IDENTIFICATION OF A THERMAL ADDITION PRODUCT OF 7 - METHOXYCYCLOHEPTATRIENE AND DIMETHYL ACETYLENEDICARBOXYLATE

Thesis for the Degree of M. S.

MICHIGAN STATE UNIVERSITY
JOHN CORD VAN HEERTUM

1974

ABSTRACT

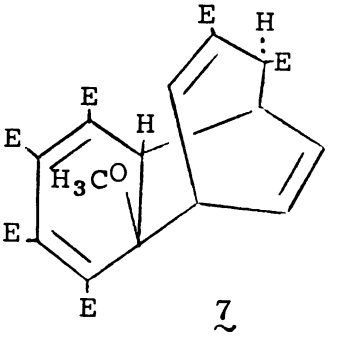
IDENTIFICATION OF A THERMAL ADDITION PRODUCT OF
7-METHOXYCYCLOHEPTATRIENE AND
DIMETHYL ACETYLENEDICARBOXYLATE

By

John Cord Van Heertum

Cycloheptatrienes are reported to yield substituted 6,7-dicarbomethoxy-tricyclo[3.2.2.$0^{2,4}$]nona-6,8-dienes as the major reaction products from their condensation with dimethyl acetylenedicarboxylate. In one case[3], 3,4-dicarbomethoxy-bicyclo[3.2.2]nona-2,6,8-triene (4) has been identified as a byproduct from the cycloaddition of cycloheptatriene (1) to dimethyl acetylenedicarboxylate. No other addition products have been reported in the literature.

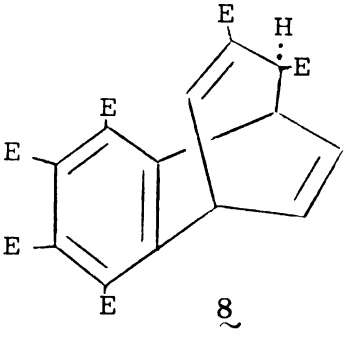
We have found that 7-methoxycycloheptatriene (5) forms a complicated mixture when reacted with dimethyl acetylenedicarboxylate. The expected product, 6,7-dicarbomethoxy-3-methoxy-tricyclo[3.2.2.$0^{2,4}$]nona-6,8-diene (6) was not detected in the reaction mixture. One product has been isolated and identified as 3,4,5,6,10,11-hexacarbomethoxy-7-methoxy-tricyclo[6.3.2.$0^{2,7}$]trideca-3,5,9,12-tetraene (7) based on its ir, uv, nmr, mass spectrum, and elemental analyses.



7

E = CO_2CH_3

This 3:1 adduct 7 of dimethyl acetylenedicarboxylate and 5 has been found to be very unreactive toward bromination and low pressure hydrogenation. Oxidation yielded intractable mixtures. High pressure hydrogenation as well as treatment with acid and heating above its melting point resulted in the loss of methanol from 7 to give 3,4-dicarbomethoxy-6,7-(2',3',4',5'-tetracarbomethoxy-benzo)-bicyclo-[3.2.2]nona-2,6,8-triene (8).



8

E = CO_2CH_3

IDENTIFICATION OF A THERMAL ADDITION PRODUCT OF 7-METHOXYCYCLOHEPTATRIENE AND DIMETHYL ACETYLENEDICARBOXYLATE

By

John Cord Van Heertum

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Chemistry

1974

To My Wife

Linda

to

gui

the

tio

for

add

cou

exp

and

the

Che

lab

com

ACKNOWLEDGMENTS

The author wishes to express his sincere appreciation to Dr. Eugene LeGoff for suggesting this project and for his guidance during the investigation.

The author is also grateful to the following people for their assistance: Dr. Lowell Markley for his many suggestions and advice during the investigation; Dr. Michael Gross for determining the nmr coupling constants of the 3:1 adduct (7).; Dr. Robert Iwamasa for confirming the nmr coupling constants of 7 and for performing a shift reagent experiment which confirmed the proposed structure of 7; and to Dr. Jack Arrington for his suggestions concerning the preparation of this thesis.

The author is particularly appreciative to The Dow Chemical Company for providing the analytical services, laboratory facilities and financial support necessary to complete this investigation.

INT
RES
EXP
BIB
APP

TABLE OF CONTENTS

	Page
INTRODUCTION	1
RESULTS	4
EXPERIMENTAL	19
General Procedures	19
7-Methoxycycloheptatriene (5)	20
3,4,5,6,10,11-Hexacarbomethoxy-7-methoxy-tricyclo[6.3.2.$0^{2,7}$]trideca-3,5,9,12-tetraene (7)	20
3-Methoxycycloheptatriene (9)	21
Reaction of 3-methoxycycloheptatriene (9) with dimethyl acetylenedicarboxylate	21
1-Methoxycycloheptatriene (10)	22
Reaction of 1-methoxycycloheptatriene (10) with dimethyl acetylenedicarboxylate	22
3,4-Dicarbomethoxy-6,7(2',3',4',5'-tetracarbomethoxy-benzo)-bicyclo[3.2.2]nona-2,6,8-triene (8)	22
Attempted bromination of 7	24
Attempted hydrogenation of 7	24
Ruthenium dioxide oxidation of 7	25
Potassium permanganate oxidation of 7	25
BIBLIOGRAPHY	27
APPENDIX	28

LIST OF FIGURES

Figure		Page
1.	Possible configurations for the 3:1 adduct 7	7
2.	Nmr comparisons of compounds 7 and 8	8
3.	Proposed mechanism for preparation of 7 . .	18
4.	Infrared spectrum of 7-methoxycycloheptatriene (5)	28
5.	Infrared spectrum of 3-methoxycycloheptatriene (9)	28
6.	Infrared spectrum of 3:1 adduct 7	29
7.	Infrared spectrum of 3:1 adduct 7	29
8.	Infrared spectrum of derivative 8	30
9.	Nmr spectrum of 7-methoxycycloheptatriene (5)	30
10.	Nmr spectrum of 3-methoxycycloheptatriene (9)	31
11.	Nmr spectrum of 3:1 adduct 7	31
12.	Nmr spectrum of derivative 8	32

stud

n =

tion

dica

lene

yiel

2

Until

ducts

boxyl

carbo

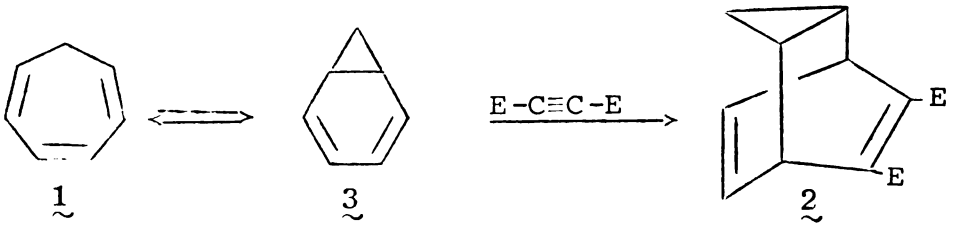
react

acety

propos

INTRODUCTION

Cycloheptatrienes are perhaps the most thoroughly studied of the odd-numbered cyclic-polyenes $CH_2(CH{=}CH)_n$, ($n = 1,2,...$).[1] They are often characterized by derivatization with a strong dienophile such as dimethyl acetylenedicarboxylate. The thermal cycloaddition of dimethyl acetylenedicarboxylate to cycloheptatriene (1) has been shown to yield 6,7-dicarbomethoxy-tricyclo[3.2.2.$0^{2,4}$]nona-6,8-diene (2) and involves norcaradiene (3) as an intermediate.[2] Until recently analogs of 2 were the only identified products of the thermal addition of dimethyl acetylenedicarboxylate to cycloheptatrienes.



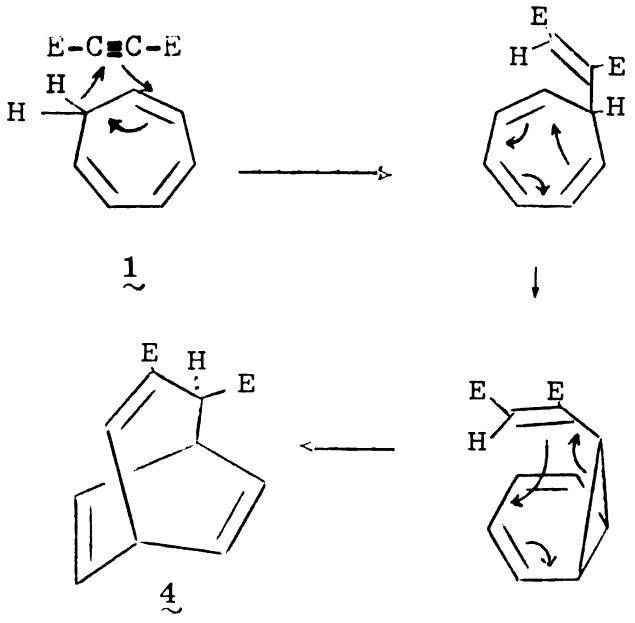
1 3 2

E = CO_2CH_3

In 1965, Goldstein[3] reported the isolation of 3,4-dicarbomethoxy-bicyclo[3.2.2]nona-2,6,8-triene (4) as a minor reaction product from the thermal addition of dimethyl acetylenedicarboxylate to 1. The following mechanism was proposed for this reaction:

Othe
the
cycl
lite

7-met
deriv
expec
[3.2.
react
showr
be a
No st

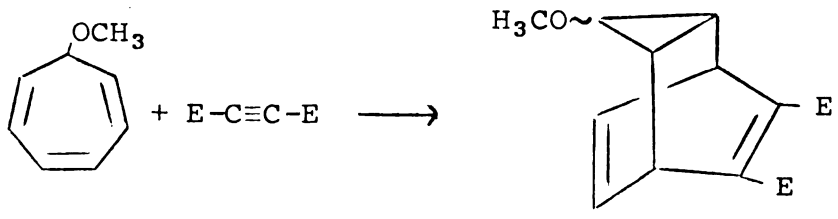


1 ↓ 4

E = CO_2CH_3

Other than 4 and analogs of 2, no other reaction products of the thermal addition of dimethyl acetylenedicarboxylate to cycloheptatrienes have been reported in the chemical literature.

