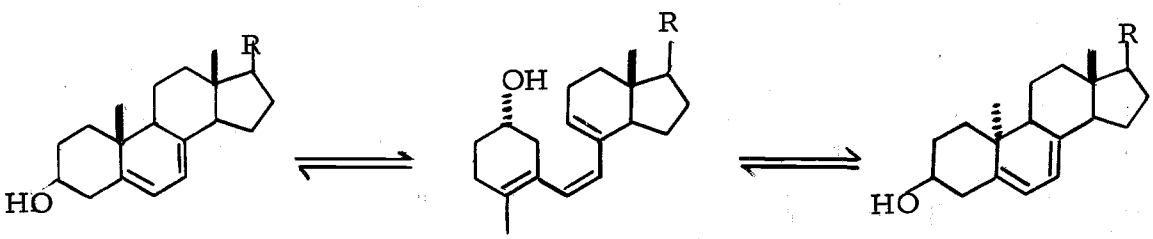
INTRODUCTION

The synthesis of cis-1, 2-dicyclohexenylethylene was reported by Inhoffen and Quinkert (13) via semihydrogenation of 1, 2-dicyclohexenylacetylene. This product was reported to have λ_{max} 249 nm ($\varepsilon=1.12\times10^{4}$). This reduction was repeated by Pippin (21), who reported that the product was mixture of unreacted starting material, over-hydrogenated products and both cis- and trans-1, 2-dicyclohexenylethylenes. He was unable to confirm the peculiar position for the λ_{max} reported.

Since most conjugated trienes possess a strong band in the ultraviolet at 260-265 nm, and since 1, 2-dicyclohexenylethylene should normally be expected to absorb near 275 nm, the preparation of this triene seemed appropriate in order to ascertain whether the steric hindrance could indeed alter the position of absorption to this extent. Furthermore the triene was of interest as a substrate for the study of electrocyclic reactions.

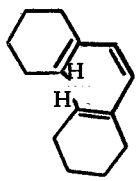
HISTORICAL

Windaus (29) in 1930 studied the effect of ultraviolet light on ergosterol. This probably constitutes the first well documented example of the interconversion of a cyclohexadiene and an open-chain triene. Complete clarification of the sequence of steps in this irradiation, and those of the thermal behavior of vitamin D_2 was to require about 25 years. During this time the investigations of a number of people contributed to the picture. Inhoffen and Quinkert (13) prepared a series of trienes resembling these expected from ergosterol in order to provide some models for ultraviolet spectral comparisons.

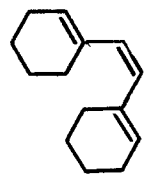


The ultraviolet spectra reported by Inhoffen and Quinkert are shown in Table 1. At first glance the data may appear reasonable, but further consideration suggests some questions. Compound IIIa is reported λ_{max} 269, a value in fair agreement with expected value of 277 based on Woodward's rules and on the λ_{max} 257 reported for trans-hexatriene (4). The value of 249 reported for IIa might be

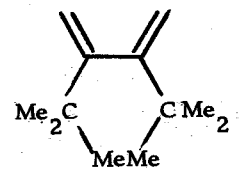
expected to relate to that for IIIa in the same way that cis- and trans-stilbene do. Thus a value of ca. 255 would be predicted, based on the conformation IVa. The results seem reasonable



IVa



IVb

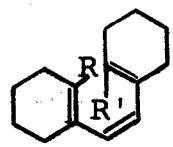


IVc

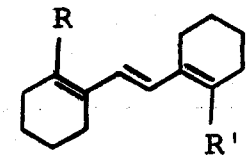
and presumably the origin of the hypsochromic shift is the steric hindrance between the two hydrogens shown. However, IIb and IIc convert one and then two of these hydrogens to methyl groups and each addition shows the ca. 5 nm bathochromic shift expected from Woodward's rules. Such a shift is definitely not in accord with the steric hindrance hypothesis.

Thus one is led to suggest that if these data are correct the proper conformation for IIa is IVb. In this geometry the additional methyl groups added in IIb and IIc do not seriously alter the steric interactions and the normal bathochromic shifts would be observed. However the effective interaction of the two methylene groups is reasonably similar to those present between the t-butyl groups in 2, 3-di-t-butylbutadiene (IVc). This molecule shows no λ_{max} in the ultraviolet above 200 nm (31). On this basis the λ_{max} for IVb might have been expected to lie near that for cyclohexenylethylene or near 225 nm.

A survey of the known conjugated trienes reveals no models which would clarify this point. The ultraviolet spectral data are listed in Tables 1-4.



II



III

a) R=R'=H

b) R=CH_3, R'=H

c) R=R'=CH_3

Table 1. UV spectra of trienes reported by Inhoffen and Quinkert (13)

Compound	λ_{max} (nm.)	$\Sigma \times 10^4$
IIa	249	1.12
IIb	252	1.24
IIc	257	1.30
IIIa	260	2.4
	269	2.62
	281	2.3
IIIb	272 (sh)	2.17
	279	2.26
	289	1.70
IIIc	274	1.95
	284	2.10
	295	1.64

Table 2. UV spectra of trienes synthesized by John Tashiro (25).

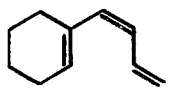
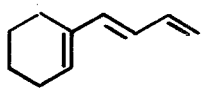
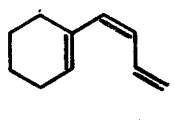
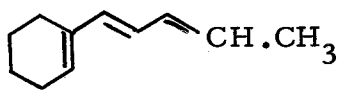
Compound	λ_{max} (nm.)	$\Sigma \times 10^4$
	259 (sh) 264 272	1.86 2.08 1.73
	255 262 272	2.27 2.91 2.48
	257 (sh) 265 274	1.95 2.25 1.76
	255 264 275	2.58 3.40 2.76

Table 3. UV spectra of trienes.

