The Photolysis of Diethyl, 3, 6-Dimethyl-2, 7-Octadienedioate.

by

Thomas Charles Mc Kenzie

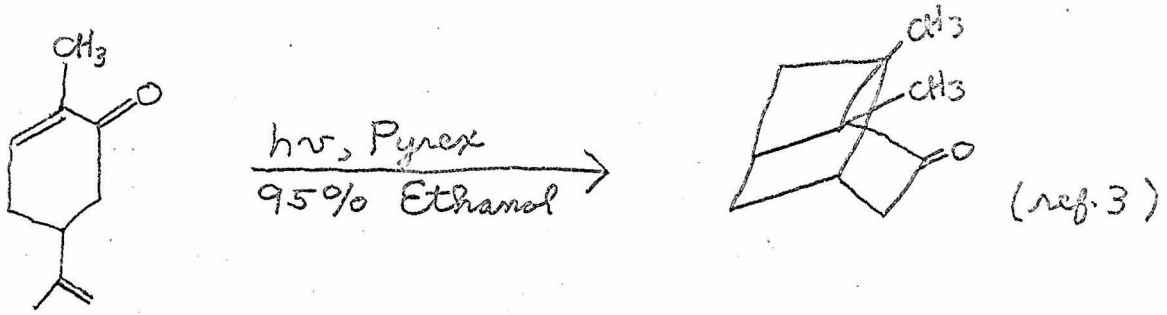
In Partial Fulfillment of the Requirements
For the Degree of
Bachelor of Science

California Institute of Technology
Pasadena, California
May 19, 1967

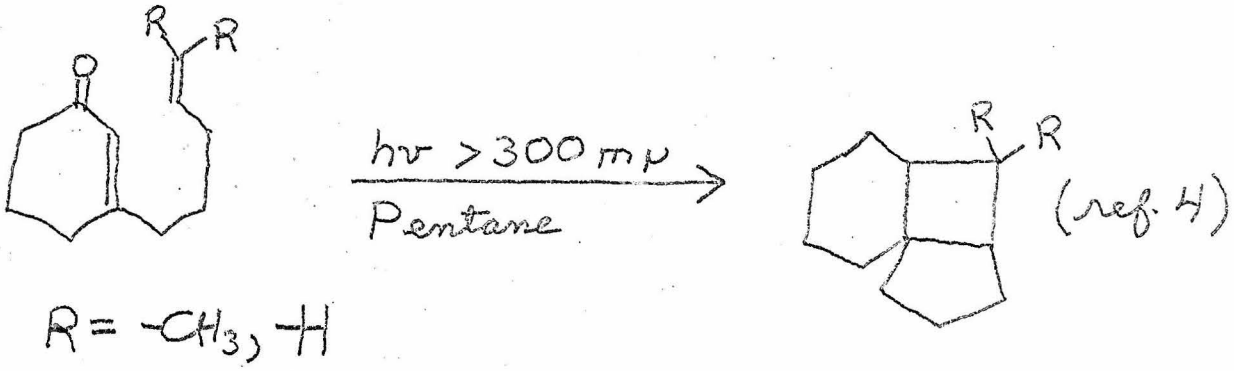
Abstract

The title compound (4) was prepared and photolyzed to give 1, 4 Dimethyl-endo-5, exo-6-dicarboethoxy [2, 1, 1] bicyclohexane (5) exclusively. Compound 5 was characterized by its spectra and the spectra of some of its derivativer.