In 1967, while investigating the photochemistry of 7-methoxycycloheptatriene (5), J. P. Szendry[4] attempted to derivatize 5 with dimethyl acetylenedicarboxylate. The expected products, 6,7-dicarbomethoxy-3-methoxy-tricyclo-[3.2.2.$0^{2,4}$]nona-6,8-diene (6), was not detected in the reaction mixture, however. The only product isolated was shown by nmr, mass spectroscopy, and elemental analysis to be a 3:1 adduct of dimethyl acetylenedicarboxylate and 5. No structure was determined for this 3:1 adduct.



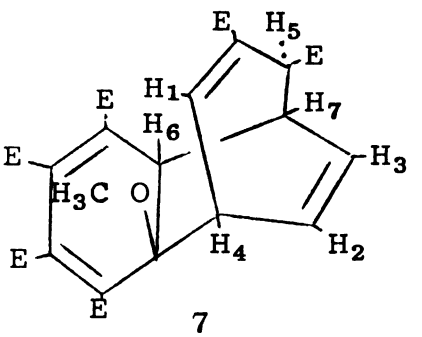
5 6

E = CO_2CH_3

The purpose of this work was to determine the structure of this 3:1 adduct by re-examination of the analytical data and by chemical derivatization and to propose a possible mechanism for the reaction.

RESULTS

Based on results to be given below, the structure of the 3:1 adduct[4] formed from the thermal addition of dimethyl acetylenedicarboxylate to 7-methoxycycloheptatriene (5) has been shown to be 3,4,5,6,10,11-hexacarbomethoxy-7-methoxy-tricyclo[6.3.2.$0^{2,7}$]trideca-3,5,9,12-tetrene (7).



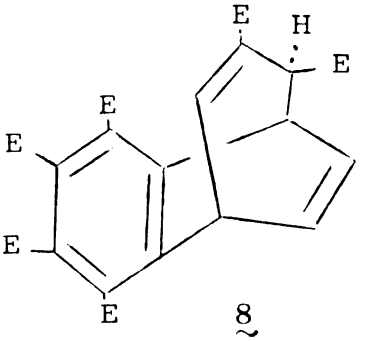
7

E = CO_2CH_3

Redetermination of the mass spectrum and the 100 MHz nmr again confirmed that the compound is a 3:1 adduct of dimethyl acetylenedicarboxylate and 7-methoxycyclohepta-triene (5). The mass spectrum did not give a molecular ion. The highest ion observed was at m/e 516 which corresponds to 7-CH_3OH from the loss of the methoxy group and the adjacent proton from 7. The nmr afforded perhaps the most useful information. The chemical shifts and coupling constants, determined by decoupling, for the individual protons are δ 7.23(d of d,1,$J_{1,4}$ = 8.5 Hz and $J_{1,5}$ = 1.3 Hz, H_1),

6.28(t,1,$J_{2,3}$ = 8 Hz, $J_{2,4}$ = 7 Hz and $J_{2,7}$ = 1 Hz, H_2), 5.90 (t,1,$J_{3,2}$ = 8 Hz, $J_{3,7}$ = 6.5 Hz and $J_{3,4}$ = 1 Hz, H_3), 4.28 (t,1,$J_{4,1}$ = 8.5 Hz, $J_{4,2}$ = 7 Hz and $J_{4,3}$ = 1 Hz, H_4), 3.88 (d of d,1,$J_{5,7}$ = 3 Hz and $J_{5,1}$ = 1.3 Hz, H_5), 3.86(s,1,H_6) and 3.79 ppm (m,1,$J_{7,2}$ = 1 Hz, $J_{7,3}$ = 6.5 Hz and $J_{7,5}$ = 3 Hz, H_7). The ester groups and the methoxy group were found at δ 3.78 (s,9), 3.72 (s,3), 3.71 (s,3), 3.62 (s,3) and 3.30 ppm (s,3). The singlet at 3.78 ppm split into three singlets when the nmr sample was warmed.

Attempted high pressure hydrogenation (PtO catalyst in methanol, 100°, 500 psi of hydrogen, 24 hours) afforded 3,4-dicarbomethoxy-6,7-(2',3',4',5'-tetracarbomethoxy-benzo)-bicyclo[3.2.2]nona-2,6,8-trene (8), formed by the loss of methanol from 7, as the only isolable product.



8

E = CO_2CH_3

Hydrogenation reactions under milder conditions (5% Pd/C, PtO or 5% Rh/C catalyst, atmospheric pressure or 50 psi of hydrogen in methanol) gave no reaction.

Heating 7 above its melting point or treating it with acid also gave 8. The 60 MHz nmr provided the most useful

information available for determining the structure of 8. The chemical shifts and coupling constants for the individual protons are δ 7.43 (d of d,1,$J_{1,4}$ = 9 Hz and $J_{1,6}$ = 1.5 Hz, H_1), 6.70 (t,1,$J_{2,3}$ = 7.5 Hz and $J_{2,4}$ = 7.5 Hz, H_2), 6.23 (t,1,$J_{3,2}$ = 7.5 Hz and $J_{3,6}$ = 7.5 Hz, H_3) and 4.47 ppm (m,2,H_4 and H_5). Proton H_6 is found among the carbomethoxy groups. The ester protons are found at δ 4.02 (s,3), 3.94 (s,3), 3.90 (s,6), 3.77 (s,3), and 3.67 ppm (s,3).

Oxidation of 7 with ruthenium tetroxide or potassium permanganate gave intractable mixtures as might be expected considering the proposed structure of 7.

The attempted bromination of 7 using carbon tetrachloride, N,N-dimethylformamide or ethyl acetate as solvents gave no reaction even after standing for several months at room temperature. Refluxing in carbon tetrachloride still gave no reaction.

The eight possible structures for 7 (not counting enantiomers) are listed in Figure 1. Figure 2 can be used to compare the nmr positions of the individual protons in 7 and 8.

In order to represent all of the structures in Figure 1 it should be noted that the positions of the methoxy group and proton H_6 can be interchanged in 7 as shown in Figure 2. The nmr data for 7 and 8 together with the reactivity data can be used to verify the proposed structure of 7. When methanol is lost from 7 to give 8 the chemical shifts of

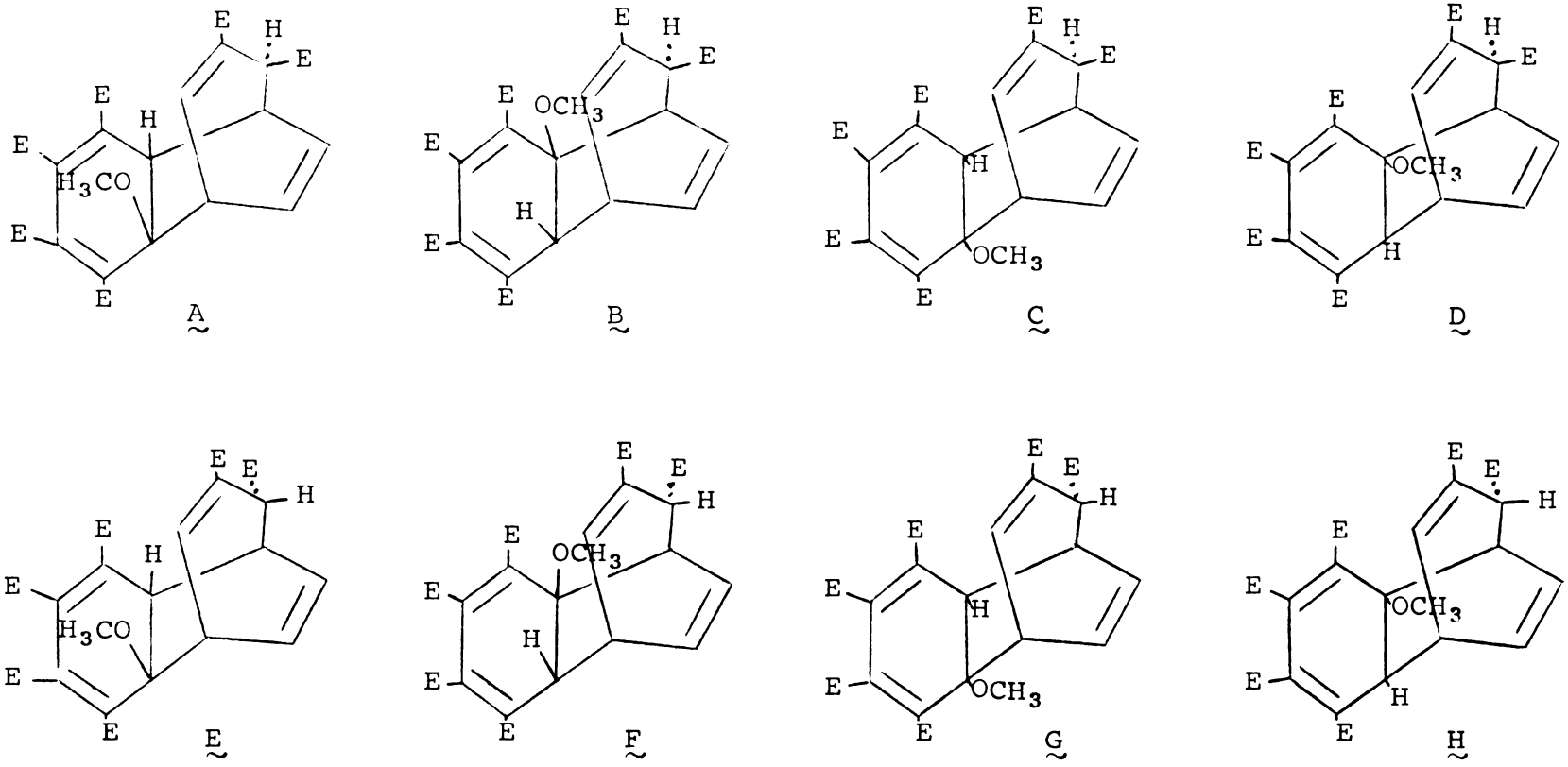
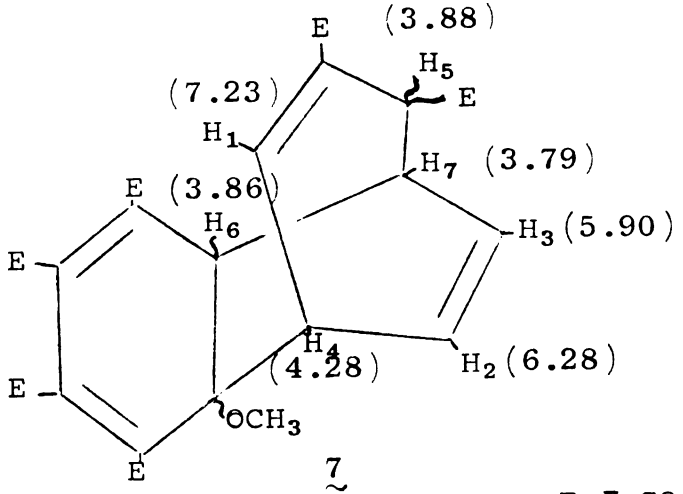
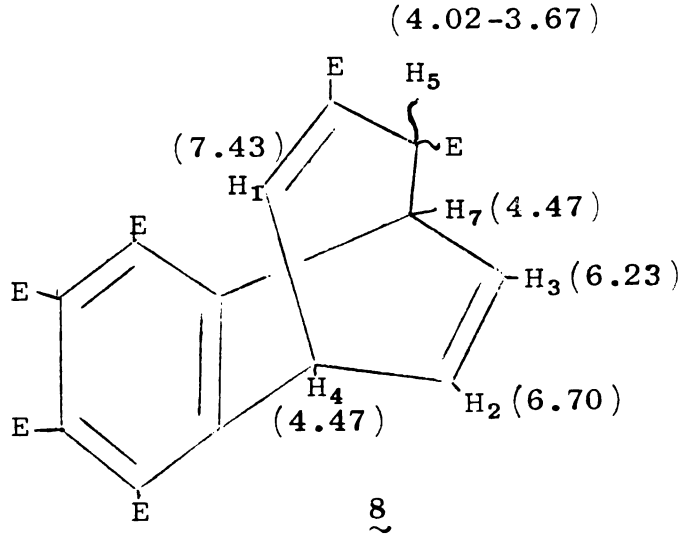


