was determined using a deuterium oxide solution of acetonitrile as standard (0.66 ml. of solution containing 30.4 mg. of acetonitrile). A solution of the salt in deuterium oxide (0.66 ml. of solution containing 74.5 mg. of salt) resulted in a singlet of 0.9 ± 0.0 v. due to exchangeable hydrogen and another singlet of 4.5 ± 0.1 v. due to N-methyl. This represents 0.58 ± 0.05 mequiv. of exchangeable hydrogen and 3.7 ± 0.4 mequiv. of hydrogen due to N-methyl. Since the singlet due to N-methyl contains 12 hydrogens, the calculated molecular weight is 242 ± 24 (assuming a monotetramethylammonium salt) and there are 1.9 ± 0.2 exchangeable hydrogens/molecule.

Determination of Ammonia Produced during the Preparation of I from Malononitrile.—A solution of 25.0 g. of freshly distilled malononitrile in 250 ml. of 1 *M* sodium carbonate was allowed to remain at room temperature for 19 hr. A 1-ml. aliquot of the reaction solution was dilu tedwith 2 ml. of 1 *N* hydrochloric acid and further diluted, by a factor of 100, with 0.1 *N* hydrochloric acid for a spectral analysis which showed the concentration of I in the reaction solution to be 0.44 mmole/ml. (87% yield). A 100-ml. portion of the reaction solution was acidified with 20 ml. of concentrated hydrochloric acid and extracted with three 75-ml. portions of ethyl acetate and finally with 75 ml. of ether. The organic extracts were washed with three 30-ml. portions of 0.1 *N* hydrochloric acid. By the procedure described in the first experiment, the tetrapropylammonium salt was isolated from the combined organic extracts in 83% yield (94% of the yield calculated above). The combined acidic aqueous layers were diluted to 250 ml. with water. A 5-ml. aliquot of this solution was treated with 10 ml. of 4 *N* sodium hydroxide and heated on the steam bath while a stream of purified nitrogen was passed through it into 25 ml. of 2% boric acid. The volatile base, collected in the buffer solution, was titrated with standard 0.1 *N* hydrochloric acid using a mixed methylene blue–methyl red indicator. After 165 min., the total volatile base titrated was 0.89 mequiv. Assuming the volatile base to be entirely ammonia (see below) this represents an 86% yield (99% of the yield expected from spectral analysis). In a parallel experiment, the volatile base was trapped in 25 ml. of 0.1 *N* hydrochloric acid. The acidic solution, on treatment with 250 mg. of *p*-(*p*-hydroxyphenylazo)benzenesulfonic acid, yielded 225 mg. of derivative identical with the authentic derivative of ammonia (melting point, mixture melting point, and infrared spectrum). This represents 85% of the titrated volatile base.

Preparation of I from 2-Amino-1,1,3-tricyanopropene (II) and Determination of Ammonia Produced.—A solution of 3.30 g. of II and 1.65 g. of freshly distilled malononitrile in 50 ml. of 1 *M* sodium carbonate was left at room temperature for 19 hr. The following results were obtained on analysis of the reaction solution by the procedures described in the preceding experiment: (a) the concentration of I in the reaction solution was found to be 0.43 mmole/ml. (86% yield) by spectral analysis, and of this 92% was isolated as the tetrapropylammonium salt; (b) the yield of volatile base by titration was 89% of that expected from spectral analysis of which 82% was isolated as the *p*-(*p*-hydroxyphenylazo)benzenesulfonic acid salt of ammonia.

Spectral Analysis of the Reaction Solution during the Preparation of I from Malononitrile.—A solution of 5.050 g. of freshly distilled malononitrile in 50 ml. of 1 *M* sodium carbonate was allowed to remain at room temperature. At intervals, 1 ml. of the solution was diluted to 100 ml. with 0.1 *N* hydrochloric acid (reaction quenched) for determination of the ultraviolet spectrum. The concentration of I in the reaction solution was calculated from the maximum at 358 mμ using ε 30,500; the concentration of 2-amino-1,1,3-tricyanopropene (II) was similarly calculated from the maximum at 272 mμ using ε 15,500. The initial concentration of malononitrile was 1.53 mmoles/ml. The results are summarized in Table I (see also Figure 1).

TABLE I

ANALYSIS OF REACTION SOLUTION DURING PREPARATION OF I

Elapsed time, min.	—Calcd. concn., mmole/ml.— II	I
2	0.145	0.048
4	0.154	0.128
6	0.148	0.197
9	0.116	0.256
12	0.112	0.289
15	0.103	0.322
17	0.095	0.354
34	0.067	0.394
56	0.057	0.417
118	0.046	0.420

Acknowledgment.—We thank Dr. G. Umbriet and associates and F. A. MacKellar of these laboratories for elemental analyses and determination of n.m.r. spectra.

Synthesis of Some 1-Substituted 2,2-Dimethyl-3-isopropylidenecyclopropanes[1a]

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Synthetic routes to compounds with general structure **3** have been examined in the hope of developing a synthesis of **1**, the reported structure for the sex attractant of *Periplaneta americana*. The Bamford–Stevens ring contraction of **9** gave the isopropylidenecyclopropane **10**, but the corresponding tosylhydrazone **6** gave a very complex mixture of products. Diazoacetic ester addition and dibromocarbene addition to tetramethylallene provide access to a variety of 1-substituted 2,2-dimethyl-3-isopropylidenecyclopropanes, whose spectral properties are at variance with those reported for **1**. Several reactions of these compounds are reported, of which the most interesting is the transformation of the allylic cyclopropyl bromide **24** to the allenic ester **25** on treatment with silver propionate.

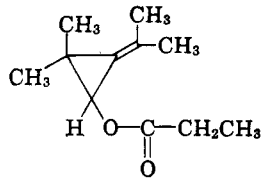
The report of the isolation of a sex attractant from the virgin female American cockroach, *Periplaneta americana* L., and of its identification as 2,2-dimethyl-3-isopropylidenecyclopropyl propionate (**1**)[2] has aroused unusual interest.[3] The estimate that less than 30 molecules (~10^{-20} g.) of this substance is needed to elicit a response in male roaches characterizes it as one of the physiologically most active substances ever described.[4] Although the postulated structure has a superficial similarity to that of pyrethrin I (**2**), a highly

(1) (a) The partial support of this research by the National Institutes of Health (Grant Numbers 5-TI GM-834-03 and E 2908) is gratefully acknowledged. (b) National Science Foundation Postdoctoral Fellow, 1962–1963. (c) National Science Foundation Undergraduate Research Participant, 1963. (d) National Institutes of Health Postdoctoral Fellow, 1963–1964.

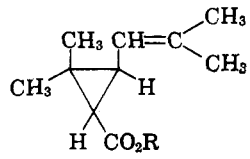
(2) M. Jacobson, M. Beroza, and R. T. Yamamoto, *Science*, **139**, 48 (1963).

(3) *Time*, (Jan. 18, 1963); *Washington Post* (Aug. 18, 1963); *Science*, **140**, 1367 (1963); *Sci. Am.*, **211**, 20 (1964); *New York Times* (Aug. 18, 1963); *Chem. Eng. News*, **41**, 126 (1963).

(4) H. S. Mosher, F. A. Fuhrman, H. D. Buchwald, and H. G. Fischer, *Science*, **144**, 1103 (1964).