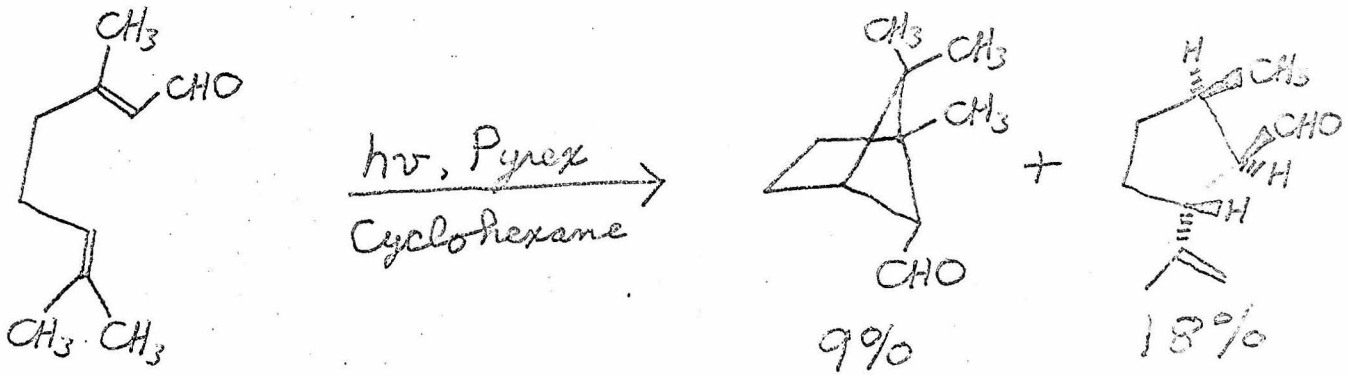
The intermolecular photoaddition of α, β unsaturated carbonyl compounds to carbon-carbon double bonds to form cyclobutane has been found to be a synthetically useful reaction.[1] Intramolecular cycloaddition of non-conjugated olefins is also a fairly well known reaction.[2] Some examples of this type of intramolecular reaction of carbonyl compounds are:



(ref. 3)

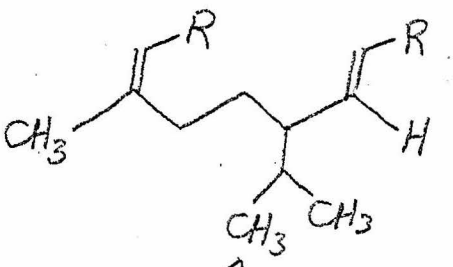


(ref. 4)

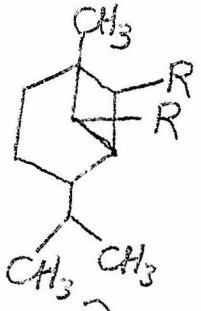


(ref. 5)

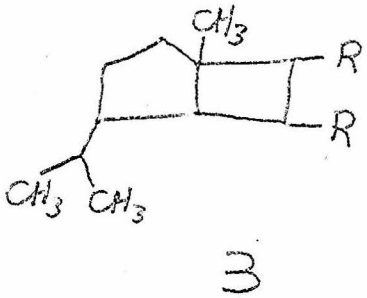
The unsaturated compound 1 was recently prepared with the hope that photolysis would yield the tail-to-head product 2, a useful intermediate for the synthesis of copaene. The head-to-head compound 3, however, was the only product formed by both direct and sensitized irradiation.[6]