Figure 1. Possible configurations for the 3:1 adduct 7.



7



8

E = CO_2CH_3

Figure 2. Nmr comparisons of compounds 7 and 8.

H_1, H_2, H_3, H_4, and H_7 move downfield 0.20, 0.42, 0.33, 0.19, and 0.68 ppm respectively. The movement of H_5 is uncertain, since H_5 is found among the ester groups in the nmr of 8.

The fact that H_2 and H_3 had a greater chemical shift change than H_1 can be accounted for if the cyclohexadiene ring in 7 faces H_2 and H_3 as in structures A, B, E, and F of Figure 1. The carbon-carbon double bonds would lie above H_2 and H_3 and thus cause some shielding in the nmr. With aromatization the shielding effect would be removed and H_2 and H_3 would indicate some deshielding since they would be found slightly out of the plane of the aromatic ring. Proton H_1 should also indicate the same shielding due to the aromatic ring. The net effect would be a much greater downfield shift of H_2 and H_3 than H_1 in going from the nmr of 7 to 8.

The lack of reactivity of 7 toward hydrogenation and bromination would also support the fact that the carbon-carbon double bond between H_2 and H_3 is covered on at least one side by a very bulky group such as the cyclohexadiene ring and its four ester groups.

Proton H_7 shows a much greater downfield chemical shift change than H_4 between 7 and 8. If the methoxy group is adjacent to H_4 as in structures A, C, E, and G in Figure 1, then the chemical shift difference between having an adjacent methoxy group and an adjacent aromatic ring would be much smaller than the difference between an adjacent

tertiary hydrogen and an aromatic ring. Proton H_7 would thus show a much greater shift change than H_4.

Both H_6 and H_7 are allylic and adjacent to an ester group. Proton H_6, however, is also adjacent to a methoxy group and should be expected to be found further downfield in the nmr of $\underset{\sim}{7}$ than H_7 which it is. Also when a model of $\underset{\sim}{7}$ is built, the dihedral angle between H_6 and H_7 is nearly 90^0 when the cyclohexadiene ring faces H_2 and H_3. This should result in a coupling constant close to zero between H_6 and H_7 as has been observed in the spectrum.

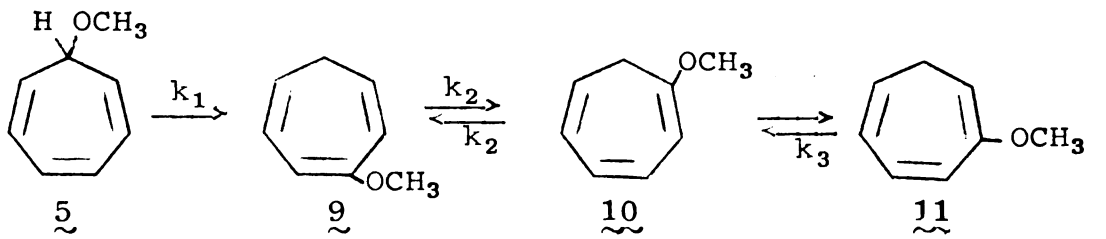
Finally the shift change of H_5 was uncertain. If H_5 lies above the aromatic ring in $\underset{\sim}{8}$ then it should be shielded and the resultant chemical shift change from the spectrum of $\underset{\sim}{7}$ should move the position of H_5 further upfield among the ester groups. If the ester group lies above the aromatic ring, however, then H_5 would lie to the side of the aromatic ring and should have a downfield chemical shift change at least as large as that found for H_1, since it would be found at almost the same distance from the ring and from the plane of the ring as H_1. This would make H_5 visible in the nmr of $\underset{\sim}{8}$. This is not the case so H_5 must lie above the ring. Since the ester group would then lie above the carbon-carbon double bond between H_2 and H_3, it would be expected to make the double bond even less reactive. Being hindered on both sides the double bond might be expected to be extremely unreactive toward bromination and hydrogenation as was observed.

Structure A in Figure 1 is the only structure that agrees with all of the observed data and should, therefore, be the correct configuration of 7.

No other possible structures have been found that fit the analytical data as well as the proposed structure for 7.

The remainder of this paper will be used to discuss a possible mechanism to obtain the 3:1 adduct 7 from 5. The 3:1 adduct 7 was first formed by heating 5 and dimethyl acetylenedicarboxylate in xylene at 140°-145° for 24 hours,[4] and is obtained in a 6 percent yield as a white crystalline solid. It is also obtained when the reaction is run in the dark, suggesting no photochemical process is involved.

At 150° 5 is converted by a rapid (k_1 = 4.4 x 10^{-4} sec^{-1}), nonreversible, transannular 1,5-hydrogen migration to 3-methoxycycloheptatriene (9).[5,6]



5 9 10 11

A slower (k_2 = 3 x 10^{-5} sec^{-1}), reversible (K_2 = 10) isomerization then converts 9 to 1-methoxycycloheptatriene (10).[5,6]

Another even slower, reversible (K_3 = 0.01) isomerization converts 10 to 2-methoxycycloheptatriene (11).[5,6]

In 24 hours at 140° 5 should be completely converted to 9 and would also be expected to isomerize considerably

to 10, but very little if any of 11 should be formed in this time, so it would not be expected to be an intermediate in the formation of 7.

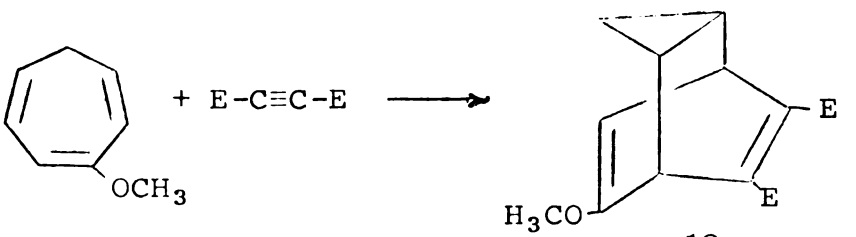
A sample of 9 was prepared,[5,6] and reacted with dimethyl acetylenedicarboxylate in xylene at 140°. The starting material was gone in one hour and the reaction was stopped and worked up. The 3:1 adduct 7 was obtained in a 10 percent yield.

A sample containing 45 percent of 9 and 55 percent of 10 was also prepared [5,6] and reacted with dimethyl acetylenedicarboxylate in xylene at 140° for one hour as above. The 3:1 adduct 7 was again obtained but only in a 3 percent yield. If 10 had been an intermediate in the formation of 7 then an enriched sample of 10 should have given a much greater yield of 7 than would be obtained when starting with 5 or 9. Compound 10 should not, therefore, be an intermediate in the formation of 7. Since 9 is formed nonreversibly from 5, then 9 must be an intermediate in the formation of 7.

It should be noted that 9 has a pair of geminal protons and 7 does not. The remainder of the reaction pathway must then involve at least one hydrogen migration.