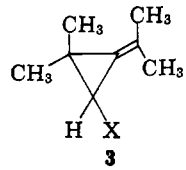
1



2

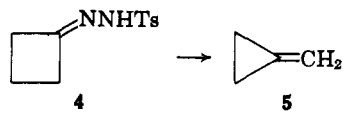
insecticidal component of pyrethrum flower heads,[5] it would be unique among natural product structures in having an isopropylidenecyclopropane nucleus and in being a cyclopropanol ester.[6]

The isolation of this attractant was an extremely arduous task, requiring nine months' continuous "milking" of 10,000 virgin females to obtain only 12.2 mg. of material.[2] It is not surprising, therefore, that only a limited amount of classical structural work could be carried out. Other workers have put forth some serious objections of both a biological and chemical nature to the assignment of structure **1** to the sex attractant.[7] Additional purely chemical considerations (summarized below) led to the conclusion that the derivation of this structure is not on firm ground. Nevertheless, given the great difficulty in isolating the natural product, and the potential intrinsic interest in novel allylic cyclopropyl systems of the general formula **3**, we have explored several syntheses and reactions of this class of compounds. Although **1** itself proved elusive,[8] several interesting properties of isopropylidenecyclopropanes have been encountered. These are now reported in the hope that they may be useful to others interested either in the attractant problem or in small-ring chemistry generally.



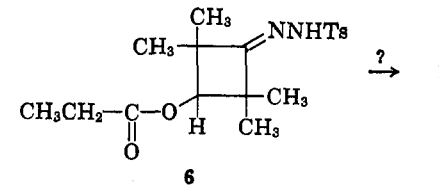
3

Our first scheme for the synthesis of **1** was seductively simple. It involved the application of Friedman and Schechter's discovery that the Bamford–Stevens reaction of cyclobutanone tosylhydrazone (**4**) gives methylenecyclopropane (**5**) as the major product.[9] The



4 5

possibility of realizing the formally analogous transformation of tosylhydrazone **6** into **1** was especially attractive since the required precursor **7** is obtained readily by partial reduction of dimethylketene dimer.[10] The preparation of **6** presented no difficulties. How-



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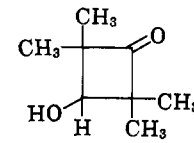
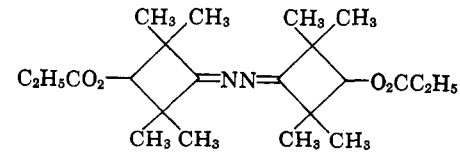


7

ever, the experiments designed to bring about the desired ring contraction, using either thermal[11] or photochemical techniques,[12] gave complex mixtures containing some very unstable components. In a typical experiment, the dry sodium salt of **6** was irradiated in 1,2-dimethoxyethane to give a mixture (b.p. 80–150° at 1.5 mm.) which appeared to have eleven components when subjected to preparative gas chromatography (LAC 446, 100°). Three major peaks whose retention times might possibly be ascribed to **1** were collected. One of these proved to be 3-propionoxy-2,2,4,4-tetramethylcyclobutanone. Another showed three components upon analytical gas chromatography, and, although its infrared spectrum was that of a simple ester (5.78 μ), its p.m.r. spectrum showed it to be a complex mixture. Encouragingly, the remaining fraction showed an infrared spectrum and elementary analysis in accord with expectations for **1**. In addition, this fraction showed a single peak upon analytical gas chromatography. However, the p.m.r. spectrum of this material was more complex than could be anticipated for structure **1** alone. It is possible that this fraction contained the desired product. On the basis of the relative areas corresponding to allylic and normal methyl groups in the p.m.r. spectrum, however, **1** did not appear to be the major constituent of this fraction. Neither this single fraction nor the total crude reaction mixture gave any evidence of physiological activity.[13]

In other experiments in which the total Bamford–Stevens product was examined before distillation, the results appeared equally complex on the basis of gas chromatographic and p.m.r. evidence. Column chromatography gave one additional crystalline product, which proved to be bis[3-propionoxy-2,2,4,4-tetramethylcyclobutyl]azine (**8**).[14] It appeared, then, that an unambiguous synthesis of **1** could hardly be expected by this technique. In order to learn whether



8

(5) H. Staudinger and L. Ruzicka, *Helv. Chim. Acta*, **7**, 177 (1924).

(6) Cyclopropanols recently have been shown to be of special interest. For leading references, see C. H. DePuy and F. W. Breitbeil, *J. Am. Chem. Soc.*, **85**, 2176 (1963); C. H. DePuy, G. M. Dappen, K. L. Eilers, and R. A. Klein, *J. Org. Chem.*, **29**, 2813 (1964).

(7) D. R. A. Wharton, E. D. Black, and C. Merritt, *Science*, **142**, 1259 (1963).

(8) M. C. Whiting and A. C. Day [*Proc. Chem. Soc.*, 368 (1964)] have now succeeded in synthesizing **1** and find it to be biologically inactive.

(9) L. Friedman and H. Schechter, *J. Am. Chem. Soc.*, **82**, 1002 (1960).

(10) (a) R. H. Hasek, E. U. Elam, J. C. Martin, and R. G. Nations, *J. Org. Chem.*, **26**, 700 (1961); (b) L. L. Miller, Doctoral Dissertation, Cornell University, 1937.

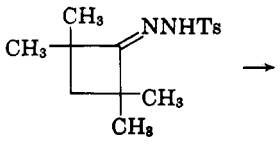
(11) G. Closs and L. Closs, *J. Am. Chem. Soc.*, **84**, 809 (1962); L. Friedman, private communication.

(12) W. G. Dauben and F. G. Willey, *J. Am. Chem. Soc.*, **84**, 1497 (1962).

(13) Bioassays were performed by Professor T. Eisner, Department of Entomology, Cornell University, and by Dr. L. M. Roth, Army Quartermaster Research Center, Natick, Mass.

(14) D. M. Lemal and A. J. Fry [*J. Org. Chem.*, **29**, 1673 (1964)] have found an azine as a minor photolysis product in a similar tosylhydrazone photolysis.

carbenoid ring contraction was capable of giving an isopropylidenecyclopropane, the Bamford–Stevens reaction of tosylhydrazone **9**, lacking only the ester group at C-3, was studied. In this case, a major product was shown to be the desired 1,1-dimethyl-2-isopropylidenecyclopropane (**10**), a compound recently prepared and



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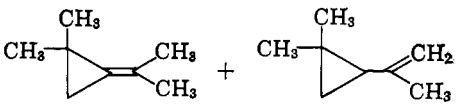
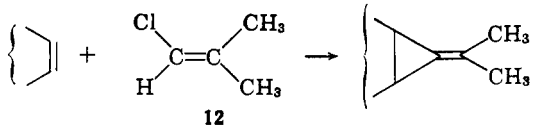


10 **11**

characterized by Hartzler.[15] One of two minor products had properties in accord with structure **11**. From this model result we conclude that the ring contraction of **6** may well have been successful, but that the complexity of the side products and possibly the lability of **1** itself did not permit satisfactory isolation and characterization of the desired product.[16]

The recent work of Tanabe showing that isopropylidenecyclopropanes could be prepared by the treatment of olefins with 1-chloro-2-methyl-1-propene (**12**) and potassium *t*-butoxide, presumably *via* the intermediate vinylidene carbene,[17] prompted us to attempt a direct



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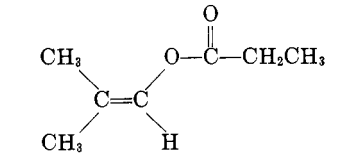
synthesis of **1** by treatment of isobutyraldehyde enol propionate (**13**) with **12** under Tanabe's conditions. Although **13** was readily prepared from isobutyralde-



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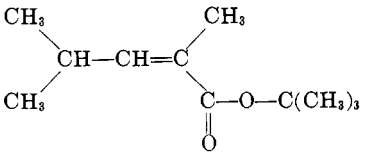
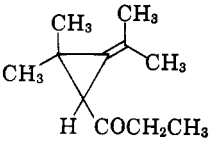


14

hyde, propionic anhydride, and potassium propionate, the only new compound which was obtained from the attempted carbene addition was a condensation product to which structure **14** may be assigned on the basis of analytical and spectral data.