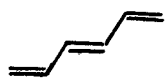
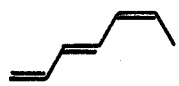
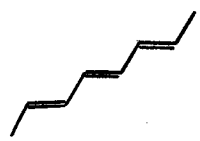
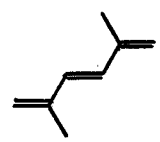
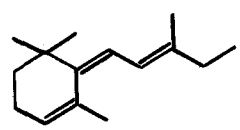
Compound	λ_{max} (nm.)	$\Sigma \times 10^4$	Ref. no.
	247.5 257.5 267.5	6.80 7.90 5.60	4
	245 255 265	2.9 4.1 3.0	11
	251 260.5 271.5	4.08 5.32 4.63	1
	263 273	4.08 3.69	1
	254 264 274	2.75 3.46 2.72	1
	255 265 276	3.46 4.74 3.67	1
	267 277	4.16 3.35	1
	251 261 271	3.70 4.60 3.40	1 or 4
	275 (sh) 284 294	2.53 2.93 2.10	20

Table 4. UV spectra of long conjugated system.

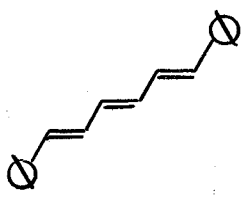
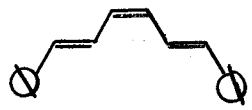
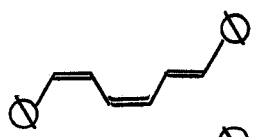
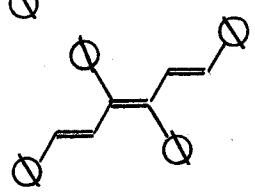
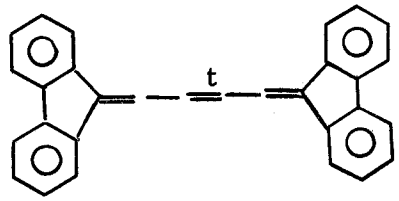
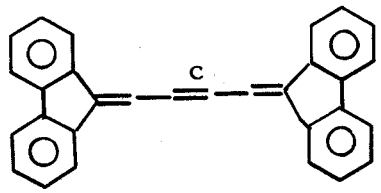
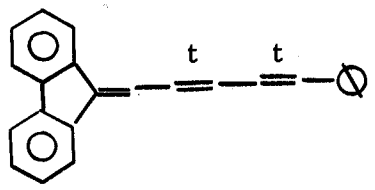
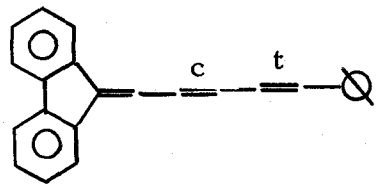
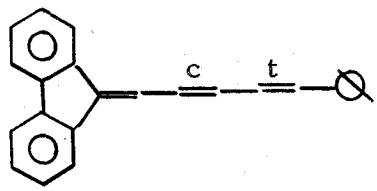
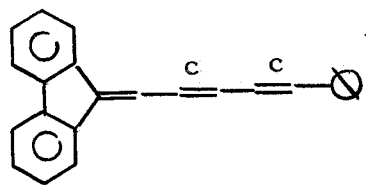
Compound	λ_{max} (nm.)	$\Sigma \times 10^4$	Ref. no.
	351	7.8	18
	349	5	18
	336	5	18
	334	5	18
	247 253 270 353 368 386	1.36 1.33 1.46 4.9 6.56 5.00	27
	465	7.65	19
	458.5	5.44	19
	388	678	19

Table 4. (Continued)

Compound	λ_{max} (nm.)	$\Sigma \times 10^4$	Ref. no.
	385.5	5.67	19
	385	5.25	19
	379	4.83	19

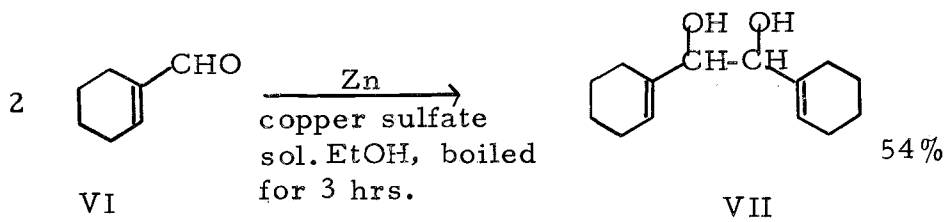
DISCUSSION

The synthesis of symmetrically-substituted trienes having a cis-central double bond generally poses a number of problems. There are only three bond types which might be generated in the terminal step of a preparative process. In a preformed carbon skeleton either the central or one of the terminal double bonds may be introduced in the final step. Both involve stereochemical control but the demands at the central double bond are stricter. Finally the single bond between the central and terminal double bond may be introduced in the final stage of the synthesis. Again a serious stereochemical problem must be faced. The scarcity of reactions useful for formation of such a single bond as well as the stereochemical question mitigate against this third alternative.

Normally the desirability of utilizing the symmetry of the molecule to good advantage suggests introduction of the central double bond in the last step. Earlier trouble with this route using semihydrogenation of an acetylenic link clearly eliminates that process from further consideration unless some convenient method of separating the desired triene from the complex reaction product is available. Thus recourse to an elimination reaction subject to reasonable stereochemical control was necessary. The discovery by Corey and Winter of an ingenious method for converting a 1, 2-diol stereospecifically to an olefin made possible use of this route. Some