Cycloheptatrienes normally yield substituted tricyclo-[3.2.2.$0^{2,4}$]nona-6,8-dienes as a major reaction product from their thermal addition to dimethyl acetylenedicarboxylate. In this case one would expect to obtain 6,7-dicarbomethoxy-8-methoxy-tricyclo[3.2.2.$0^{2,4}$]nona-6,8-diene (12) as the major product from the reaction of 9 with

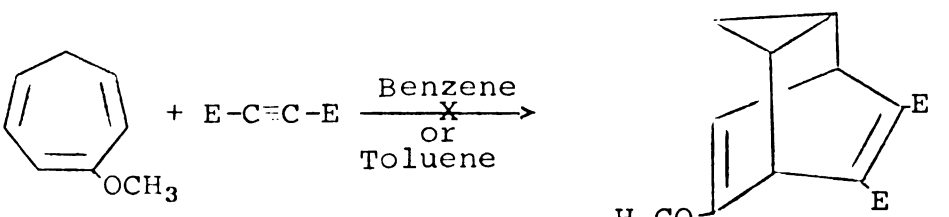
dimethyl acetylenedicarboxylate. No evidence of this compound was found in the reaction mixture, however.



9 E = CO_2CH_3 12

Attempts to prepare 12 in order to prove that it is an intermediate in the formation of 7 all proved unsuccessful, but are briefly described below.

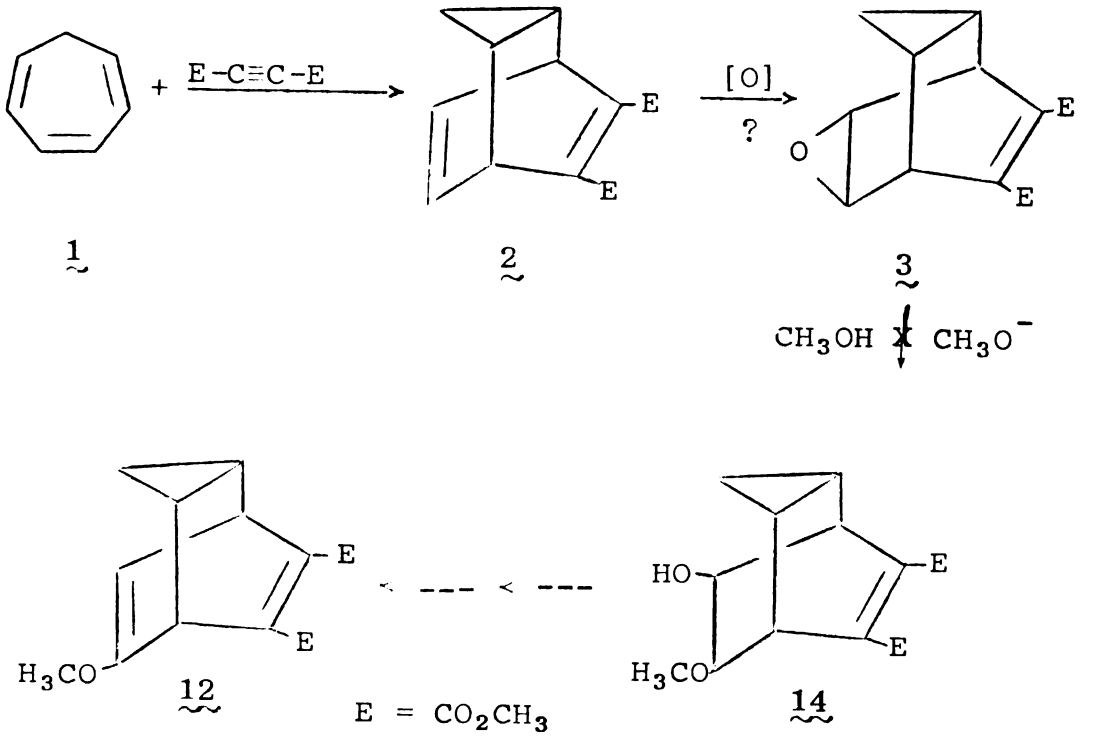
The reaction of 9 with dimethyl acetylenedicarboxylate in refluxing benzene or toluene gave very little reaction even after several days and showed no indication of the desired product. The reaction products were not identified.



9 E = CO_2CH_3 12

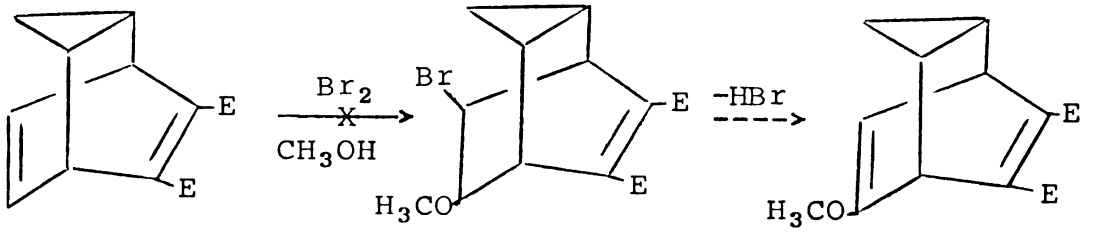
6,7-Dicarbomethoxy-tricyclo[3.2.2.$0^{2,4}$]nona-6,8-diene (2) was prepared[1] from cycloheptatriene (1) and dimethyl acetylenedicarboxylate. It was then oxidized with 40 percent peracetic acid in an attempt to prepare

8,9-epoxy-6,7-dicarbomethoxy-tricyclo[3.2.2.$0^{2,4}$]nona-6-ene (13). The structure of the crude reaction product could not be verified. This crude product was reacted with sodium



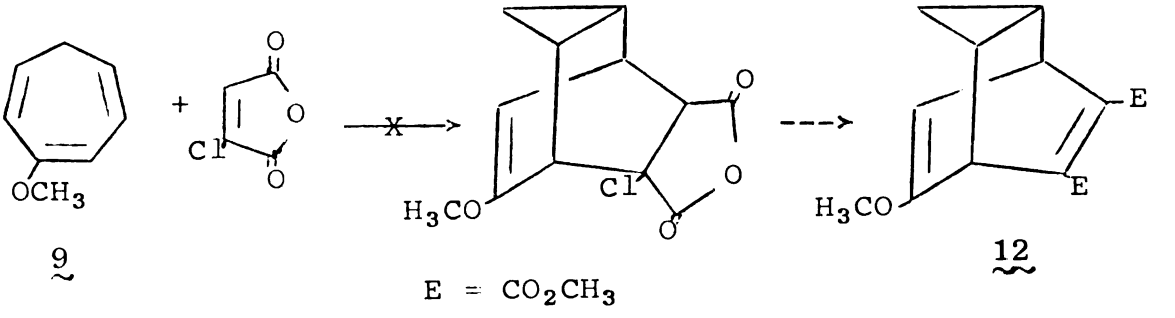
methoxide in refluxing methanol in an attempt to prepare 6,7-dicarbomethoxy-8-hydroxy-9-methoxy-tricyclo[3.2.2.$0^{2,4}$]-nona-6-ene (14) but no reaction occurred.

Since bromo-methoxy compounds can be formed by bromination of a carbon-carbon double bond in methanol, this was tried with 2, but a bad mixture resulted and none of the products could be isolated or identified.



2 12

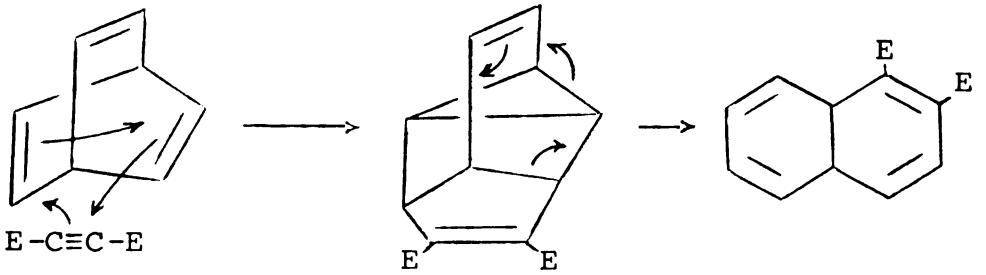
Finally attempts were made to react 9 with chloromaleic anhydride in refluxing xylene. A black, tarry mixture resulted from which none of the products were identified.



9 12

Even though 12 could not be prepared it is still assumed to be an intermediate in the formation of 7.