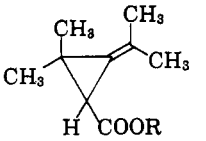
Our third approach was based on the observation of Emmons and Lucas[18] that cyclopropanol esters can be formed by Baeyer–Villiger oxidation of cyclopropyl ketones. Although the required precursor **15** might be expected to form an epoxide under these conditions, the subsequent reconversion of the epoxide group to a double bond appeared possible.



15

$N_2CHCOCH_2CH_3$

16



17, R = C_2H_5
18, R = CH_3
19, R = H

Direct preparation of **15** from tetramethylallene[19] and 1-diazo-2-butanone (**16**) was complicated by the formation of a mixture which decomposed on gas chromatography. Addition of ethyl (or methyl) diazoacetate to tetramethylallene gave the corresponding cyclopropane carboxylate **17** (or **18**).[20] The unsaturated acid **19** was obtained in modest yield by hydrolysis of the ester. Treatment of the unsaturated acid **19** with ethyllithium gave the desired ketone **15**. Although unstable to gas chromatography, **15** was homogeneous by thin layer chromatography. Attempted Baeyer–Villiger oxidation of the ketone **15** with trifluoroperacetic acid and with *m*-chloroperbenzoic acid gave complex mixtures. When these mixtures were subjected to the conditions of Cornforth[21] for reduction of epoxides to olefins, no unsaturated esters could be isolated.

Since direct Baeyer–Villiger oxidation of ketone **15** proved complex, presumably because of the presence of a double bond, we sought a method of protecting this function. Toward this end, bromine was added to **15**, but a very labile product was formed. The unsaturated acid **19** reacted smoothly with bromine, but gave, instead of the expected dibromo acid, 2,2-dimethyl-3-bromo-3-[1-hydroxy-1-methylethyl]-cyclopropyl-1-carboxylic acid lactone (**20**),[22] from which the unsaturated acid **19** could be regenerated by treatment with zinc and acetic acid.[23] The analogous iodo lactone **21** was isolated from similar treatment of the acid with iodine. Bromination of ester **17** followed by base hydrolysis gave a crystalline lactone to which the ring-opened structure **22** may be assigned on the basis of its composition and spectral properties. This lactone was also isolated from treatment of bromo lactone **20** with base.

(15) H. D. Hartzler, *J. Am. Chem. Soc.*, **86**, 526 (1964).

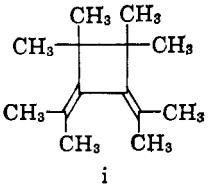
(16) Professor E. J. Corey (private communication) has also explored this path with similarly disappointing results.

(17) M. Tanabe and R. A. Walsh, *J. Am. Chem. Soc.*, **85**, 3522 (1963).

(18) W. D. Emmons and G. B. Lucas, *ibid.*, **77**, 2287 (1955).

(19) Columbia Organic Chemicals Co., Inc., Columbia, S. C.

(20) In addition to the cyclopropane carboxylates which were formed, a high-boiling liquid corresponding to the symmetrical dimer of tetramethylallene (i) was isolated by column chromatography. The mass spectrum of



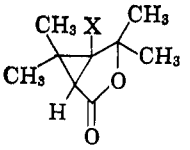
i

this material, taken by Dr. A. F. Thomas, was in accord with this structural assignment.

(21) J. W. Cornforth, R. H. Cornforth, and K. K. Mathew, *J. Chem. Soc.*, 112 (1959).

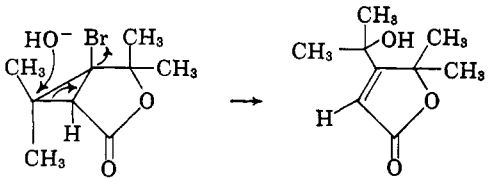
(22) *Cf.* M. Ettlinger, *J. Am. Chem. Soc.*, **74**, 5805 (1952).

(23) J. Meinwald, S. S. Labana, and M. S. Chadha, *ibid.*, **85**, 582 (1963).



20, X = Br
21, X = I

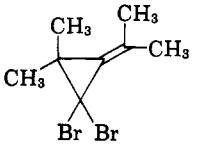
The formation of **22** from **20** may be rationalized by assuming solvolytic loss of bromine, accompanied by opening of the cyclopropane ring and attack of water or hydroxide ion at the incipient positive carbon atom as shown in eq. 1. Although there is analogy for nucleophilic opening of a properly substituted cyclopropane ring,[24] no very direct precedent for this transformation can be cited.



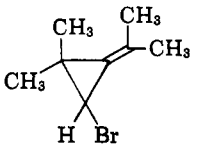
20 **22** (1)

Attempts to protect the double bonds of acid **19** or ketone **15** with nitrosyl chloride or with osmium tetroxide were unrewarding.

As protection of the double bond did not appear promising, a functional group which could be converted easily to a propionoxy group was sought. Direct displacement of the halide in a halocyclopropane seemed suitable. Acid **19** was treated with lead tetraacetate–iodine, but, instead of the expected iodocyclopropane,[25] iodo lactone **21** was isolated. Direct addition of a dihalo- or monohalocarbene to tetramethylallene was then considered. By means of Doering's procedure,[26] the dibromocyclopropane **23** was prepared and was converted into the monobromocyclopropane **24** with tri-*n*-butyltin hydride.[27,28] This procedure was superior to direct addition of chlorocarbene[29] to tetramethylallene.



23



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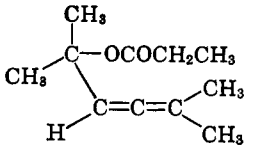

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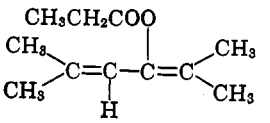
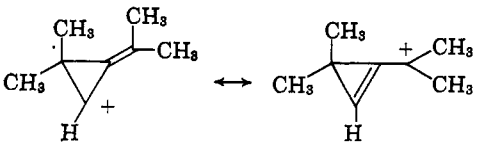


26

Attempts to replace the bromine in **24** by a propionoxy substituent failed to give the desired **1**. However, solvolysis of **24** in a variety of solvents in the presence of silver (or potassium) propionate gave an interesting ester of rearranged structure. The presence of an infrared absorption band at 5.1 μ in this ester showed it to be allenic.[30] The elementary analysis and other spectral data for this allenic ester establish it to have structure **25**.