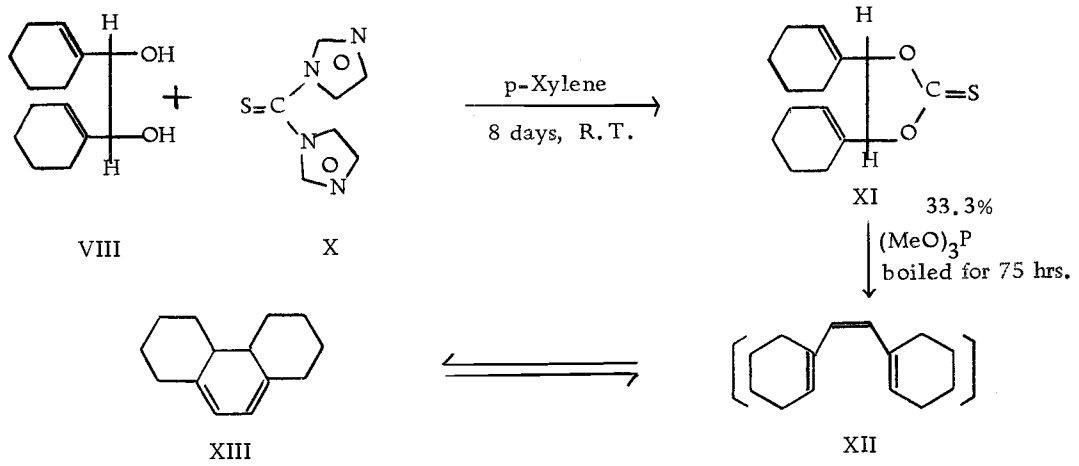
doubt, however, exists as to the utility of this process for this purpose since it involves a relatively high temperature in the final step, and might therefore give rise to a cyclization product rather than the desired triene. However simplicity and possible general value in further studies where substitution other than hydrogen might be desired on the central pair of carbon atoms prompted a study of this route.

The known cyclohexene-1-carboxaldehyde (7) serves as the starting material for this synthesis. Thiele (26) has reported that a zinc-copper couple reduces cinnamaldehyde bimolecularly to a diol. The same procedure was utilized give a 54% yield of 1, 2-dicyclohexenyl-1, 2-ethanediol (VII). The diol was a crystalline solid



VI VII

which was shown by thin layer chromatography to consist of two isomeric forms in a ratio of 1:0.8. Preparative layer separation was accomplished conveniently on silica gel. One isomer melts at 107-108° while the second melts at 94-94.5°.



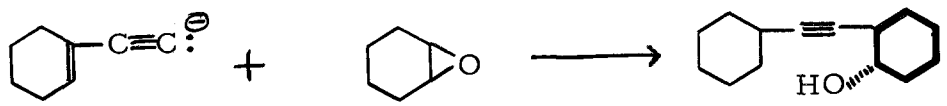
VIII X XI

XIII XII

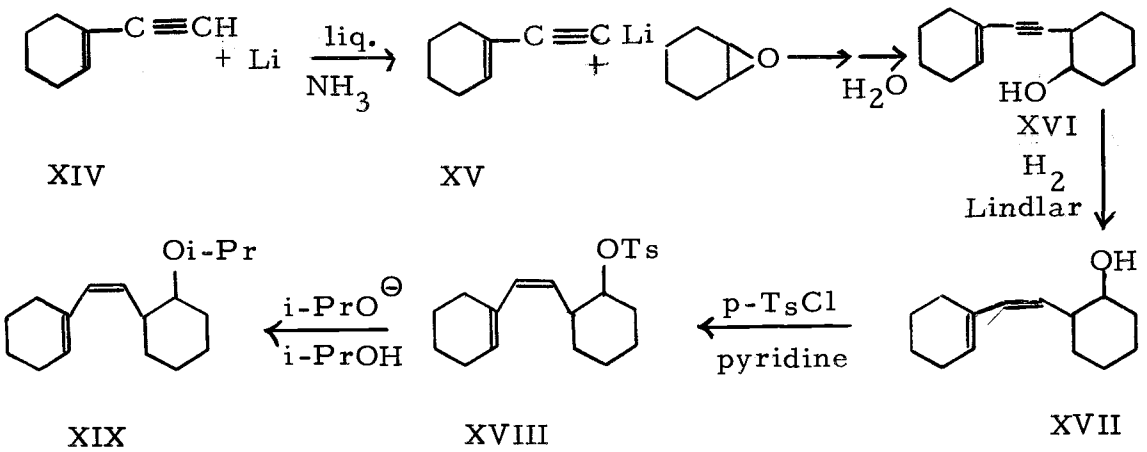
Treatment of higher melting form with N, N-thiocarbonyl diimidazole gave the thioncarbonate (XI) as expected. Reaction of XI with trimethyl phosphite proved disappointingly slow at 110°. After 75 hrs. a small yield of hydrocarbon was recovered from the reaction mixture. Purification gave, λ_{max} 276 nm. (Σ=7400). The molecule showed an n. m. r. specturn having a peak at 6. 62 (olefinic H, rel. area 1. 95), a multiplet centered at 2. 55 (allylic H, rel. area 9. 00), and another multiplet centered at 1. 70 (aliphatic CH_2, rel. area 9. 05). Clearly this is not the desired triene, and the properties suggest that the product is the decahydrophenanthrene XIII. Apparently a ring closure has occurred after formation of the cis-triene. This is not unreasonable since the rate of electrocyclization of 1-cyclohexenyl-cis-butadiene is 12.8×10^{-5} sec.$^{-1}$ at 132°, and that of cis-hexatriene is 5.1×10^{-5} sec.$^{-1}$ at 132°. Thus one could expect that the rate of XII would be between 2×10^{-4} and 5×10^{-4} sec.$^{-1}$ at 132°. Assuming a $\Delta H^{\ddagger}$ of ca. 30 kcal/mole this would correspond to a half-life of ca. 4. 5 hrs. for XII at 110°.

Since XII is thus a reasonable intermediate in the formation of XIII under these conditions, we may assume that decomposition of the thioncarbonate gave XII. This would indicate that the higher of melting form of diol (VIII) can be assigned the meso stereochemistry.

Failure of this route to give the desired triene (XII) led us to study a route involving formation of the terminal double bond at the final step. This method has been employed successfully in a number of cases. However it suffers in the present case in that generation of the necessary functionality for formation of the final double bond utilizes ring opening of an epoxide. With the cyclohexene ring this



must form a trans-product as shown. Normal E_2 elimination is favored by an anti-periplanar arrangement of the proton and the functional group being eliminated. Thus in this case the most favorable stereochemistry cannot be achieved. Despite this problem the route appeared attractive enough to warrant investigation.