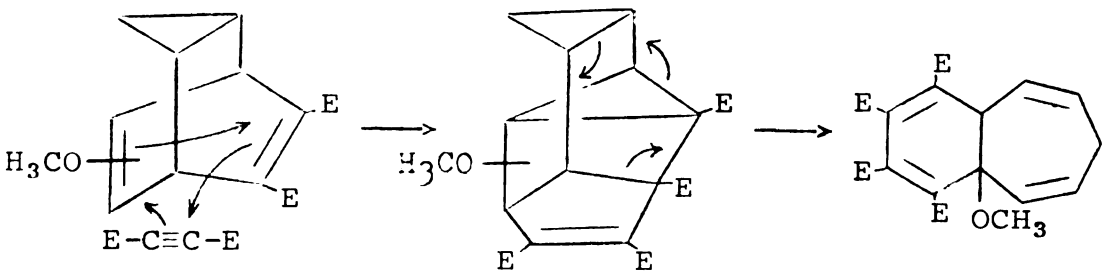
Dimethyl acetylenedicarboxylate has been reported to react with bicyclo[2.2.2.]octa-2,5,7-triene (barrelene) (15) to yield 7,8-dicarbomethoxy-tetracyclo[4.4.0.$0^{2,10}$.$0^{5,9}$]-deca-3,7-diene (16). With continued heating 16 will rearrange to 1,2-dicarbomethoxy-dehydronaphthylene (17).[7]



15 16 17

E = CO_2CH_3

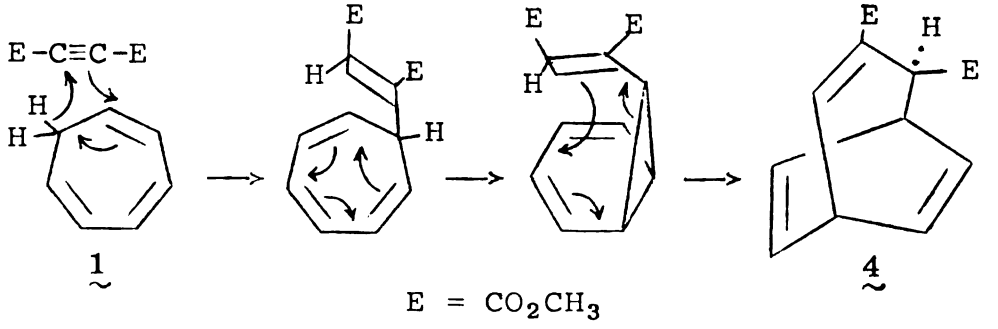
If 12 reacted similarly it would yield a 2:1 adduct, 1(7)-methoxy-8,9,10,11-tetracarbomethoxy-pentacyclo[5.4.0.$0^{2,11}$.$0^{3,5}$.$0^{6,10}$]undeca-8-ene (18). This 2:1 adduct 18 could then rearrange in a similar manner to 1-methoxy-8,9,10,11-tetracarbomethoxy-bicyclo[5.4.0]undeca-2,5,8,10-tetraene (19).



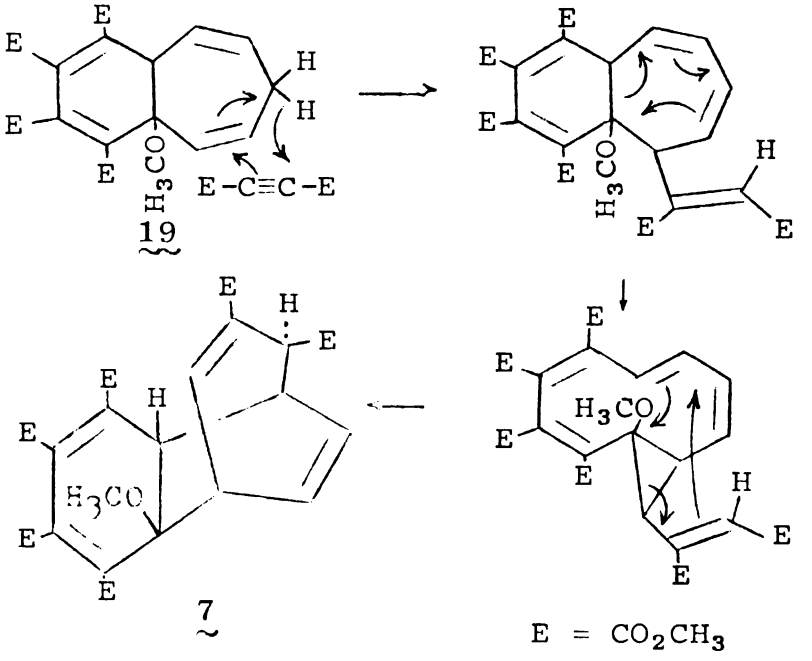
12 18 19

E = CO_2CH_3

If the mechanism proposed by Goldstein[3] for the preparation of 3,4-dicarbomethoxy-bicyclo[3.2.2]nona-2,6,8-triene (4) from 1 and dimethyl acetylenedicarboxylate is applied



to 19 then the 3:1 adduct 7 would result. It should be noted that this final sequence also contains a hydrogen



migration which was found necessary earlier in the paper.

The entire proposed mechanism is given in Figure 3.

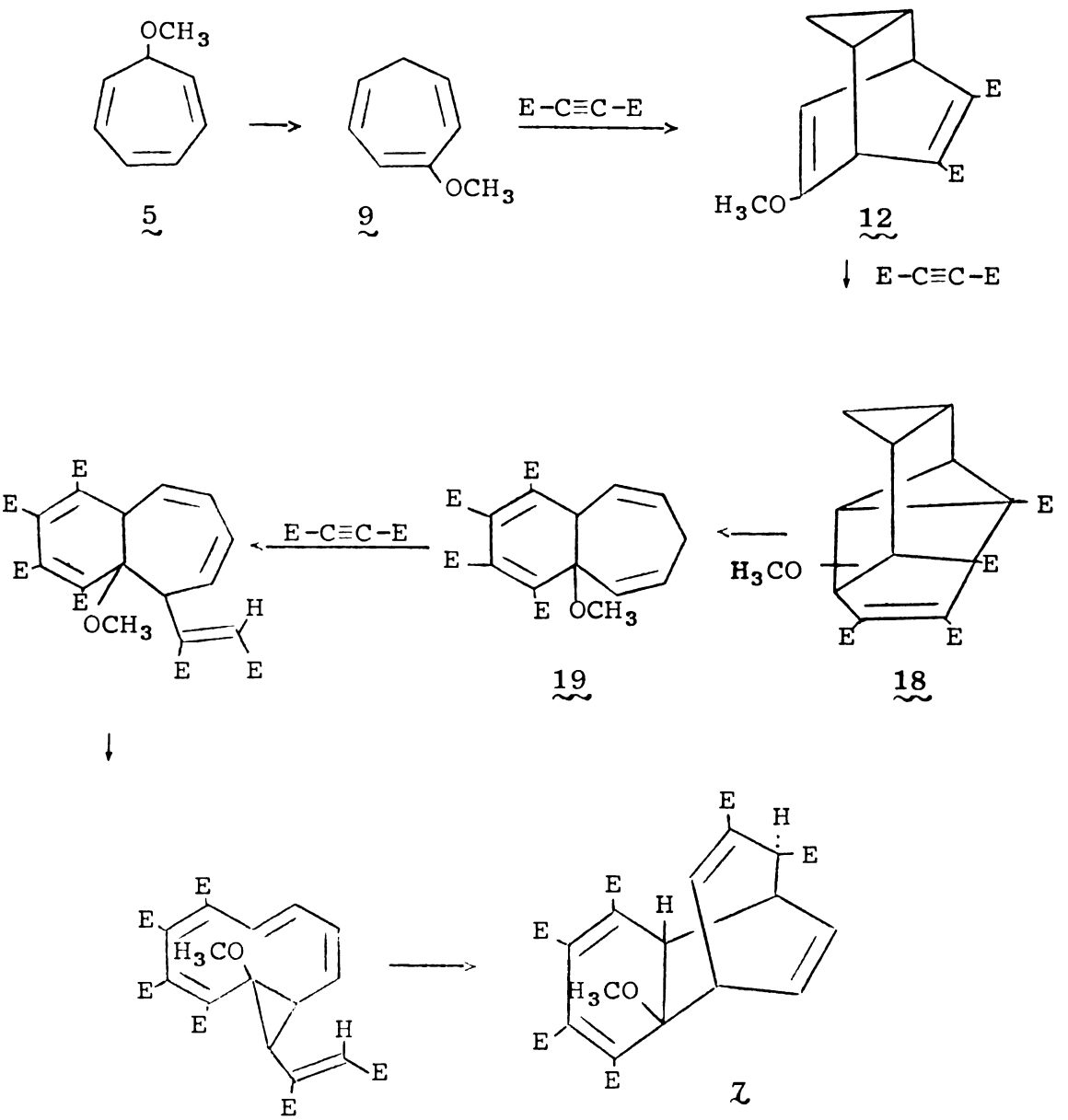


Figure 3. Proposed mechanism for formation of 7 from 5.

EXPERIMENTAL

General Procedures

Nmr spectra were run on Varian A-60 or T-60 spectrometers. Dr. M. Gross of Michigan State University did decoupling and variable temperature nmr experiments on 7. Dr. R. T. Iwamasa of the Chemical Physics Research Laboratory of the Dow Chemical Company redetermined the coupling constants of 7 and confirmed the proposed structure of 7 by using the shift reagent $Eu(fod)_3$. Mass spectral analysis of 7 was determined by J. H. Mark of the Chemical Physics Research Laboratory of the Dow Chemical Company.

Elemental and ultraviolet analyses were determined by the Analytical Laboratory of the Dow Chemical Company.

Infrared spectra were obtained on an Infracord^R or Perkin Elmer Model 237 spectrometer.

Gas Chromatography was carried out on an F & M Model 500 gas chromatograph with a 2' x 1/4" ID glass column packed with 5% DC-410 on Gas Crom Q, 60-80 mesh, helium carrier (40 ml/min), programmed at 50-300^0 at 11^0 per minute.

Thin layer chromatography was carried out on Brinkman Instruments F-254, 5 x 20 cm silica gel covered glass plates

eluted with chloroform and acetone (v/v 19:1) except where the solvent system is stated to be different.

7-Methoxycycloheptatriene (5)

7-Methoxycycloheptatriene (5) was prepared by the method of Dauben.[8,9] Starting with 70 g of cycloheptatriene, 50 g of 5 (49%) was obtained: b.p. 45-6° (4.5 mm); nmr (neat) δ 6.53 (t, 2, J = 3.5 Hz), 6.03 (m, 2), 5.37 (d of d, 2, J = 3.5 Hz and J = 10 Hz), 3.28 (s, 3, $-OCH_3$) and 3.23 ppm (m, 1).