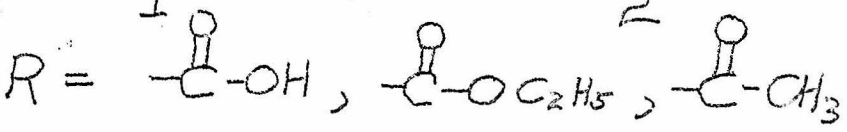
1



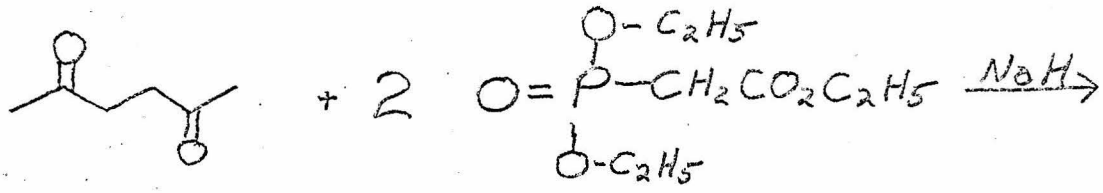
2

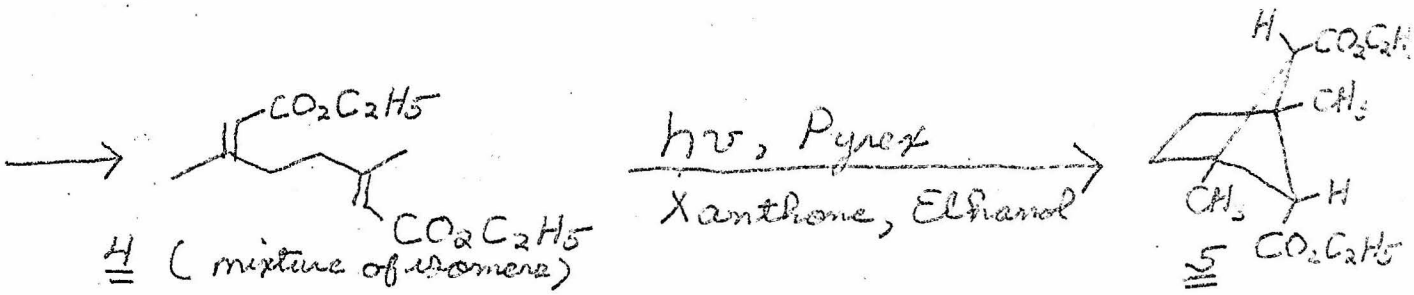


3



To further study this type of intramolecular photoreaction, diethyl, 3, 6-dimethyl-2, 7,-octadiene-dioate (4) was synthesized and irradiated. The diene 4 was prepared by condensing 2, 5-hexanadione with two equivalents of triethyl phosphonoacetate.

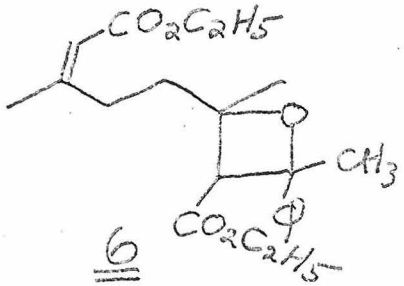




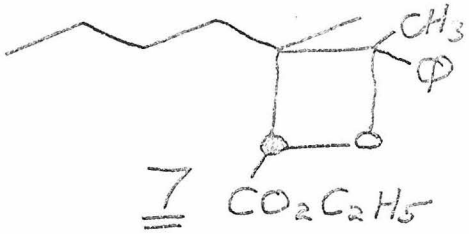
Irradiation of 4 in 95% Ethanol with xanthone sensitizer in Pyrex apparatus yielded 1,4-dimethyl,-

<u>endo</u>-5, <u>exo</u>-6-dicarboethoxy [2, 1, 1] bicyclohexane (5).

Before xanthone (E_t 74.2 kcal/mole)[7] was found to be the sensitizer of choice several other sensitizers were tried. Acetophenone (E_t 73.6 kcal/mole)[7] sensitization produced 5 along with high boiling material which exhibited aromatic protons in the NMR. Presumably the material was the oxetanes 6 and/or 7.