It is interesting to note that the loss of bromide from **24** would give the ion **27**. It is conceivable that **27** would suffer ring opening to the new tertiary allylic ion **28** with considerable ease, since the strain in the



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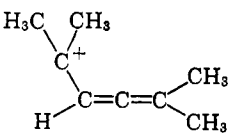


28

cyclopropane ring would be thus removed. Although **28** might even be a canonical structure contributing to **27**, analogous to the allylcarbinyl contributor in the cyclopropylcarbinyl system,[31] geometrical requirements of allenes make such a contribution negligible, if the planarity of **27** is maintained.

Chromatography of **25** on silicic acid converted this ester to a diene ester tentatively assigned structure **26**.[32] Neither of these esters showed any physiological activity.[13] In contrast to **23**, which was a stable, crystalline compound, the bromocyclopropane **24** was a labile liquid which decomposed upon gas or column chromatography or on prolonged standing at 5°. It reacted with magnesium, but subsequent addition of carbon dioxide gave no acid, only dimeric hydrocarbon. Similarly, addition of oxygen to the reaction mixture gave no alcohol. Thus, although the bromocyclopropane precursor **24** for the desired ester **1** was reactive, its mode of reaction was not the desired one.

One other attempt to prepare **1** was based on the discovery by Corey and Casanova that the norbornane-2-carboxylic acids (**29**) are converted into *exo*-2-norbornyl acetate (**30**) on treatment with lead tetraacetate in pyridine.[33] When this reaction was applied to acid **19**, the only product which could be characterized was the acetate of lactone **22**, although other esters were

(24) W. A. Bone and W. H. Perkin, *J. Chem. Soc.*, **67**, 108 (1895); R. P. Linstead, R. W. Kierstead, and B. C. L. Weedon, *ibid.*, 3616 (1952); J. K. Crandall, Doctoral Dissertation, Cornell University, 1964.

(25) D. H. R. Barton and E. P. Serebryakov, *Proc. Chem. Soc.*, 309 (1962).

(26) W. von E. Doering and A. K. Hoffmann, *J. Am. Chem. Soc.*, **76**, 6162 (1954); W. J. Ball and S. R. Lander, *Proc. Chem. Soc.*, 246 (1961).

(27) G. J. M. van der Kerk, *J. Appl. Chem.* (London), **7**, 366 (1957); D. Seyferth, H. Yamazaki, and D. L. Alleston, *J. Org. Chem.*, **28**, 703 (1963).

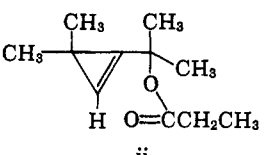
(28) For recent syntheses of dihalocyclopropanes, see L. Skattebøl, *ibid.*, **29**, 2951 (1964).

(29) G. L. Closs and L. Closs, *J. Am. Chem. Soc.*, **82**, 5723 (1960).

(30) L. Skattebøl, *Tetrahedron Letters*, 167 (1961); W. von E. Doering and P. M. LeFlamme, *Tetrahedron*, **2**, 75 (1958); H. D. Hartzler, *J. Am. Chem. Soc.*, **83**, 4990 (1961).

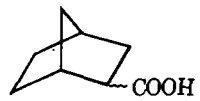
(31) J. D. Roberts and R. H. Mazur, *ibid.*, **73**, 2509 (1951).

(32) Professor G. L. Closs has informed us that **26** is formed (presumably *via* **25**) when ii is subjected to conditions favoring the Cope rearrangement.

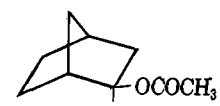


ii

(33) E. J. Corey and J. Casanova, *J. Am. Chem. Soc.*, **85**, 165 (1963).



29



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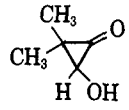
also obtained. When lead tetrapropionate was used, no product corresponding to structure **1** could be isolated.

With regard to the original work of Jacobson, Beroza, and Yamamoto,[2] our results have some bearing on the assignment of structure **1** to their isolated natural product. Their reported p.m.r. spectrum for this material, consisting of two absorptions, one at 75.5 c.p.s. (τ 8.74) and the other at 140.5 c.p.s. (τ 7.66), seems abbreviated. The signal corresponding to allylic methyl groups which consistently appears in the τ 8.3 region in **10**, **15**, **17–19**, **23**, and **24** would be expected to be as strong as the signal corresponding to normal methyl groups (τ 8.74). The terminal methyl of the propionate group should appear as a triplet at a position similar to that of the normal methyl groups. Furthermore, the reported absorption at τ 7.66 appears to be more suitable for that of the methylene protons of the propionate group (τ 7.6–7.8, see Experimental) than for a proton α to an oxygen atom.[34] This misassignment of the τ 7.66 absorption places the ratio of normal methyl protons to methylene protons in the propionate group at 12:2, a ratio entirely at odds with expectations for the postulated structure. The assignment of an infrared absorption at 12.5 μ to an isopropylidene group is also unjustified.[35] Catalytic hydrogenation of this type system might be expected to occur with hydrogenolysis.[36] Although we observe this with **15**, **17**, and **19**, a normal uptake of hydrogen is reported for **1**.

Aside from the physical data, some of the degradations described for the sex attractant, such as the isolation of hydroxycyclopropanone **31** as a stable solid, find no precedent.[37]



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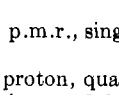
Finally, the preliminary report[8] that unambiguously synthesized 2,2-dimethyl-3-isopropylidenecyclopropyl propionate (**1**) has physical properties clearly different from those of the natural product (but closely analogous to those of the compounds with general structure **3** described in this work) provides chemical evidence that the original structural assignment was erroneous.

Experimental

Melting points are corrected. Boiling points are uncorrected. Chromatography was carried out on Mallinckrodt silicic acid, 100 mesh, acid-washed, and with fines removed according to the procedure of Brockmann,[38] and on Merck alumina (71707). Infrared spectra were taken on a Perkin-Elmer Infracord. Ultraviolet spectra were taken on a Cary Model 14 in 95% ethanol. Proton magnetic resonance spectra were taken on a Varian A-60 spectrometer, using tetramethylsilane as an internal standard and carbon tetrachloride as a solvent. Analyses were carried out by Schwarzkopf Microanalytical Laboratory, Woodside, N. Y., and by Scandinavian Microanalytical Laboratory, Harveg, Denmark.

3-Hydroxy-2,2,4,4-tetramethylcyclobutanone (**7**).—Hydroxy ketone **7** was prepared according to the procedure of Miller[10b] from 2,2,4,4-tetramethylcyclobutane-1,3-dione. The procedure of Hasek, *et al.*,[10a] gave predominantly the 2,2,4,4-tetramethyl-1,3-cyclobutanediols. The yield of hydroxy ketone **7** (m.p. 112–114°, lit. m.p. 114°,[10a] 114.5–115.5°[10b]) was 75%; infrared spectra ($CHCl_3$), 2.9 (OH), 5.68 (C=O), 9.1 μ (C—O); p.m.r., doublet at τ 8.82 (area 12 protons), two doublets at 7.22 and 6.08 (each with an area of 1 proton).