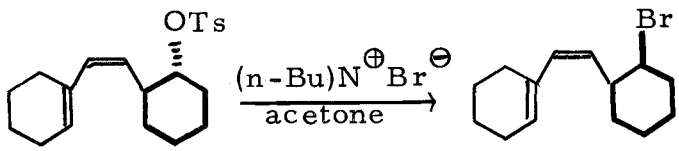


The initial step followed a procedure developed by Inhoffen and Quinkert (15) and proceeded quite satisfactorily. No problems were experienced prior to the final elimination step. Direct E_2 elimination gave a mixture of two products. The major product showed the present of an isopropoxy group suggesting that substitution had occurred. A small amount of impure hydrocarbon isolated had an n.m.r. spectrum showing a ratio of olefinic to alicyclic protons of ca. 1:4. Definitely not the conjugated triene this product may have been the triene with the new double bond in an unconjugated position.

Two solutions may be proposed to overcome this stereochemical difficulty. The tosylate group may be replaced by a new function using an S_N2 displacement. Thus the necessary cis-stereochemistry between the new function and the ethylene substituent would be achieved, and E_2 elimination might be brought about readily in the proper direction. Either bromide ion or trimethylamine could be

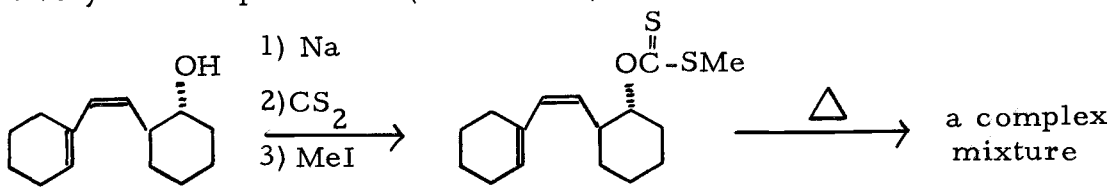
used for the displacing group. Bromide ion was chosen since it readily adopts an axial position, and seemed less likely to cause elimination instead of displacement.

An attempt to displace the tosylate with tetra-n-butyl-ammonium bromide in acetone failed when the starting material was recovered unchanged. Perhaps more drastic condition would have been successful. No attempt to use the amine was made.



XVIII

A second solution to the problem of the unfavorable stereochemistry was to use an elimination process favored by syn-periplanar geometry. Unfortunately most of these are pyrolytic processes. One representative reaction of this type was examined. The Chugaev reaction was chosen because it generally proceeds at relatively low temperatures (~100-150°) and the xanthate is quite



XVII XX

simply obtained from the alcohol. The reaction product from the methyl xanthate XX was a complex mixture from which no pure hydrocarbon could be isolated by preparative thin layer chromatography.

EXPERIMENTAL

All m.p.'s and b.p.'s are uncorrected. The infrared spectra were run on a Beckman model I. R. 8 and all ultraviolet spectra on a Beckman model D. B. spectrometer. N.M.R. spectra were run on a Varian A-60 instrument with tetramethylsilane as an internal standard.

1-(2, 2, 2-Trichloro-1-hydroxyethyl)cyclohexene

A mixture of cyclohexene(164 g., 2 moles) and anhydrous chloral(148 g., 1 mole) was stirred vigorously for three hours at 0° C. with the gradual addition of 14 g. of aluminum chloride. The aluminum complex was hydrolysed with water and the product was taken up in ether. The ether solution was dried over anhydrous magnesium sulfate, and the solvent was removed by vacuum evaporation. The product was isolated by distillation, b.p. 128° - 130° C. (2.3 mm.); $n^{22}D$ 1.5131; yield 156 g. (67.6%); $\tilde{\nu}$ 3520, 1100 cm^{-1} (OH). The n.m.r. spectrum showed a singlet at 5.90 (olefinic H, rel. area 0.95), a peak at 3.90 (CHOH, rel. area 1.0), a singlet at 2.95 (OH, rel. area 0.95), a multiplet centered at 2.08 (allylic H, rel. area 4.10), and a multiplet centered at 1.80 (aliphatic CH_2, rel. area 4.08). This compound was reported previously by Cologne and Perrot (6); b.p. 138° C. (16 mm.) and $n^{22}D$ 1.5185.

Cyclohexene-1-carboxaldehyde

This aldehyde was prepared according to the method of Cologne and Perrot (7). A mixture of 156 g. (0.68 mole) of 1-(2, 2, 2-trichloro-1-hydroxyethyl) cyclohexene, 192 g. (1.37 moles) of potassium carbonate and 4.5 l. of water was boiled with 2 g. of Labtone for 2.5 hrs. The product was taken up in ether, and dried over anhydrous magnesium sulfate. The solvent was removed by vacuum evaporation and the residue distilled as a colorless liquid, b.p. 44°-45° C. (0.3 mm.); $n^{22}D$ 1.4950; yield 13.50 g. (18.10%). The infrared spectrum showed bands at 2720 cm.$^{-1}$, 2820 cm.$^{-1}$ (CHO), 1685 cm.$^{-1}$ (α,β unsaturated C=O) and 1645 cm.$^{-1}$ (C=C).

The compound was reported to boil at 65°-66° C. (12 mm.); $n^{22}D$ 1.490.

1, 2-Dicyclohexenyl-1, 2-ethanediol

The glycol was prepared according to the method described by Thiele (26). A mixture of 33.8 g. (0.52 mole) of zinc dust, 13 g. (0.081 mole) of copper sulfate and 2.5 liters of 30% ethyl alcohol was boiled while 13.5 g. (0.123 mole) of cyclohexene-1-carboxaldehyde was added dropwise. After the mixture had been heated for 3 hrs., the catalyst was removed by filtration and the ethyl alcohol was removed by vacuum evaporation. About 7.5 g. (54%) of diol

mixture was obtained as colorless crystals. The meso and racemic forms were separated by preparative thin layer chromatography (silica gel PF_{254}) using 15% acetone and 85% chloroform, R_f 0.60 and 0.34. A weight ratio of 1:0.8 was found. After both of the diols were recrystallysed from n-hexane, they showed the following physical properties.