6

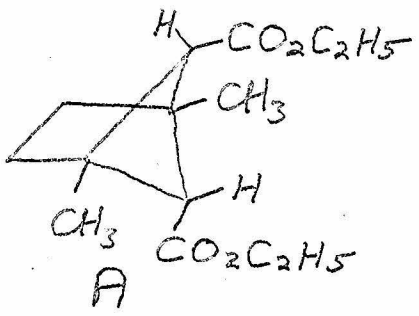


7

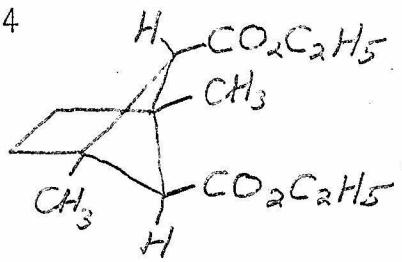
Benzophenone (E_t 68.7 kcal/mole)[7] and dibenzyofuran (E_t 70.1 kcal/mole)[7] sensitization produced only changes in the cis/trans isomer ratios.

The structure 5 was assigned to the photoproduct on the basin of NMR. The spectrum showed absorption for four protons as two overlapping quartets (J = 15, 7 cps) at (δ =) 4.13 and 4.07 (carboethoxy methylene), one proton as a broad singlet at 3.18 (<u>exo</u>-5 proton), one proton as a sharp singlet at 2.02 (<u>endo</u>-6 proton), four protons as a broad multiplet from 1.90 to 1.45 (bridging methylenes), six protons as a triplet (J = 7 cps) at 1.25 (carboethoxy methyls) and six protons as a singlet at 1.28 (bridge head methyls).

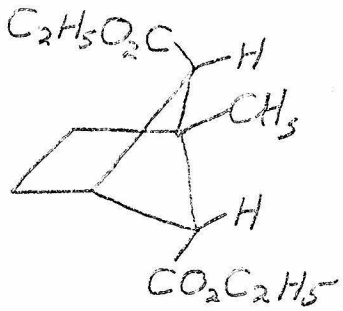
There are six possible structures to consider for the photoproduct (ignoring <u>trans</u> [2, 2, 0] bicyclohexanes): A, B, C, D, E, and F



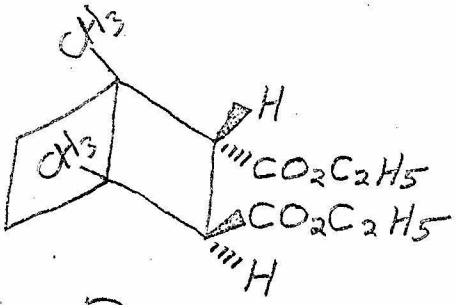
A



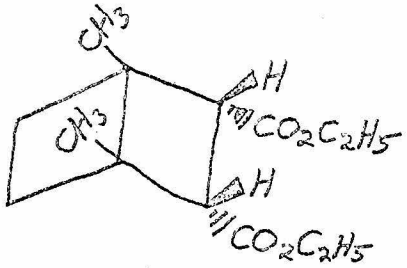
B



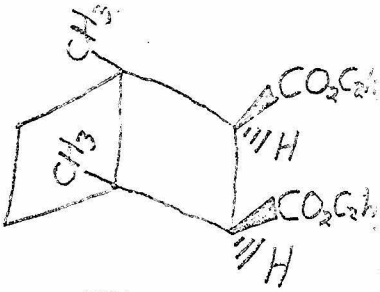
C



D

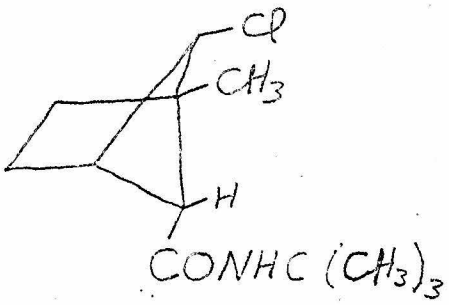


E

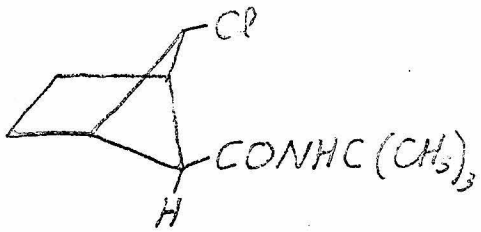


F

Structures B, C, E, and F can be eliminated since there are two different ester signals in the NMR. The two bridge head methyl groups have the same chemical shifts, so structure D is probably eliminated since the two methyls in this molecule are probably in different magnetic environments. Meinwald and Lewis have found the endo-5 amide 8 exhibits absorbtion for the exo-5 proton at 3.57 and the epimeric 9 exhibits absorption at 2.50[8]