3-Propionoxy-2,2,4,4-tetramethylcyclobutanone.—3-Hydroxy-2,2,4,4-tetramethylcyclobutanone (15.0 g., 0.105 mole) was mixed with propionic anhydride (24.0 g., 0.18 mole) and *p*-toluenesulfonic acid (300 mg.), and the reaction mixture was allowed to stand for 24 hr. The reaction mixture was poured into ice–water, then heated on a steam bath for 2 hr. with a small amount of sodium acetate. It then was extracted three times with methylene chloride. The extracts were washed twice with 5% sodium bicarbonate, and once with water, and dried over anhydrous sodium sulfate; the methylene chloride was removed on a steam bath. The crude product was distilled through a Vigreux column yielding 16.5 g. (78%) of ester: b.p. 72–75° (3 mm.); infrared (neat film), 5.62, 5.75 μ; p.m.r., singlet at τ 5.3  with an area corresponding to 1 proton, quartet at 7.55 (area 2 protons), and overlapping absorptions at 8.6–8.9 (area 15 protons) consistent with the structure assigned.

An analytical sample was collected from a preparative gas chromatography column (LAC 446, 100°) and redistilled at 185° (bath) (760 mm.).

Anal. Calcd. for $C_{11}H_{18}O_3$: C, 66.64; H, 9.15. Found: C, 66.56; H, 9.13.

3-Propionoxy-2,2,4,4-tetramethylcyclobutanone Tosylhydrazone (**6**).—3-Propionoxy-2,2,4,4-tetramethylcyclobutanone (21.0 g., 0.015 mole) and *p*-toluenesulfonylhydrazine (19.5 g., 0.105 mole) were dissolved in methanol (60 ml.), concentrated hydrochloric acid (2 drops) was added, and the solution was allowed to stand overnight. The reaction mixture was cooled, and the product was induced to crystallize. The mother liquors were diluted with water and recooled. A total of 31.5 g. (82%) of product (m.p. 129–130.5°) was obtained, along with an additional 3.8 g. of lower melting material (m.p. 120–132°): infrared ($CHCl_3$), 5.79, 6.25 μ; p.m.r., a singlet at τ 5.65 with area equivalent to 1 proton, five peaks at 2.2–2.8 (area 5 protons), singlet 7.6 (area 3 protons), quartet 7.8 (area 2 protons), and 6 sharp absorptions at 8.7–9.0 (area 15 protons) consistent with the structure assigned.

Anal. Calcd. for $C_{18}H_{26}N_2O_4S$: C, 59.00; H, 7.15; S, 8.75. Found: C, 58.95; H, 7.18; S, 8.80.

3-Hydroxy-2,2,4,4-tetramethylcyclobutanone Tosylhydrazone.—3-Hydroxy-2,2,4,4-tetramethylcyclobutanone (525 mg., 3.7 mmoles) was dissolved in glacial acetic acid (10 ml.), 1 drop of concentrated hydrochloric acid was added along with *p*-toluenesulfonhydrazine (700 mg., 3.75 mmoles), and the solution was allowed to stand overnight at room temperature. The acetic acid was removed on a rotary evaporator, and the crystalline residue was recrystallized from chloroform. Two crops of crystals gave 1.02 g. (90%) of product (m.p. 129.5–130.5°): infrared ($CHCl_3$), 3.1, 3.5, 5.95, and 6.23 μ.

Anal. Calcd. for $C_{15}H_{22}N_2O_3S$: C, 58.05; H, 7.15; S, 10.3. Found: C, 58.03; H, 7.29; S, 10.26.

Photolysis of the Sodium Salt of 3-Propionoxy-2,2,4,4-tetramethylbutanone Tosylhydrazone.—The tosylhydrazone **6** (5.0 g., 0.013 mole) and sodium methoxide (0.74 g., 0.013 mole) were dissolved in a minimum of anhydrous methanol, and the solution was evaporated to dryness on a rotary evaporator. Benzene was added and the solution was re-evaporated. The sirup so obtained was dissolved in 300 ml. of 1,2-dimethoxyethane (freshly

(34) N. S. Bhacca, L. F. Johnson, and J. N. Shoolery, "High Resolution NMR Spectra Catalog," Vol. I, Varian Associates, Palo Alto, Calif., 1962, spectrum no. 79.

(35) L. J. Bellamy, "The Infrared Spectra of Complex Molecules," John Wiley and Sons, New York, N. Y., 1958, p. 52.

(36) J. Smejkal and J. Farkas, *Collection Czech. Chem. Commun.*, **28**, 1557 (1963); J. Newham, *Chem. Rev.*, **63**, 123 (1963).

(37) H. G. Richey, Jr., J. M. Richey, and D. C. Clagett, *J. Am. Chem. Soc.*, **86**, 3907 (1964).

(38) H. Brockmann and H. Muxfeldt, *Chem. Ber.*, **89**, 1379 (1956).

distilled from lithium aluminum hydride), then photolyzed for 1.5 hr. in a quartz vessel using a 500-w. Hanovia mercury lamp without filters. The yellow solution, which had deposited a white solid, was diluted 1:1 with water and extracted three times with pentane. The yellow pentane extracts were washed six times with water and dried over anhydrous sodium sulfate, and the pentane was removed on a rotary evaporator. The residue partially crystallized. The crystals were washed with cold pentane and were identified as the starting tosylhydrazone (0.3 g.) by a mixture melting point. The residue was diluted with pentane, cooled to remove remaining tosylhydrazone (0.13 g.), then distilled at 1.5 mm., the receiver being cooled in Dry Ice–acetone. The distillate (1.40 g., b.p. 80–150° at 1.5 mm.) was preparatively gas chromatographed (LAC 446, 100°). Three major peaks of the eleven present were collected. These showed retention times of (1) 18 min., (2) 24 min., and (3) 72 min. Fraction 3 (150 mg.) was demonstrated to be 3-propionoxy-2,2,4,4-tetramethylcyclobutanone by its g.c. retention time and by infrared comparison with an authentic sample. Fraction 2 (106 mg.) gave three peaks in the analytical g.c. Its infrared spectrum was simple (only one C=O, 5.78 μ) but its p.m.r. spectrum showed it to be a complex mixture. Fraction 1 (80 mg.) showed a simple ester in its infrared spectrum (5.78 μ), appeared homogeneous on a gas chromatography column (LAC 446, 98°), but was shown by p.m.r. to be a mixture, the major constituent of which was shown not to be the desired 2,2-dimethyl-3-isopropylidenecyclopropyl propionate on the basis of the ratio of the areas corresponding to allylic methyl groups and saturated methyl groups. A sample of fraction 1 was distilled for analysis.

Anal. Calcd. for $C_{11}H_{18}O_2$: C, 72.49; H, 9.96. Found: C, 71.99; H, 9.90.

Pyrolysis of the dry sodium salt diluted with Celite gave results similar to those above. Photolyses carried out in diglyme and benzene (in the presence and absence of oxygen) gave results similar to those performed in 1,2-dimethoxyethane. The crude mixture was not simpler than its gas chromatogram indicated (eleven components) as evidenced by the complexity of its p.m.r. spectrum. The undistilled photolysis product showed identical behavior by g.c. and had a p.m.r. spectrum very similar to that of the distilled material. Chromatography on silica gel, silicic acid, and activity III alumina gave only one product that could be purified. Elution of a silica gel column with pentane–ether (10%) gave crystalline material (m.p. 84–100°) in an over-all yield of 5%. Recrystallization of this material from pentane gave white plates, m.p. 102–103°. An analytical sample (m.p. 102–103°) was sublimed at 100° (1.5 mm.): infrared ($CHCl_3$), 5.75 (s), 5.90 (m), 8.5 (s) μ; p.m.r., singlet at τ 5.8 with area equivalent to 2 protons, quartet at 7.75 (area 4 protons), and at least 6 peaks at 8.8–9.0 (30 protons) consistent with bis[3-propionoxy-2,2,4,4-tetramethylcyclobutyl]azine (**8**).