The meso form melts at 107°-108° C., $\tilde{\nu}$ 3400, 1050 cm.$^{-1}$ (OH). The n.m.r. spectrum showed a peak centered at 5.6 (olefinic H, rel. area 2.05), a singlet at 3.76 (C<u>H</u>OH, rel. area 1.98), a singlet at 2.40 (O<u>H</u>, rel. area 2.00), a multiplet at 1.98 (allylic H, rel. area 8.02), and a multiplet centered 1.60 (aliphatic CH_2, rel. area 8.03).

<u>Anal.</u> Calc'd for $C_{14}H_{22}O_2$: C, 75.63; H, 9.97. Found: C, 75.52; H, 9.90.

The racemic form melts at 94°-94.5° C., $\tilde{\nu}$ 3580 cm.$^{-1}$ sharp (monomeric OH), 3250 cm.$^{-1}$ broad, 1060 cm.$^{-1}$ (OH). The n.m.r. spectrum showed a peak centered at 5.60 (olefinic H, rel. area 2.08), a singlet at 3.77 (C<u>H</u>OH, rel. area 2.00), a singlet at 3.04 (O<u>H</u>, rel. area 1.95), a multiplet at 1.98 (allylic H, rel. area 7.90), and a complex multiplet centered at 1.60 (aliphatic CH_2, rel. area 8.10).

<u>Anal.</u> Calc'd for $C_{14}H_{22}O_2$: C, 75.63; H, 9.97. Found: C, 75.48; H, 9.88.

N, N' Thiocarbonyl diimidazole

This compound was prepared according to the method described by Staab and Walther (24). Ten grams (0.913 mole) of thiophosgene in 70 ml. of benzene was dropped slowly into a solution containing 24.8 g. (0.364 mole) of imidazole in 196 ml. of chloroform. The mixture was stirred at room temperature for 10 hrs. After the imidazole hydrochloride had been removed, the solvent was evaporated in vacuo. The product was recrystallized in dry tetrahydrofuran and then sublimed. This compound melts at 100° -104° C., yield 9.5 g. (59%) and has an infrared spectrum identical to that described by Staab and Walther.

1, 2-Dicyclohexenylethylene Thioncarbonate

The thioncarbonate was prepared by allowing 0.70 g. (3.15×10^{-3} mole) of the meso form of the diol and 0.85 g. (4.73×10^{-3} mole) of N, N' thiocarbonyl diimidazole in 15 ml. of dry p-xylene to stand at room temperature for eight days. The product was separated by preparative thin layer chromatography (silica gel PF_{254}) using chloroform as eluant (R_f 0.56), yield 0.277 g. (33.3%). After crystallization from n-hexane-ether the pure product melted at 122.5° - 124° C.; $\tilde{\nu}$ 1050 $cm.^{-1}$ (C=S stretch). The n.m.r. spectrum showed a multiplet centered at 5.70 (olefinic H, rel. area 2.05), a singlet at

5.00 (CHO, rel. area 1.85), a multiplet centered at 2.00 (allylic H, rel. area 8.02), and a multiplet centered at 1.58 (aliphatic CH_2, rel. area 7.90).

Anal. Calc'd for $C_{15}H_{20}O_2S$: C, 68.16; H, 7.63. Found: C, 68.34; H, 7.50.

1, 2, 3, 4, 4a, 5, 5a, 6, 7, 8-Decahydrophenanthrene

A mixture of 0.200 g. (0.758×10^{-4} mole) of 1, 2-dicyclohexenylethylene thioncarbonate and 25 ml. of trimethylphosphite was heated under nitrogen atmosphere for 75 hrs. The carbon dioxide evolved was trapped by calcium hydroxide solution. The product was separated by preparative thin layer chromatography (silica gel PF_{254}) using chloroform as eluant (R_f 0.785) and then purified by the preparative gas chromatography (5% FFAP on Chromosorb W, 5' x 1/4", 165° C., retention time 16 min.). The decahydrophenanthrene showed the following bands in infrared spectrum 1470 cm.$^{-1}$ (CH_2), 1420 cm.$^{-1}$, 793 cm.$^{-1}$ and a peak in the u.v. region, λ_{max} 276 nm. (Σ=7,400). The n.m.r. spectrum showed a peak at 6.63 (olefinic H, rel. area 1.95), a multiplet centered at 2.55 (allylic H, rel. area 9.00) and another multiplet centered at 1.70 (aliphatic CH_2, rel. area 9.05). Too small an amount was obtained for analysis or further examination.

1-Ethynylcyclohexene

This compound was prepared according to the method of Hamlett, Henbest, and Jones (9). A solution of 200 g. (1.88 moles) of 1-ethynylcyclohexanol in 300 ml. of anyhydrous pyridine was placed in a 2 l. flask and a mixture of 110 ml. of phosphorous oxychloride in 110 ml. of anhydrous pyridine was added at such a rate to maintain reflux. After the addition was complete, the mixture was heated on the steam bath for 1 hrs., the hot solution was poured over ice (with stirring), and the product taken up in pentane. The extract was dried over calcium chloride, the solvent removed by vacuum evaporation and the product distilled, b.p. 52°-55° C. (27 mm.), $n^{20}D$ 1.4962, yield 136.8 g. (80%), λ_{max} 222 nm (Σ=12,400), $\tilde{\nu}$ 3325 $cm.^{-1}$ (C≡C, C-H stretch), 1628 $cm.^{-1}$ (C=C stretch). The n.m.r. spectrum showed a poorly resolved quintet at 6.63 with relative area 1.00 (vinyl H), a singlet at 2.97 (rel. area 1.05, acetylenic H), a complex multiplet centered at 2.55 (rel. area 3.89, allylic H), and another complex multiplet centered at 1.73 (rel. area 3.99), aliphatic H). The physical constants reported previously (9) are; b.p. 53°-56° C. (43 mm.), $n^{17}D$ 1.4978, λ_{max} 223.5 nm (Σ=10,500).