8

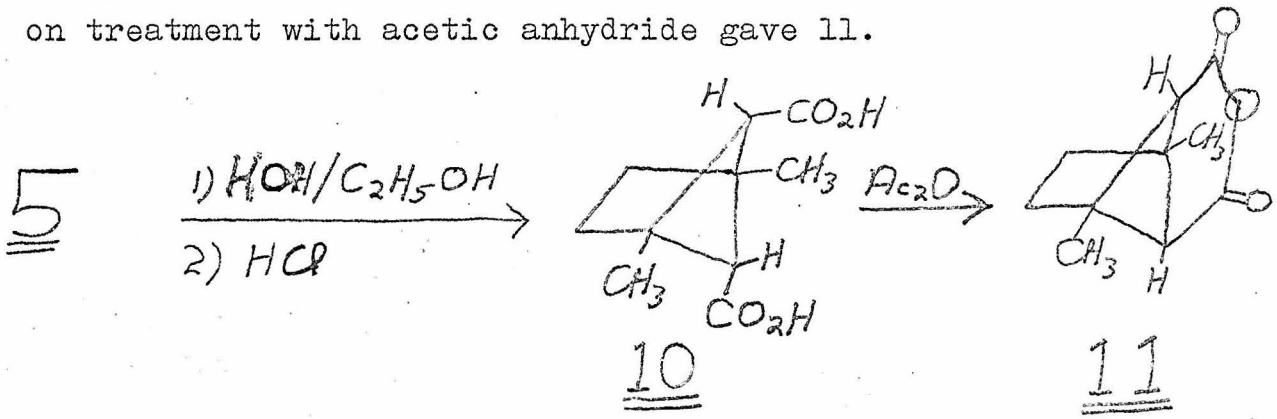


9

These amides show a difference in chemical shift of 1.07 ppm for the exo and endo protons. This compares favorably with the 1.12 ppm difference between endo and exo protons the diester 5.

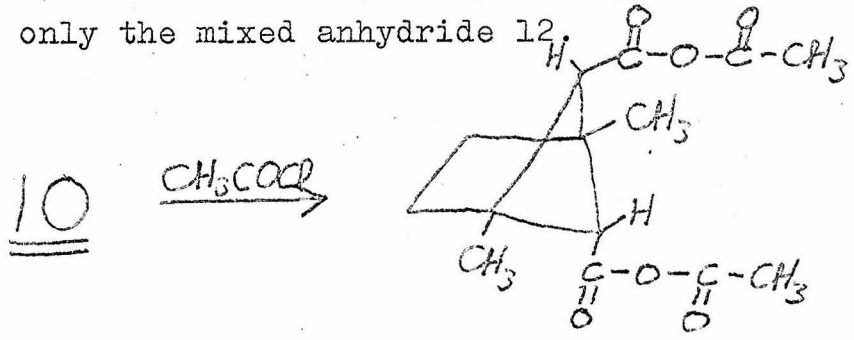
A 100 Mc spectrum of 5 showed the exo-5 proton signal to be a triplet (J = 2.0 cps). Spin decoupling of this proton caused two triplets in the methylene A_2 B_2 multiplet to coalesce into two doublets. The exo-5 proton is presumably coupled to the anti-2, 3 protons.[9]

Confirmation of the assigned structure 5 comes from the infrared spectrum of the cyclic anhydride 11. The photoproduct was saponfied to yield diacid 10 which on treatment with acetic anhydride gave 11.