3,4,5,6,10,11-Hexacarbomethoxy-7-methoxy-tricyclo[6.3.2.$0^{2,7}$]-trideca-3,5,9,12-tetraene (7); 3:1 adduct 7

7-Methoxycycloheptatriene[8] (7 g, 57.4 mmol) and dimethyl acetylenedicarboxylate (28.4 g, 200 mmol) were dissolved in xylene (75 ml) and heated at 140-145° for 24 hours. The resulting dark solution was mixed with hexane. The hexane was decanted and the remaining oily residue was triturated with methanol to give 7 as a white crystalline solid; 1.2 g, 3.8%; mp 222-223°; uv max (CH_3OH) 234 mμ (ε = 10750), 305 mμ (ε = 500); ir ($CHCl_3$) 3.3 (C-H), 5.87 (C=O), 6.02 (C=C), 6.23 (C=C), 7.7 and 7.85 μ; ms m/e 516; nmr ($CDCl_3$) δ 7.23 (d of d, 1, $J_{1,4}$ = 8.5 Hz and $J_{1,5}$ = 1.3 Hz, CH = C, H_1), 6.28 (t, 1, $J_{2,3}$ = 8 Hz, $J_{2,4}$ = 7 Hz and $J_{2,7}$ = 1 Hz, CH = C, H_2), 5.90 (t, 1, $J_{3,2}$ = 8 Hz, $J_{3,7}$ = 6.5 Hz and $J_{3,4}$ = 1 Hz, CH = C, H_3), 4.28 (t, 1, $J_{4,1}$ = 8.5 Hz, $J_{4,2}$ = 7 Hz and $J_{4,3}$ = 1 Hz, bridgehead, H_4), 3.88

(d of d, 1, $J_{5,7}$ = 3 Hz and $J_{1,5}$ = 1.3 Hz, $CHCO_2CH_3$, H_5), 3.86 (s, 1, bridgehead, H_6), 3.79 (m, 1, $J_{7,2}$ = 1 Hz, $J_{7,3}$ = 6.5 Hz and $J_{7,5}$ = 3 Hz, bridgehead, H_7), 3.78 (s, 9, CO_2CH_3), 3.72 (s, 3, CO_2CH_3), 3.71 (s, 3, CO_2CH_3), 3.62 (s, 3, CO_2CH_3), and 3.30 ppm (s, 3, OCH_3); tlc Rf 0.61.

Anal. Calcd for $C_{26}H_{28}O_{13}$: C, 56.93; H, 5.15.

Found: C, 57.11; H, 5.42.

An additional sample (0.6 g) of 7 was obtained from the methanol mother liquor: mp 214-7°. Total yield 5.7%.

3-Methoxy-cycloheptatriene (9)

The procedure of Nozoe and Takahashi[5] was used to prepare 9. Starting with 5 g of 7-methoxycycloheptatriene, 2 g (40%) of 9 was obtained: bp 86° (33 mm); nmr (neat) δ 6.23-4.90 (m, 5, CH = C), 3.50 (s, 3, OCH_3), and 2.23 ppm (t, 2, J = 6.5 Hz, $-CH_2-$).

Reaction of 3-methoxycycloheptatriene (9) with dimethyl acetylenedicarboxylate

7-Methoxycycloheptatriene (5) (3.5 g, 28.7 mmol) was heated at 150° for 1 hour. Nmr analysis of the peaks at 3.50, 3.57, and 3.35 ppm, respectively, indicated that the product was composed of 11% 10, 84% 9, and 5% 5. A solution of this crude product and dimethyl acetylenedicarboxylate (12.8 g, 90 mmol) in xylene (8 ml) was heated at 140-145° for 1 hour. Gas chromatographic analysis showed that 9 had completely reacted. The reaction solution was mixed

with hexane. The hexane was decanted and the remaining oily residue triturated with methanol to yield 7 as a white crystalline solid; 1.61 g, mp 222-3°, 10.2% yield.

1-Methoxycycloheptatriene (10)

Following the procedure of Nozoe and Takahashi[5] 3-methoxycycloheptatriene (9) (4 g, 32.8 mmol) was heated at 145° for 21 hours. Comparison of the peak areas in the nmr at 2.45 and 2.23 ppm showed that the crude product was composed of 55% 10 and 45% 9. The product was used without further purification.

Reaction of 1-methoxycycloheptatriene (10) with dimethyl acetylenedicarboxylate

1-Methoxycycloheptatriene (10) (15.8 mmol) and dimethyl acetylenedicarboxylate (17 g, 120 mmol) were dissolved in xylene (10 ml) and heated at 140-145° for 1 hour. The reaction solution was cooled and mixed with hexane. The hexane was decanted and the remaining oily residue was triturated with methanol to give 7 as a white crystalline solid; 0.63 g, mp 219-220°, 3.5% yield.

3,4-Dicarbomethoxy-6,7(2',3',4',5'-tetracarbomethoxybenzo)-bicyclo[3.2.2]nona-2,6,8-triene (8)

(A) Attempted high pressure hydrogenation of 7.

The 3:1 adduct 7 (1 g) platinum oxide (0.2 g) and methanol (150 ml) were placed in a stainless steel bomb. This was pressurized to 500 psi with hydrogen and heated

at 100° with rocking for 24 hours. The reaction mixture was filtered and the bomb and filter cake washed well with chloroform and acetone. The solvents were evaporated and the residue crystallized from methanol to yield 8 as a white crystalline solid: 0.5 g; mp 164-5°; tlc, Rf 0.75; uv (CH_3OH) 219 mμ (ϵ = 33,300), 287 mμ (ϵ = 1,450); ir (mull) 5.75 (C=O), 6.05 (C=C), 7.85, 8.05 and 8.2 μ) nmr ($CDCl_3$) δ 7.45 (d of d, 1, $J_{1,5}$ = 1.6 Hz and $J_{1,4}$ = 9 Hz, C<u>H</u>=C, H_1), 6.38 (t, 1, $J_{2,3}$ = 7.5 Hz and $J_{2,4}$ = 7.5 Hz, C<u>H</u>=C, H_2), 5.95 (t, 1, $J_{3,2}$ = 7.5 Hz and $J_{3,5}$ = 7.5 Hz, C<u>H</u>=C, H_3), 4.33 (m, 2, bridgehead protons, H_4 and H_5), 4.00 (s, 3, $CO_2C\underline{H}_3$), 3.93 (s, 3, $CO_2C\underline{H}_3$), 3.87 (s, 6, $CO_2C\underline{H}_3$), 3.77 (s, 3, $CO_2C\underline{H}_3$) and 3.65 ppm (s, 3, CO_2CH_3). The entire ester region integrates for 19 protons so H_6 must be found in this region.

Anal. Calcd for $C_{25}H_{24}O_{12}$: C, 58.14; H, 4.68.

Found: C, 57.93; H, 4.97.

(B) <u>Effect of acid on 7</u>

A xylene solution (20 ml) of 7 (0.3 g), concentrated sulfuric acid (5 drops), and acetic anhydride (3 ml) was allowed to stand at room temperature until tlc analysis indicated that all of 7 had reacted. Sodium bicarbonate was added and the mixture filtered. The cake was rinsed well with chloroform. The solvents were evaporated and the residue crystallized from methanol to give 8 as a white crystalline solid; 0.2 g, mp 164-5°.

(C) Effect of heating 7 above its melting point.

A sample of 7 in a melting point capillary was heated at 300° for a few minutes. The capillary was crushed and the contents extracted with methanol. Tlc analysis corresponded to a mixture of 7 and 8.

Attempted bromination of 7

(A) Bromine (100 µl) was added to solutions of 7 (50 mg) in carbon tetrachloride, N,N-dimethylforamide and ethyl acetate. These solutions were allowed to stand at room temperature for two months. Tlc analysis indicated no reaction in any of the solutions.

(B) A solution of 7 (50 mg) and bromine (0.5 g) in carbon tetrachloride was refluxed for 2 hours. Tlc analysis indicated no reaction.

Attempted hydrogenation of 7

(A) A methanolic (25 ml) solution of 7 (212 mg, 0.386 mmol) and 5% palladium on carbon (100 mg) were mixed in a micro-hydrogenation apparatus at atmospheric pressure for two days. No hydrogen was absorbed and tlc analysis indicated no reaction.

Using platinum oxide or 5% rhodium on carbon catalysts under the same conditions also showed no indication of reaction by tlc analysis.

(B) An ethyl acetate (50 ml) solution of 7 (300 mg), concentrated hydrochloric acid (1 ml), and the mixed catalysts platinum oxide (100 mg), 5% palladium on carbon (100 mg), 5% rhodium on carbon (100 mg) were shaken on a Parr hydrogenation apparatus at 50 psi of hydrogen for five days. Tlc analysis indicated no reaction.

Ruthenium dioxide oxidation of 7

A solution of sodium metaperiodate (590 mg) in water (10 ml) was added to a mixture of 7 (300 mg, 0.548 mmol) and ruthenium dioxide (15 mg) in carbon tetrachloride (10 ml). After the mixture was stirred for one day it was filtered and the aqueous layer extracted with chloroform. The combined organic layers were evaporated and the residue chromatographed through silicic acid (20 gm) eluted with chloroform and acetone (V/V 1:1). The main fraction was eluted as a dark band. The nmr spectrum was very complicated and was not evaluated.

Potassium permanganate oxidation of 7

A solution of potassium permanganate (7 g, 44 mmol) in water (400 ml) was added quickly to an acetone (300 ml) solution of 7 (1 g, 1.82 mmol). The temperature rose from 25° to 40°. In 5 minutes the permanganate had been consumed. Sulfur dioxide was added to give a clear solution to which concentrated hydrochloric acid (5 ml) was added. The solution was extracted with chloroform and the extract

evaporated. The residue was eluted with chloroform through silicic acid (20 g). The first seven 50 ml fractions contained a mixture of four compounds. The eighth fraction was evaporated and the residue dissolved in benzene (50 ml). Hexane (1 l) was quickly added to give a powdery solid: 0.2 g; mp 102-5°; Tlc (CCl_4:CH_3OH, V/V 10:4) Rf 0.33, (EtOAc) Rf 0.64.

The nmr spectrum was very complicated and could not be evaluated.