1-(Cyclohexenyl)-2-(2-hydroxycyclohexyl)ethyne

This alcohol was prepared according to the method of Inhoffen, Weissermel, Quinkert and Bartling (15). A solution of lithamide in liquid ammonia was prepared by the reaction of 0.655 g. (9.400 x 10^{-2} g. atom) of lithium metal, 200 ml. of liquid ammonia and 3.5 mg. of ferric nitrate. A solution of 10 g. (9.4 x 10^{-2} mole) of 1-ethynylcyclohexene in 25 ml. of dry ether was added dropwise. The mixture was stirred overnight and the ammonia was allowed to evaporate. Cyclohexene oxide (8.35 g., 8.5 x 10^{-2} mole) in 20 ml. of dry ether was added to the lithium salt and the mixture was heated for 30 min. As much of the ether as possible was distilled and 35 ml. of dry tetrahydrofuran was added. This mixture was boiled for 23 hrs. Saturated ammonium chloride was added and the product was taken up in ether. The ether extract was dried over anhydrous magnesium sulfate and the solvent was evaporated in vacuo. The residue was distilled, b.p. 102°-105°C. (2.5 x 10^{-2} - 0.5 x 10^{-2} mm.); yield 7 g. (40.5%). A sample was purified by thin layer chromatography (silica gel PF_{254}, pentane R_f=0) followed by preparative gas chromatography (5% FFAP on Chromosorb W, 5' x 1/4" column, 170°C., retention time 17 min.); λ_{max} 230 nm (Σ= 1.5 x 10^{-4}), $\tilde{\nu}$ 3400 $cm.^{-1}$ (OH), 3020 (w), and 1660 $cm.^{-1}$ (w) (C=C stretch). The n.m.r. spectrum showed a peak centered at 5.91

(vinyl H, rel. area 1.00), a complex multiplet centered at 3.30 (C<u>H</u>OH, rel. area 1.02), a singlet at 2.85 (O<u>H</u>, rel. area 0.98), a complex multiplet centered at 2.04 (allylic H, & ≡C-C<u>H</u>, rel. area 5.10), and a complex multiplet centered at 1.58 (aliphatic H, rel. area 12.08).

<u>Anal.</u> Cal'd for $C_{14}H_{20}O$: C, 82.3; H, 9.87. Found C, 82.19; H, 9.73.

The p-nitrobenzoate prepared according to the directions given in Shriner, Fuson, and Curtin (22), melted at 92°-93° C., λ_{max}260 nm (Σ=1.5x10^4), λ_{max}230 nm (1.7x10^4), $\tilde{\nu}$ 1720 cm.$^{-1}$ (C=O stretch of aromatic ester), 1605 cm.$^{-1}$ (phenyl), 1515 cm.$^{-1}$ (NO_2 asymetric stretch), and 1335 cm.$^{-1}$ (NO_2 symmetric stretch). The n.m.r. spectrum showed a singlet at 8.05 (aromatic H, rel. area 4.00), and a multiplet centered at 5.71 (vinyl H, rel. area 0.98), a complex multiplet centered at 4.80 (C<u>H</u>OCO, rel. area 1.01), a complex multiplet centered at 2.57 (C<u>H</u>-C≡C, rel. area 0.98), a complex multiplet at 1.76 (allylic H, rel. area 4.00), and a peak centered at 1.37 (aliphatic CH_2, rel. area 10.13).

<u>Anal.</u> Cal'd for $C_{21}H_{23}NO_4$: C, 71.37; H, 6.56. Found: C, 71.31; H, 6.68.

The alcohol was oxidised to the corresponding ketone using Jone's oxidation method described by Lee, <u>et al.</u> (16). The ketone obtained showed λ_{max}230 (Σ=1x10^4), $\tilde{\nu}$ 3020 cm.$^{-1}$ (w), 2190 cm.$^{-1}$

(w) (-C≡C stretch), and 1715 cm.$^{-1}$ (C=O stretch).

Semihydrogenation of 1-(Cyclohexenyl)-2-(2-hydroxycyclohexyl)ethyne

A mixture of 1.02 g. of Lindlar catalyst (17), 50 ml. of ethyl acetate, and 0.05 g. of synthetic quinoline was stirred under hydrogen atmosphere for 15 min. to saturate the catalyst. The sample (10.20 g.; 0.05 mole) was introduced and the mixture hydrogenated until 1210 ml. (0.05 mole) of hydrogen had been absorbed. The catalyst was removed by filtration, and the solvent by vacuum evaporation. The product melted at 45°-46°; 9.8 g. (95%); λ_{max} 230 nm (Σ=1.32 x 10^4), $\tilde{\nu}$ 3400 cm.$^{-1}$(OH), and 1645 cm.$^{-1}$ (C=C stretch). The n.m.r. spectrum showed a doublet at 5.8 (vinyl H), a peak at 5.62 (vinyl H), a triplet at 4.95 (vinyl H), a complex multiplet centered at 3.10 (CHOH), a singlet 2.28 (OH), a complex multiplet centered at 2.10 (allylic H), and another complex multiplet centered at 1.60 (aliphatic CH_2).

Anal. Cal'd for $C_{14}H_{22}O$: C, 81.50; H, 10.75. Found: C, 81.37; H, 10.49.