10 11

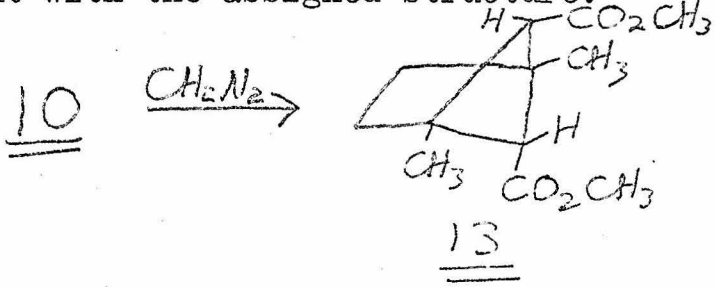
Treatment of 10 with acetyl chloride produced only the mixed anhydride 12.



12

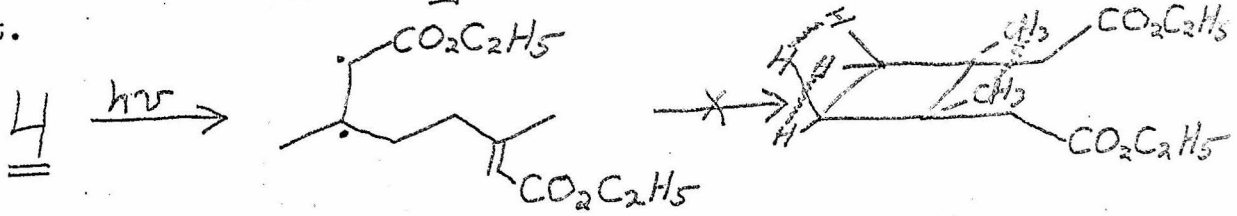
Infrared spectra of 11 exhibited two bands in the carbonyl region, a asymmetric streaching band at 1838 cm^{-1} and a more intense symmetric streaching band at 1754 cm^{-1}. The location and intensities of these bands are indicative of a six member cyclic anhydride.[10]

Treatment of diacid 10 with diazomethane gave the methyl ester 13. The NMR and infrared spectra are consistant with the assigned structure.



13

The proclivity for five member ring formation in intramolecular photoaddition is apparent. The reason for this selectivity in the present case may be due to the strong eclipsing strain that would have to be overcome to form the [2, 2, 0] bicyclohexane head-to-head product.



Experimental Section

The melting point was determined on a Reichart hot stage. Infrared spectra were made with a Perkin-Elmer Infracord 137. Ultraviolet spectra were determined with a Cary 14 recording spectrophotometer. Nuclear magnetic resonance at 60 Mc/sec were obtained

with a Varian A-60A instrument employing carbon tetrachloride as solvent and tetramethylsilane (TMS) as internal standard. The NMR spectrum at 100 Mc/sec was obtained using a Varian HA-100 instrument equipped with spin decoupling accessory in chloroform solution with the assistance of Dr. Morris Brown. Microanalysis were performed by Spang Laboratories.

Diethyl 3, 6-Dimethyl-2, 7-Octadienedioate (4).

In a dry 500 ml, three neck, round bottom flask fitted with reflux condenser, stirrer, and dropping funnel were placed 20.48 gm (0.50 mole) of NaH dispersion (58.6% in mineral oil) and 250 ml of dry dimethoxyethane. In the dropping funnel was placed 112.1 gm (0.50 mole) of triethyl phosphoacetate.[11] The flask was cooled in an ice bath and the phosphate ester added dropwise, under N_2, over a period of three hours to the stirred NaH slurry. When addition was complete 28.53 gm (0.249 mole) of 2, 5 hexadione (distilled) was placed in the funnel. The system was flushed with N_2 and the solution heated to reflux. The diketone was then added to the solution over a period of one hour and the resulting mixture was allowed to reflux an additional 16 hours. The hot solution was cooled and then poured onto 500 gm of ice. The organic phase was removed and the aqueous layer extracted with ether. The combined organic phases were washed with saturated brine and dried over anhydrous sodium sulfate. Distillation gave 26.43 gm bp 85°-90°/0.05 mm, 41.6% yield. The infrared spectrum (film) showed bands at 1715 and 1645 cm^{-1}. The ultraviolet spectrum in 95% ethanol has a maximum at 221 mp (E 21,800). The NMR showed peaks (in δ): broad singlet at 5.58, two protons