BIBLIOGRAPHY

BIBLIOGRAPHY

1. J. A. Berson and M. R. Willcott, III, J. Amer. Chem. Soc., 88, 2494 (1966).

2. K. Alder and G. Jacobs, Chem. Ber., 86, 1528 (1953).

3. M. J. Goldstein and A. H. Gevirtz, Tetrahedron Letters, 4413 (1965).

4. J. P. Szendry, Master's Thesis, Michigan State University (1967).

5. T. Nozoe and K. Takahashi, Bull. Chem. Soc. Japan, 38, 665 (1965).

6. E. Weth and A. S. Dreiding, Proc. Chem. Soc. 1964, 59.

7. H. E. Zimmerman and G. L. Grunewald, J. Amer. Chem. Soc. 86, 1434 (1964).

8. A. G. Harrison, L. R. Honnen, H. J. Dauben, F. P. Lossing, J. Amer. Chem. Soc., 82, 5593 (1960).

9. H. J. Dauben, L. R. Honnen, K. M. Harmon, J. Org. Chem., 25, 1442 (1960).

APPENDIX

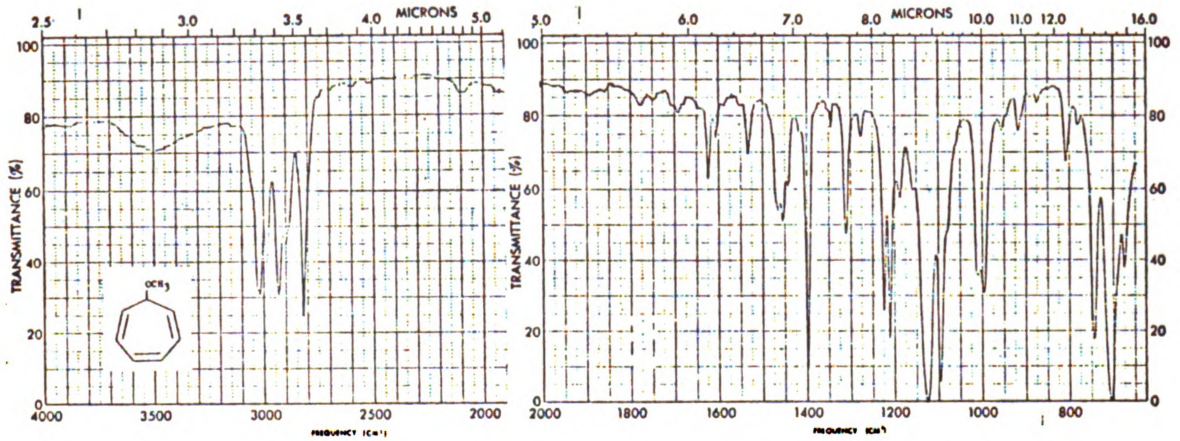


Figure 4. Infrared spectrum of 7-methoxycycloheptatriene (5).

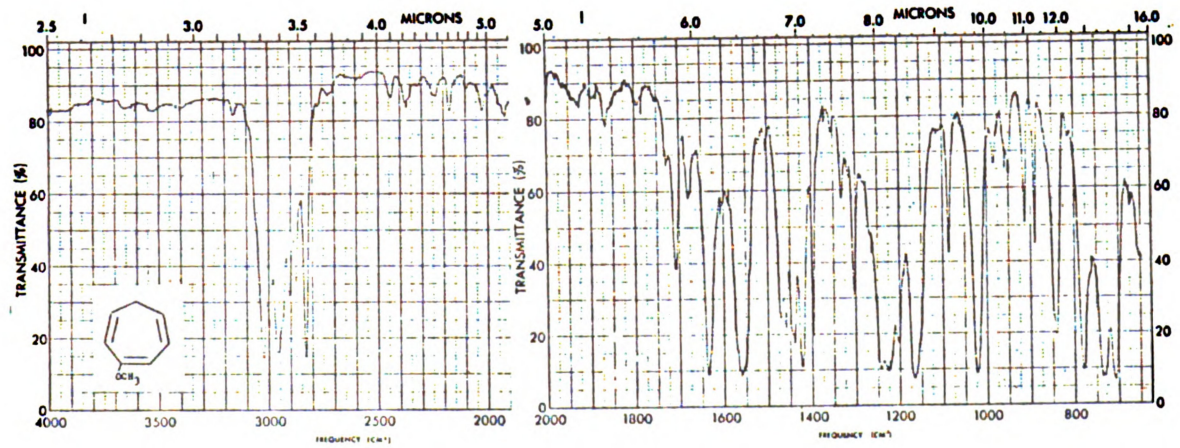


Figure 5. Infrared spectrum of 3-methoxycycloheptatriene (9).

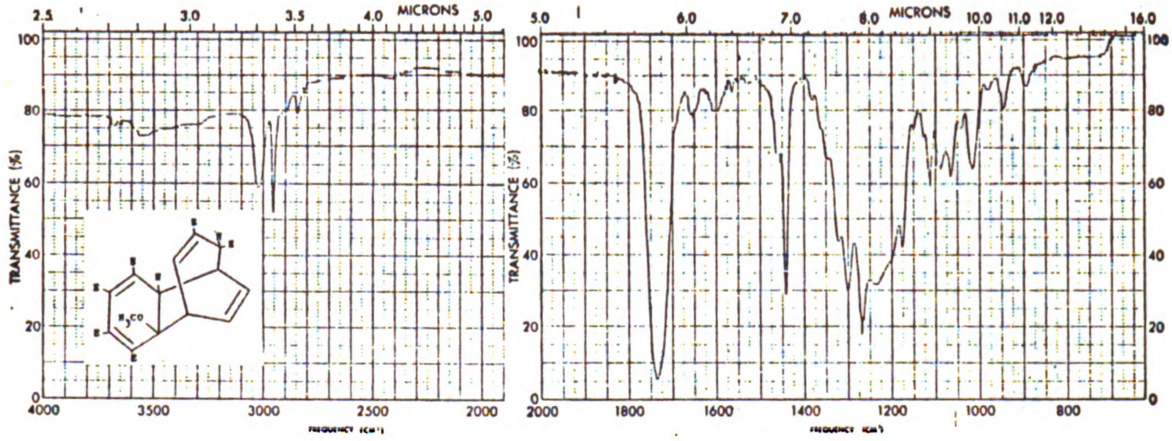


Figure 6. Infrared spectrum of 3:1 adduct 7.

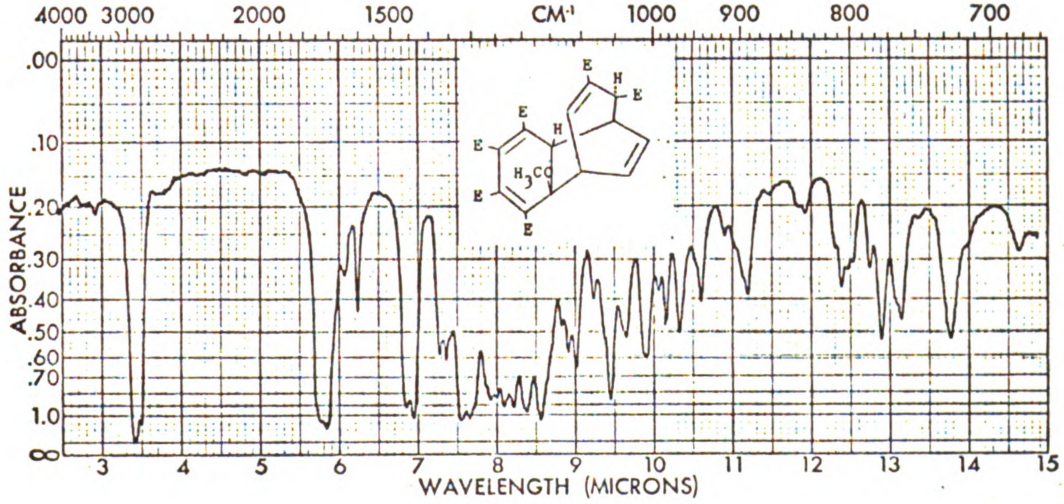


Figure 7. Infrared spectrum of 3:1 adduct 7.

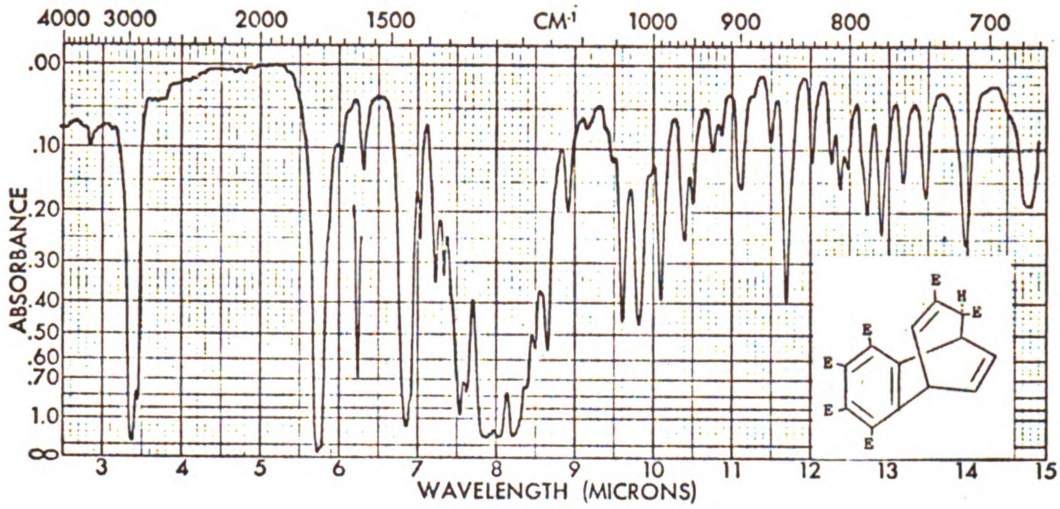


Figure 8. Infrared spectrum of derivative 8.