Anal. Calcd. for $C_{22}H_{36}N_2O_4$: C, 67.31; H, 9.24; N, 7.14. Found: C, 67.49; H, 8.98; N, 7.12.

2,2,4,4-Tetramethylcyclobutanone.—This ketone (b.p. 127.5–129°, lit.[39] 128.5–129°) was prepared from 2,2,4,4-tetramethylcyclobutane-1,3-dione by the procedure of Herzog and Buchman[39] in 26% yield: infrared (neat film), 5.63 μ; p.m.r., singlet at τ 8.85 with an area equivalent to 12 protons and singlet 8.27 (area 2 protons).

In addition to the reported ketone, bis[2,2,4,4-tetramethylcyclobutyl] azine was isolated from the distillation residue of this reaction in low yield: infrared (melt), 5.96, 9.5 μ; p.m.r., singlet at τ 8.32 (area 2 protons) and doublet 8.77 (area 12 protons). An analytical sample (m.p. 98–99°) was obtained by sublimation at 100° (3 mm.).

Anal. Calcd. for $C_{16}H_{28}N_2$: C, 77.36; H, 11.36; N, 11.28. Found: C, 77.32; H, 11.32; N, 11.21.

2,2,4,4-Tetramethylcyclobutanone Tosylhydrazone (9).—2,2,4,4-Tetramethylcyclobutanone (8.77 g., 0.07 mole) and *p*-toluenesulfonylhydrazine (13.0 g., 0.07 mole) were dissolved in methanol (25 ml.), concentrated hydrochloric acid (2 drops) was added, and the solution was allowed to stand overnight. Most of the tosylhydrazone crystallized on cooling (10.5 g.). Dilution of the mother liquors with water gave an additional 5.5 g. of crystals, giving a total yield of 16.0 g. (79%) (m.p. 148–149°). An analytical sample was recrystallized twice from methanol–water and gave material of m.p. 150–151°: infrared ($CHCl_3$), 3.1, 3.5, 5.95, 7.23 μ; p.m.r., 5 peaks at τ 2.15–2.85 with area equivalent to 5 protons, singlet at 7.60 (3 protons), singlet at 8.43 (2 protons), and doublet at 8.85 (12 protons) consistent with the structure assigned.

Anal. Calcd. for $C_{15}H_{22}N_2O_2S$: C, 61.20; H, 7.53; S, 10.9. Found, C, 61.03; H, 7.55; S, 10.91.

Pyrolysis of the Sodium Salt of 2,2,4,4-Tetramethylcyclobutanone Tosylhydrazone.—The tosylhydrazone **9** (4.40 g., 0.015 mole) was dissolved in a minimum of anhydrous methanol and sodium methoxide (0.81 g., 0.015 mole) was added in one portion. The solution was evaporated to dryness on a rotary evaporator. After the addition of Celite (4 g.), the residue was dried overnight on a vacuum line at 75°.

The diluted salt was heated slowly to 150° at 35 mm. and the distillate was trapped in a Dry Ice–acetone bath. Decomposition began at 120° and a red distillate was formed. The distillate (0.54 g.) [infrared (neat film), 3.0, 3.4, 5.0, 5.6, 6.0, 6.9, 7.3 μ] was fractionated using gas chromatography (Carbowax 30%, 40°) and the fractions were collected in Dry Ice–acetone. The major fraction (104 mg.) exhibited these spectra: infrared (neat film), 5.6, 6.9, 7.3, 8.7, 8.8, and 10.0 μ; p.m.r., broad singlet at τ 8.3 with area equivalent to 6 protons, singlet at 8.9 (6 protons), and broad absorption at 9.25 (2 protons) consistent with 1,1-dimethyl-2-isopropylidenecyclopropane (**10**).

Anal. Calcd. for C_8H_{14}: C, 87.19; H, 12.81. Found: C, 87.51; 87.06; H, 12.59, 12.90.

Later runs gave enough of two minor products to be characterized. The ratio of these products to the major one varied considerably (1:10 to 1:2) from run to run. The first minor product showed these spectra: infrared (neat film), 5.6, 6.0, 6.9, 11.1 (s) μ; p.m.r., doublet at τ 5.5 (2 protons), singlet at 8.3 (3 protons), doublet 9.0 (6 protons), and broad doublet at 9.5 (2 protons) consistent with 1,1-dimethyl-2-isopropenylcyclopropane (**11**).

Anal. Calcd. for C_8H_{14}: C, 87.19; H, 12.81. Found: C, 87.20; H, 12.66.

The second minor product exhibited these spectra: infrared (neat film), 5.6, 6.0, 6.9, 7.1, 11.1 (s) μ; p.m.r., doublet at τ 8.35 (9 protons), doublet at 7.4 (2 protons), singlet at 5.4 (2 protons), and multiplet at 4.9 (1 proton) consistent with 2,5-dimethyl-1,4-hexadiene.

Anal. Calcd. for C_8H_{14}: C, 87.19; H, 12.81. Found: C, 82.39, 82.93; H, 12.02, 12.37.

These values, which do not correspond to C_8H_{14}, suggest that the 2,5-dimethyl-1,4-hexadiene may be contaminated with some methanol. Methanol was the material closely following this substance on the gas chromatography column.

Ozonolysis of 1,1-Dimethyl-2-isopropylidenecyclopropane (10).—1,1-Dimethyl-2-isopropylidenecyclopropane (70 mg., 0.63 mole) in carbon tetrachloride (0.5 ml.) was mixed with ethyl acetate (5 ml.) and tetracyanoethylene (81 mg., 0.63 mmole). The solution was saturated with ozone at −70°, allowed to warm to room temperature, and diluted 1:1 with methanol; 2,4-dinitrophenylhydrazine reagent[40] was added. The solution turned dark red. The ethyl acetate was removed on a rotary evaporator, the residue was taken up in chloroform, extracted with sodium bicarbonate, and dried, and the solvent was removed. The residue (20 mg.) was chromatographed on silicic acid with benzene–chloroform (1:2). Two bands were eluted. The first consisted of acetone dinitrophenylhydrazone (6 mg.) identified by mixture melting point and thin layer plate chromatography (chloroform–benzene, 2:1). The second band (12 mg.) was dark red in color, indicating a conjugated system, and was not investigated.

2-Methyl-1-propen-1-ol Propionate (13).—A mixture of isobutyraldehyde (36 g., 0.5 mole), propionic anhydride (91 g., 0.7 mole), and potassium propionate (5.0 g., 0.05 mole) was refluxed overnight in a moisture-free atmosphere. The mixture was poured onto ice, allowed to stand overnight at room temperature, heated for 15 min. on a steam bath, and extracted with ether. The ether extracts were washed with 10% sodium carbonate until the washings were basic. The ether extract was then washed three times with water and dried, and the ether was removed on a rotary evaporator. The residue was distilled at atmospheric pressure giving 30 g. (47%) of the enol propionate of isobutyraldehyde (b.p. 140°). This enol ester exhibited these spectra: infrared (neat film), 5.72, 5.95, 8.8 μ; p.m.r., a singlet at τ 8.35 (area 6 protons), a singlet at 3.18 (area 1 proton), a triplet at 8.9

(39) H. L. Herzog and E. R. Buchman, *J. Org. Chem.*, **16**, 99 (1951).