Preparation of Tosylate of cis-1-Cyclohexenyl-2-(2-hydroxycyclohexyl) ethylene

A solution of 7.7 g. (0.044 mole) of p-toluenesulfonyl chloride in pyridine was cooled in an ice bath and 7.0 g. (0.034 mole) of the

above alcohol in pyridine was added dropwise to the mixture which was maintained under nitrogen. The mixture was stirred for 24 hrs. and 25 ml. of water was then added. The product was taken up in ether, washed successively with distilled water, dilute phosphoric acid, dilute sodium bicarbonate, and finally again with water. After the ether solution had been dried over anhydrous magnesium sulfate, the ether was removed by vacuum evaporation. The yield of crude tosylate was 9 g. (77%), m.p. 59°-61°C.; $\tilde{\nu}$ 1600 cm.$^{-1}$ (phenyl), 1450 cm.$^{-1}$, 1360 cm.$^{-1}$ (SO_2 asymmetric stretch), and 1175 cm.$^{-1}$ (SO_2 symmetric stretch). The n.m.r. spectrum showed a quartet at 7.4 (aromatic H, rel. area 4.12), a doublet at 5.55 (vinyl H, rel. area 0.85), a multiplet centered at 5.45 (vinyl H, rel. area 1.08), a triplet at 4.70 (vinyl H, rel. area 1.20), a complex multiplet centered at 4.10 (C<u>H</u>OH, rel. area 1.05), a singlet at 2.40 (CH_3, rel. area 2.90), two complex multiplet at 2.05 and 1.58 corresponding to allylic protons and aliphatic protons respectively (rel. area 20.52).

<u>Attempted Preparation of 1,2-Dicyclohexenylethylene</u>

The reaction was carried out under nitrogen. The mixture of 2 g. (5.8×10^{-3} mole) of the crude tosylate in 8 ml. of isopropyl alcohol and 0.3 g. (6.96×10^{-3} mole) of potassium hydroxide in 8 ml. of isopropyl alcohol was boiled for one hour. After the addi-

tion of 25 ml. of water, the product was taken up in pentane. The pentane solution was washed with water, then dried over anhydrous magnesium sulphate. The solvent was removed by evaporation in vacuo. The n.m.r. spectrum showed three multiplets at 5.70, 5.40 and 4.85 (vinyl H), a multiplet at 3.45 (O-C<u>H</u>$(CH_3)_2$), a multiplet at 3.00 (C<u>H</u>-O-), a multiplet at 1.90 (allylic H), a multiplet at 1.55 (aliphatic CH_2) and another multiplet at 1.10 ($C\underline{H}_3$).

Attempted Preparation of <u>cis</u>-1-Cyclohexenyl-2-(2-bromocyclohexyl) ethylene

This reaction was run according to the method described by Winstein, Savedoff, Smith, Steven and Gall (30). A mixture of 3.4 g. (9.5×10^{-3} mole) of the above tosylate and 2.63 g. (9.5×10^{-3} mole) of tetra-n-butyl ammonium bromide (5) in 40 ml of dry acetone was heated at reflux for 21 hrs. The mixture was poured into 75 ml. of water, and the product was taken up in pentane. After the solution had been dried over magnesium sulfate, the solvent was removed by vacuum evaporation. The infrared spectrum showed bands at 1600 $cm.^{-1}$ (phenyl), 1450 $cm.^{-1}$, 1460 $cm.^{-1}$ (SO_2 asymmetric stretch), and 1175 $cm.^{-1}$ (SO_2 symmetric stretch). The n.m.r. spectrum showed a quartet at 7.41 (aromatic H, rel. area 4.12), a doublet at 5.55 (vinyl H, rel. area 1.00), a multiplet centered at 5.45 (vinyl H, rel. area 1.10), a triplet at 4.70 (vinyl H, rel. area 0.85), a

complex multiplet centered at 4.10 (CHOH, rel. area 1.00), a singlet at 2.40 (CH_3, rel. area 2.90), two complex multiplets at 2.05 and 1.58 corresponding to allylic protons and aliphatic protons respectively (rel. area 19.85). These above data showed this to be recovered starting material.

Methyl Xanthate of cis-1-(Cyclohexenyl)-2-(2-hydroxycyclohexyl) ethene

This xanthate was prepared according to the method described by Alexander and Muddrak (2). To a solution of 5 g. (2.42×10^{-2} mole) of cis-1-(cyclohexenyl)-2-(2-hydroxycyclohexyl)ethylene in 80 ml. of dry ether was added 0.58 g. (2.5×10^{-2} mole) of metallic sodium freshly cut into small pieces. The mixture was stirred for 30 hrs. at room temperature and 2.85 g. (3.72×10^{-2} mole) of carbon disulfide was added. Excess sodium was removed mechanically and stirring was continued for 2 hrs. Methyl iodide (7.1 g.; 4.84×10^{-2} mole) was added and the mixture was stirred overnight. An additional 5 ml. of methyl iodide was added and stirring was continued for 1 hr. longer. The inorganic salts were removed by filtration and the volatile material was removed by evaporation under reduced pressure. The crude product isolated weighed 6 g. (85%), λ_{max} 278 nm ($\Sigma = 1.1 \times 10^4$), λ_{max} 230 nm ($\Sigma = 1.25 \times 10^4$), $\tilde{\nu}$ 1670 $cm.^{-1}$ (w) (trisubstituted C=C), and 1050 $cm.^{-1}$ (C=S stretch). The n.m.r. spectrum showed a doublet at 5.60 (vinyl H, rel. area 0.92) a peak centered at 5.40

(vinyl H, rel. area 1.10), a complex multiplet centered at 4.70 (vinyl H, rel. area 1.20), another complex multiplet centered at 2.75 (CH-O-, rel. area 1.00), a singlet at 2.26 (CH_3, rel. area 2.85), a complex multiplet centered at 1.88 (allylic H, rel. area 4.90), and another complex multiplet at 1.40 (aliphatic H, rel. area 12.35). No attempt to purify this material was made and it was used directly in the next step.