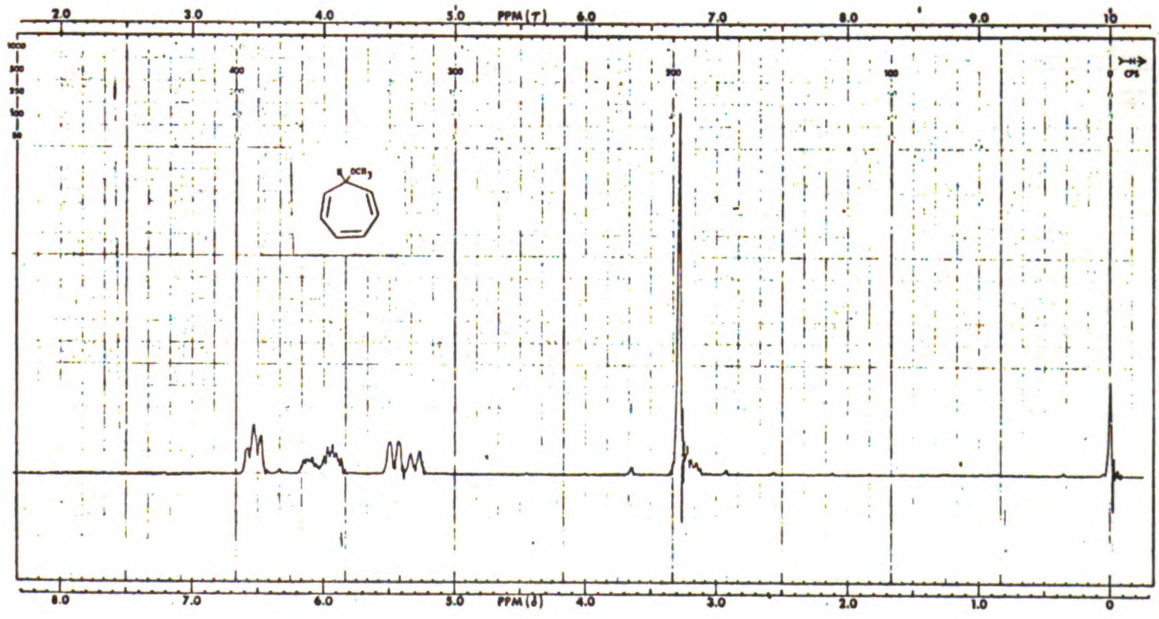


Figure 9. Nmr spectrum of 7-methoxycycloheptatriene (5).

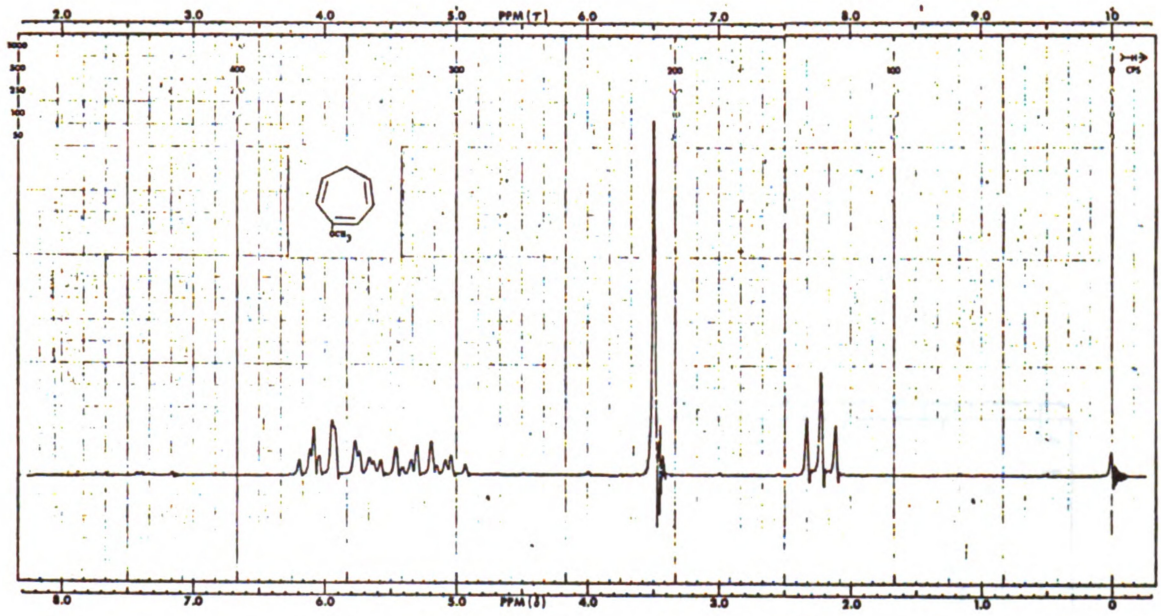


Figure 10. Nmr spectrum of 3-methoxycycloheptatriene (9).

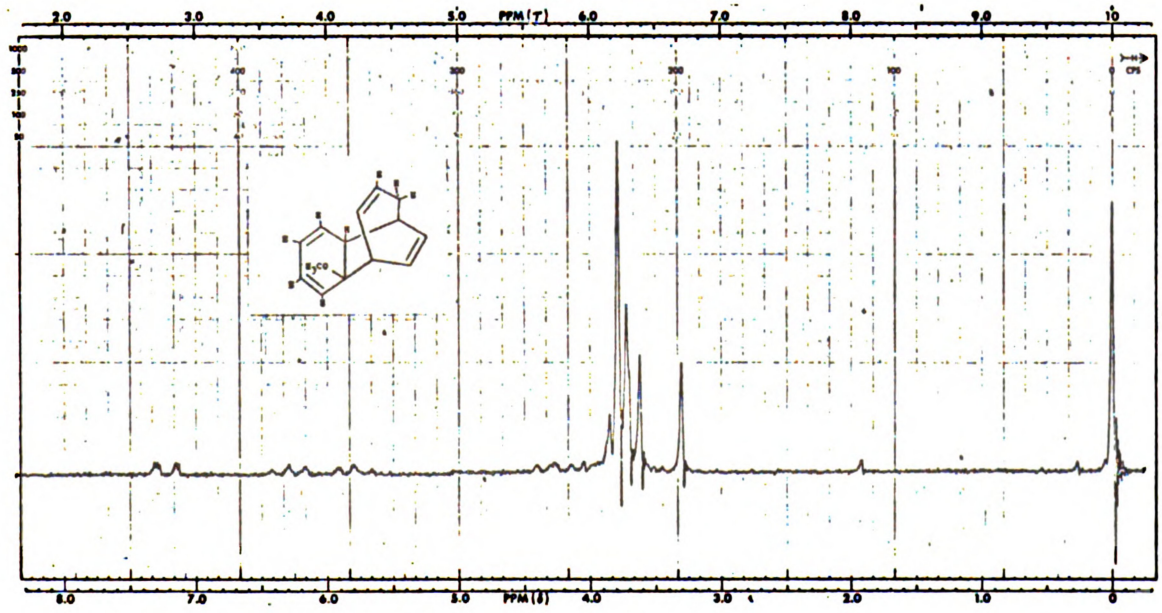


Figure 11. Nmr spectrum of 3:1 adduct 7.

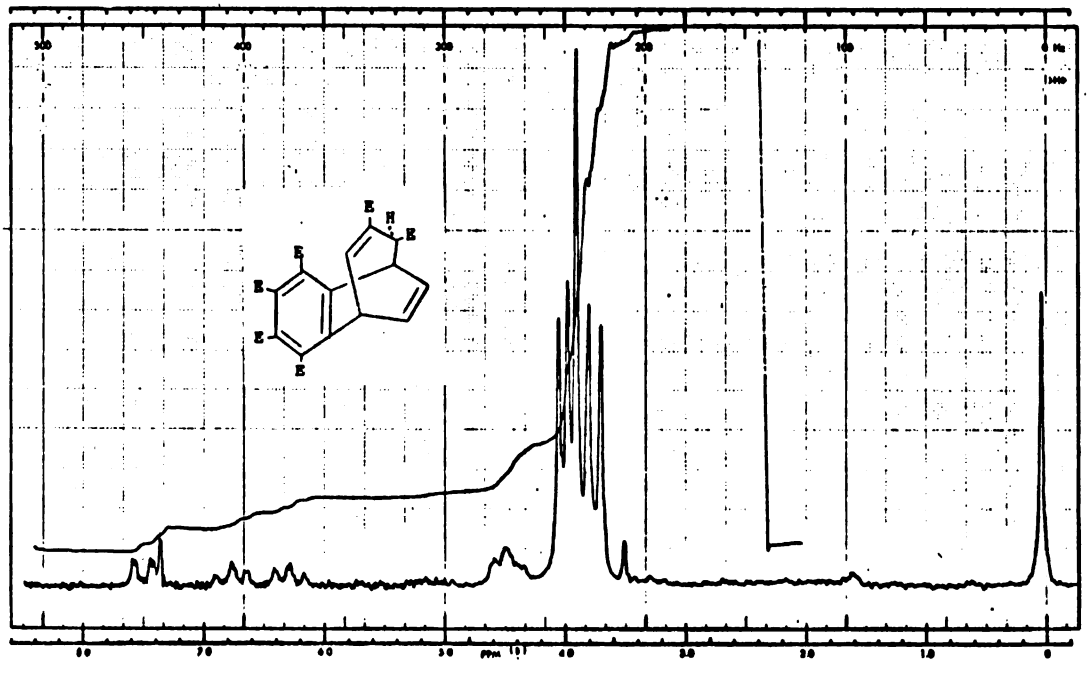


Figure 12. Nmr spectrum of derivative 8.