(40) A. Vogel, "A Textbook of Practical Organic Chemistry," Longmans, Green and Co., New York, N. Y., 1951, p. 344.

(area 3 protons), and a quartet at 7.65 (2 protons) consistent with the structure assigned.

Anal. Calcd. for $C_7H_{12}O_2$: C, 65.64; H, 9.37. Found: C, 65.57; H, 9.59.

Attempted Preparation of 2,2-Dimethyl-3-isopropylidenecyclopropyl Propionate from 13.—2-Methyl-1-propen-1-ol propionate (**13**) (21 g., 0.16 mole) was dissolved in toluene (20 ml.), and to the solution was added 1-chloro-2-methyl-1-propene[41] (4.5 g., 0.05 mole) and potassium *t*-butoxide (6.2 g., 0.055 mole). The colorless reaction mixture was refluxed overnight in a moisture-free atmosphere. The toluene solution was washed three times with water, dried, and subjected to g.c. analysis (Carbowax, 103°). Following the unchanged enol propionate at 2.3 min., three other peaks were apparent at 4.0, 5.2, and 17 min. The crude product was distilled, the enol propionate and toluene were removed, and the residue was separated into a low-boiling fraction (b.p. 28–79° at 0.5 mm., 5.7 g.) and a high-boiling fraction (b.p. 99–104° at 0.5 mm., 2.26 g.). The lower boiling fraction was separated by preparative g.c. (LAC, 116°) into enol propionate (4 g.) and a material of longer retention time (505 mg.). This latter material was subjected to preparative g.c. again and gave 300 mg. of a colorless liquid which exhibited these spectra: infrared (neat film), 3.5, 5.85, 6.07, 8.0, 8.8, 13.3 μ (a Beilstein test for chlorine was negative); p.m.r., two multiplets at τ 3.5 and 3.6 (area 1 proton), doublet 8.2 (area 3 protons), singlet 8.5 (area 9+ protons), and doublet 9.0 (area 6 protons), consistent with a mixture of the *cis* and *trans* isomers of *t*-butyl 2,4-dimethyl-2-pentenoate (**14**). Thin layer chromatography showed two spots moving almost together.

Anal. Calcd. for $C_{11}H_{20}O_2$: C, 71.69; H, 10.94. Found: C, 71.58; H, 10.96.

The higher boiling fraction was subjected to preparative g.c. (LAC 446, 144°) and was separated into five major fractions the first four of which showed two carbonyl absorptions, one at 5.70 and the other at 5.75 μ. The last fraction (128 mg.) showed these spectra: infrared (neat film), 3.5, 5.75, 6.9, 8.7, 10.0 μ; p.m.r., complex, no CH_3—C= present, all methyl groups on saturated carbon. Since this fraction was not the expected 2,2-dimethyl-3-isopropylidenecyclopropyl propionate, this approach was not pursued further.

Ethyl 2,2-Dimethyl-2-isopropylidenecyclopropyl-1-carboxylate (17).—To a suspension of anhydrous cupric chloride (1.40 g., 0.01 mole) in tetramethylallene[19] (63 g., 0.65 mole) contained in a 200-ml. flask fitted with a mechanical stirrer, addition funnel, and condenser topped with a drying tube was added ethyl diazoacetate[42] (22 g., 0.2 mole). The rate of addition was such that the reaction mixture did not reflux, and the addition required 1.5 hr. After the addition was complete, the mixture was stirred for an additional hour, filtered, diluted with ether, washed four times with 6 *N* ammonium hydroxide and twice with water, and dried over sodium sulfate. The ether–tetramethylallene was removed on a rotary evaporator. The tetramethylallene was recovered by fractional distillation and reused. The residue weighed 14.6 g. (40%). This material was sufficiently pure for subsequent use. An analytical sample was prepared by preparative g.c. (LAC 446, 100°). It exhibited these spectra: infrared (neat film), 5.81, 8.8 μ; p.m.r., a quartet at τ 6.25 (2 protons), doublet at 8.35 (6+ protons), and a singlet superimposed on a triplet at 8.87 (9 protons) consistent with the structure assigned. Attempted hydrogenation (Pd–C) gave extensive hydrogenolysis.

Anal. Calcd. for $C_{11}H_{18}O_2$: C, 72.49; H, 9.96. Found: C, 72.49; H, 10.02.

Methyl 2,2-Dimethyl-3-isopropylidenecyclopropyl-1-carboxylate (18).—The methyl ester **18** was prepared in a fashion similar to that described for **17**, using methyl diazoacetate. The dimethyl fumarate formed as a by-product crystallized from the crude ester and was easily removed. The methyl ester **18** (b.p. 100° at 40 mm.) exhibited these spectra: infrared (neat film), 3.4, 5.6, 5.79, 8.6 μ; p.m.r., singlet at τ 6.36 (area 3 protons), two doublets 8.15 and 8.23 (area 7.4 protons), and a doublet at 8.70 (area 6 protons). The methyl ester was unstable to gas chromatography (Carbowax, 100°). An analytical sample was prepared by alumina chromatography (activity III) and subsequent distillation.

Anal. Calcd. for $C_{10}H_{16}O_2$: C, 71.39; H, 9.59. Found: C, 71.18; H, 9.78.

2,2-Dimethyl-3-isopropylidenecyclopropyl-1-carboxylic Acid (19).—Methyl 2,2-dimethyl-3-isopropylidenecyclopropyl-1-carboxylate **18** (10.0 g., 0.06 mole) was heated with aqueous potassium hydroxide (95 ml. of a 5% solution, 0.09 mole) on a steam bath for 63 hr. The still heterogeneous mixture was extracted once with ether and acidified to a pH of 4 with 6 *N* hydrochloric acid in the cold, and the crude acid was filtered. The acid was air dried and sublimed at 80° (0.3 mm.), giving a 35% yield of 2,2-dimethyl-3-isopropylidenecyclopropyl-1-carboxylic acid (**19**, 2.80 g., m.p. 107–108°), taking recovered ester (1.36 g.) into account. Extraction of the aqueous filtrate with ether gave no additional acid. The sublimed acid exhibited these spectra: infrared ($CHCl_3$), 2.9–3.1, 3.5, 5.90, 7.8, and 9.2 μ; p.m.r., a singlet at τ 1.14 (1 proton), multiplet 8.0 (1 proton) doublet 8.23 (6 protons), doublet at 8.70 (6 protons), consistent with the structure assigned. Attempted hydrogenation (Pd–C) gave extensive hydrogenolysis.

Anal. Calcd. for $C_9H_{14}O_2$: C, 70.10; H, 9.15. Found: C, 70.25; H, 9.00.

From the recovered ester was obtained by chromatography on alumina (activity III) with pentane–ether 610 mg. of a high-boiling liquid (b.p. 100° (bath) at 10 mm.). It exhibited the following spectra: infrared (neat film), 3.4, 6.05, 6.9, 7.3, 8.8, 9.2, 9.7 μ; p.m.r., two singlets, one at τ 8.30 (broad), the other at 8.93 (sharp). The ratio of integrated areas was 1:1; ultraviolet, $\lambda_{max}^{95\%\ EtOH}$ 250 mμ (ϵ 14,000); mass spectrum, parent peak *m/e* 192, base peak 149.