(vinyl proton); quartet (J = 14, 7 cps) at 4.02, four protons (carboethoxy methylene); singlet at 2.27, doublet (J = 1.5 cps) at 2.13, doublet (J = 1.5) at 1.87, total ten protons (vinyl methyl and methylene); and a triplet (J = 7 cps) at 1.23, six protons (carboethoxy methyl).

Anal. Calculated for $C_{14}H_{22}O_4$: C 66.12; H 8.17. Found: C 66.26; H 8.55.

1,4 Dimethyl, endo-5, exo-6-Dicarboethoxy [2, 1, 1] Bicyclohexane (5).

In a cyclindrical Pyrex irradiation apparatus having a neck for addition and sampling and a water-cooled well for the lamp were placed 12.50 gm (47.0 mmole) of diester 4, 0.730 gm xanthone,[12] and 125 ml 95% ethanol. The solution was irradiated with a 450 Watt, high pressure, Hanovia mercury arc lamp for 94 hours. Fractional distillation gave 4.73 gm of a colorless oil (b.p. 84-85°/0.2 mm). Much tar was left in the pot. The product contained mainly bicyclic compound 5 but also 40% of the starting material. (Analytical vpc on 20% silicone oil 4 ft. at 200°). This was separated by preparative VPC on a 20% Carbowax 20M on Chromosorb-P column (8 ft.) at 210°. The infrared (film) showed a single band at 1733 cm^{-1}. The NMR showed peaks: two overlaping quartets (J = 15, 7 cps) at 4.13 and 4.07, four protons (carboethoxy methylene); broad singlet at 3.18, one proton (exo-5 proton); sharp singlet at 2.02, one proton (endo-6 proton); multiplet from 1.90 to 1.45, four protons (bridging methylene); triplet (J = 7 cps) at 1.25, six protons (carboethoxy methyl); and a singlet at 1.28 six protons, (bridge head methyl).

Anal. Calculated for C_{14} H_{22} O_4: C 66.12; H 8.17. Found C_____; H_____.

1,4 Dimethyl [2, 1, 1] Bicyclohexane-5, 6-Dicarboxylic Acid (10).

In a 25 ml round bottom flask, fitted with reflux condenser, was placed 400 mg (1.56 mmole) of the bicyclic ester 5 and 25 ml of 0.5 M KOH in absolute ethanol. After refluxing 22 hours under N_2 the solution was cooled and mixed with 25 ml water. The solution was extracted with ether. The remaining aqueous phase was acidified with 1 M HCl and extracted with methylene chloride. The methylene chloride solution was washed with saturated brine and dried over anhydrous magnesium sulfate. The solvent was removed under reduced pressure. The crude acid was crystalized from acetonitrile to give 140 mg, 45.0% yield. Crystalization from benzene-acetone, and recrystalization from acetonitrile followed by sublimation gave an analytical sample mp. 213-214°C. The infrared(K B_r)showed a broad band at 2950 cm^{-1} and a sharper band at 1689 cm^{-1}.

Anal. Calculated for C_{10} H_{14} O_4: C 60.59; H 7.12. Found: C 60.71; H 7.08.

1,4 Dimethyl [2, 1, 1] Bicyclohexane-5, 6-Dicarboxylic Anhydride (11).