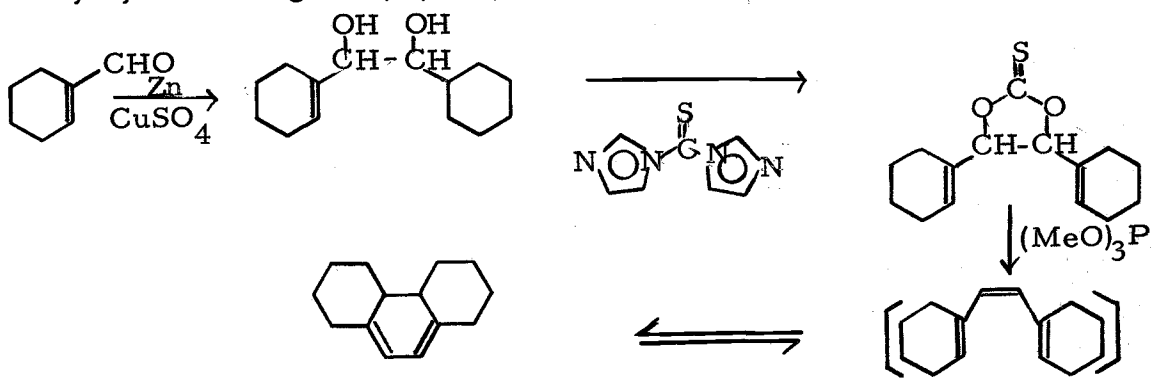
Thermal Decomposition of Methyl Xanthate of cis-1-(Cyclohexenyl)-2-(2-hydroxycyclohexyl)ethene

A sample (3 g., 0.01 mole) of the methyl xanthate above was heated under the nitrogen flow at 2 mm. pressure at 170-175° for 1 hr. Volatile products were trapped from the nitrogen stream by a trap immersed in liquid nitrogen. The condensate in the trap (ca. 2 g.) was separated by thin layer chromatography on silica gel PF_{254} using n-pentane as eluant. Two fractions in the weight ratio of 0.5 to 1.5 g. were obtained with R_f value of 0.8 and 0.5 respectively.

The compound with R_f 0.8 had λ_{max} 243 nm; $\tilde{\nu}$ = 2900, 1440, 1125 $cm.^{-1}$; n.m.r. δ 5.81 (singlet), 5.53 (multiplet), 5.05 (triplet), 2.50 (multiplet), and two complex series of peaks centered at 2.08 and 1.60. The substance with R_f 0.5 was characterized by λ_{max} 278 nm; n.m.r. δ 4.50 (quartet), 2.55 (doublet), and 1.4 (quartet).

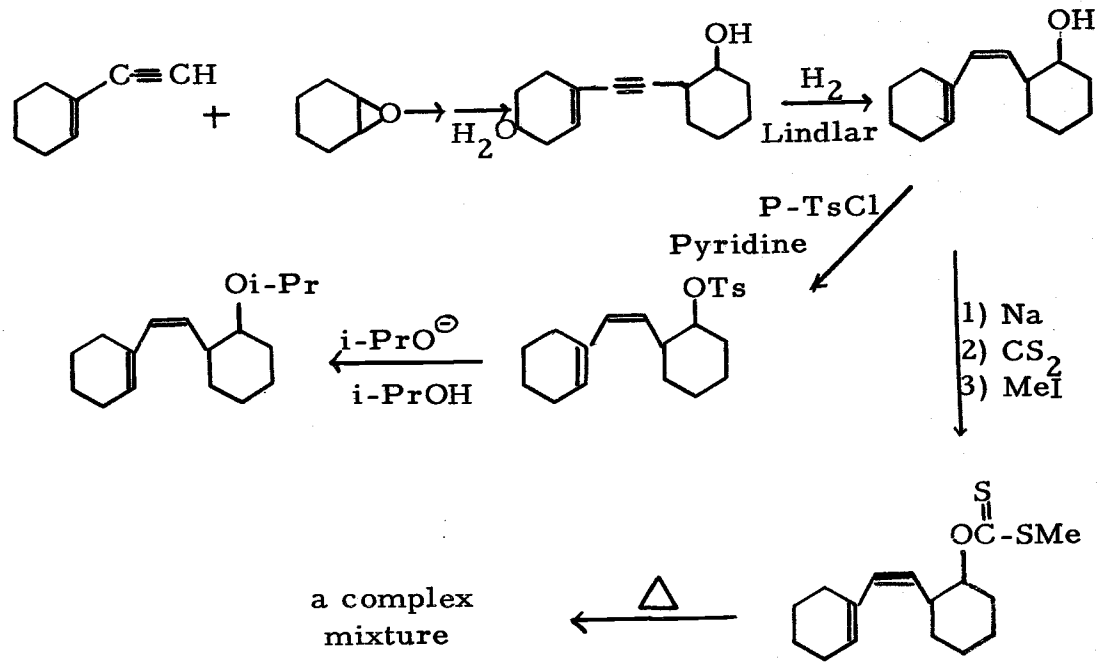
SUMMARY

This thesis reports two attempts to synthesize cis-1, 2-dicyclohexenylethylene. Cyclohexene-1-carboxaldehyde was reduced by Thiele's method (26) to a mixture of meso and racemic forms of 1, 2-dicyclohexenyl-1, 2-ethanediol. The meso was separated from the mixture and a thioncarbonate was synthesized from this by the procedure of Corey and Winter (8). Thermal decomposition of this thioncarbonate proceeded slowly in trimethylphosphite. Under the conditions of the reaction the cis-1, 2-dicyclohexenylethylene apparently cyclized to give 1, 2, 3, 4, 4a, 5, 5a, 6, 7, 8-decahydrophenanthrene.



A second attempt to prepare the desired triene involved elimination reactions of cis-1-cyclohexenyl-2-(2-substituted cyclohexyl) ethylenes. The basic substrate cis-1-cyclohexenyl-2-(2-hydroxycyclohexyl) ethylene was prepared by treating the lithium salt of cyclohexenylacetylene with cyclohexene oxide followed by semi-hydrogenation of the initial product. Attempted E_2 elimination from the tosylate of that alcohol gave mainly the substitution

product. In order to invert the stereochemistry at the tosylate-bearing carbon, it was treated with tetra-n-butyl ammonium bromide in acetone, but the unreacted starting material was recovered. Finally a methyl xanthate was prepared from the alcohol. Thermal decomposition of the xanthate gave a complex mixture from which no pure product was isolated.



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