In a 5 ml round bottom flask fitted with reflux condenser and drying tube was placed 40 mg (0.202 mmole) diacid 10 and 3 ml acetic anhydride (distilled). The mixture was stirred magnetically and refluxed 22 hours. The excess acetic anhydride was then removed under reduced pressure. The anhydride 11 was tube distilled to give 20 mg 55.0% yield, furnace temperature 80°/0.3 mm.

The infrared (film) showed a weak band at 1838 cm^{-1} and a strong band at 1754 cm^{-1}.

Anal. Calculated for $C_{10} H_{12} O_3$: C 66.65; H 6.71. Found C_____; H_____.

1,4 Dimethyl [2, 1, 1] Bicyclohexane-endo-5, exo-6-Dicarboxylic bis Acetic Anhydride (12).

In a 10 ml round bottom flask fitted with reflux condenser and drying tube was placed 127.5 mg (0.643 mmole) diacid 10 and 4 ml acetyl chloride (distilled). The mixture was stirred magnetically and refluxed for 28 hours. The reaction mixture was then cooled and the excess acetyl chloride removed at reduced pressure. The remaining oil was distilled to give 119.5 mg, (68.8% yield), bp 55-57/0.3 mm.

The infrared (film) showed a strong band at 1792 cm^{-1} and a weaker band at 1724 cm^{-1}. The NMR showed peaks: broad singlet at 3.33, one proton, (exo-5 proton); sharp singlet at 2.70, one proton (endo-5 proton); two overlapping singlets at 1.53 (methyls) superimposed on a multiplet from 2.23 to 1.18 (bridging methylene) total 16 protons.

Anal. Calculated for $C_{14} H_{18} O_6$: C 59.57; H 6.43. Found: C_____; H_____.

1, 4 Dimethyl,-endo-5,-exo-6-dicarbomethoxy [2, 1, 1] Bicyclohexane (13)

Treatment of 157 mg (0.785 mmole) of diacid 10 with etheral diazomethane followed by destruction of excess diazomethane with acetic acid and removal of solvent under reduced pressure gave a colorlen oil. Distillation gave 109 mg, (61.9% yield) bp 54-6°/ 0.06 mm. The infrared (film) showed a band at 1733 cm^{-1}.

The NMR showed peak: two singlets at 3.65 and 3.60, six protons (carbomethoxy); broad singlet at 3.20, one proton (exo-5 proton); sharp singlet at 2.03, one proton (endo-6 proton); multiplet at 1.33 to 1.83, four protons (bridging methylene; and singlet at 1.23, six protons (bridge head methyl).

Anal. Calculated for $C_{12}H_{18}O_4$: C 63.70; H 8.02.
Found: C 63.81; H 8.02.

References Cited

1. a. E. J. Corey, Rajat B. Mitra, and Hisashi Uda, JACS, 86 485 (1964).

   b. Philip E. Eaton, JACS, 84, 2344 (1962).

2. Recently reviewed by Wendell L. Dilling Chem. Rev., 66, 373 (1966).

3. G. Biichi and I. M. Goldman, JACS, 79, 4741 (1957).

4. E. J. Corey and K. Senstanj quoted in Dilling Chem. Rev. (1966).

5. R. C. Cookson, J. Hudec, S. A. Knight, and B. R. D. Whiteas, Tetrahedron, 19, 1995 (1965).

6. Morris Brown, Chem. Comm. 1965, 340.

7. William G. Herkstroeter, Angelo A. Lamola, and George S. Hammond, JACS, 86, 4537 (1964).

8. Jerrold Meinwald and Arthur Lewis JACS, 83, 2769 (1961).

9. Long range coupling in rigid rings requires overlap of orbitals directed 180° away from the carbon-proton bond. See reference 8.

10. Robert T. Conley, "Infrared Spectrorcopy," Allyn and Bacon, Boston, 1966, p. 158.

11. W. S. Wadsworth Jr. and W. D. Emmons, JACS, 83, 1733 (1961).

12. Org. Syn., Col. Vol I, p. 552.