Anal. Calcd. for $C_{14}H_{24}$: C, 87.42; H, 12.58. Found: C, 87.50; H, 12.65.

These data appear consistent with those expected for 1,2-diisopropylidene-3,3,4,4-tetramethylcyclobutane (i).

Other attempted hydrolyses (methanolic potassium hydroxide, methanolic–aqueous potassium hydroxide, aqueous lithium hydroxide, ethanolic potassium hydroxide, isopropanolic potassium hydroxide, aqueous ethanolic potassium hydroxide, ethanolic sodium hydroxide) of the methyl and ethyl esters were less successful. In all cases, much less acid was formed, and it was accompanied by liquid acids which hindered crystallization.

2,2-Dimethyl-3-isopropylidenecyclopropyl Ethyl Ketone (15).—2,2-Dimethyl-3-isopropylidenecyclopropyl-1-carboxylic acid (**19**, 1.85 g., 12 mmoles) was dissolved in ether (25 ml.) and to the solution, under nitrogen, was added ethyllithium[43] (15 ml. of a 2.2 *M* solution, 33 mmoles) over a 2-min. period with cooling. The solution precipitated a white solid, then cleared. It was stirred an additional 15 min., Dry Ice was added to destroy excess ethyllithium, then water was added. The aqueous solution was extracted with ether, the ether extracts were washed with water and dried over sodium sulfate, and the ether was removed on a rotary evaporator. The residue (1.76 g., 88%) exhibited these spectra: infrared (neat film), 5.90 μ; p.m.r., quartet at τ 7.6 (2 protons), doublet at 8.25 (6 protons), and four peaks between 8.7 and 9.1, a total area of 10.7 protons compatible with the assigned structure. Gas chromatography (Carbowax, 110°) showed the ketone to be 60% pure. Attempts to form a dinitrophenylhydrazone or a semicarbazone derivative were unrewarding. Attempted purification of the crude ketone on preparative g.c. (LAC 446, 116°) was unsuccessful, since extensive rearrangement and decomposition occurred. The crude ketone was distilled (b.p. 60° at 0.6 mm.) and analyzed. Thin layer chromatography (silica gel) (pentane–ether, 10%) showed only one spot (R_f 0.6). Attempted hydrogenation of this ketone (Pd–C) gave extensive hydrogenolysis.

Anal. Calcd. for $C_{11}H_{18}O$: C, 79.46; H, 10.92. Found: C, 79.64; H, 10.80.

Attempted Direct Preparation of 2,2-Dimethyl-3-isopropylidenecyclopropyl Ethyl Ketone (15) from Tetramethylallene.—To a solution of diazomethane [prepared from 50 g. (0.49 mole) of N-nitrosomethylurea[44]] in ether was added, over a 0.5-hr. period, propionyl chloride (14.9 g., 0.16 mole) with cooling. The chilled solution was stirred for another 0.5 hr. at 0°, then for 1 hr. at room temperature. The ether was removed on a rotary evaporator at temperatures below 20°, leaving a yellow residue (15.9 g., 100%). This residue exhibited in its infrared spectrum a large absorption at 4.8 μ and broad absorption at 5.8–6.2 μ. It was dried over calcium chloride and sodium sulfate.

(41) K and K Laboratories, Jamaica, N. Y.

(42) E. C. Horning "Organic Syntheses," Coll. Vol. III, John Wiley and Sons, Inc., New York, N. Y., 1955, p. 392.

(43) Lithium Corp. of America.

(44) H. Gilman and A. H. Blatt "Organic Syntheses," Coll. Vol. I, John Wiley and Sons, Inc., New York, N. Y., 1941, p. 50.

The crude diazo ketone **16** prepared above was mixed with tetramethylallene (20 g.), and this solution was added over a 3-hr. period to a suspension of anhydrous cupric chloride (700 mg., 0.005 mole) in tetramethylallene (20 g.; total tetramethylallene, 0.42 mole).

After 1 hr. of additional stirring, the mixture was filtered to remove most of the copper salts. The filtrate was diluted with ether, extracted once with 5% hydrochloric acid, three times with 6 *N* ammonium hydroxide, once with 5% sodium bicarbonate, and three times with water. The ether extracts were dried, and the ether and most of the tetramethylallene were removed on a steam bath. The residue was distilled. The crude distillate showed four peaks by g.c. (LAC 446). About 6 ml. of colorless liquid (b.p. 43–70° at 0.3–0.6 mm.) was collected. This material was redistilled and the distillate (1.76 g., b.p. 40–58° at 0.3 mm.) was separated using preparative g.c. (LAC 446, 116°). Four fractions were collected, all of which were shown to be mixtures by their infrared spectra and gas chromatograms.

Attempted Baeyer–Villiger Oxidation of 2,2-Dimethyl-3-isopropylidenecyclopropyl Ethyl Ketone.—A solution of trifluoroperacetic acid was prepared from 90% hydrogen peroxide (750 mg., 20 mmoles) and trifluoroacetic anhydride (5.05 g., 24 mmoles) in methylene chloride (100 ml.) according to the procedure of Emmons and Lucas.[18] It was added over a 15-min. period to a stirred suspension of disodium hydrogen phosphate (5.68 g., 40 mmoles) in methylene chloride (100 ml.) containing the ketone (1.23 g., 7.5 mmoles). The suspension was refluxed for 1 hr. with stirring. The solid material was filtered and the solution was extracted twice with 5% sodium carbonate and once with water, and dried over sodium sulfate; the methylene chloride was removed. The residue (1.37 g.) showed absorption in its infrared spectrum (neat film) at 3.0, 5.65–5.80, 6.2, 8.8 μ, and by g.c. (Carbowax, 127°) showed peaks with retention times of 6, 10, and 16 min.

This material (1.37 g.) was subjected to the procedure of Cornforth[21] to remove any epoxide. It was added over a 5-min. period to an ice-cooled suspension of anhydrous sodium acetate (590 mg., 7.2 mmoles) and sodium iodide (1.88 g., 12.5 mmoles) in glacial acetic acid–water (100:6) to which had been added zinc dust (1.86 g., 30 mmoles). The solution turned green, then colorless. After 1 hr., the solution was filtered, the solid material was washed with a small amount of ether, and the filtrate was extracted with ether. The acetic acid was removed by extraction with 10% sodium carbonate; the ether then was washed with water, dried, and removed. The residue (881 mg.) was chromatographed on silicic acid with pentane–ether mixtures, but gave only material whose infrared spectrum was ill-defined in the carbonyl region and exhibited hydroxyl absorption in the 3-μ region. No material was eluted from the column with pentane–ether (5%), an eluent that had removed similar unsaturated esters previously.

m-Chloroperbenzoic acid gave similar results. On the basis of the residue's infrared spectrum (3.0, 3.4, 5.65–5.80, 6.35, 8.0, 13.5 μ) it was concluded that a *m*-chlorobenzoate ester had formed.

2,2-Dimethyl-3-bromo-3-[1-hydroxy-1-methylethyl]cyclopropyl-1-carboxylic Acid Lactone (20.)—2,2-Dimethyl-3-isopropylidenecyclopropyl-1-carboxylic acid (**19**, 500 mg., 3.25 mmoles) was dissolved in carbon tetrachloride (10 ml.), and to the solution was added with stirring at 0° a solution of bromine in carbon tetrachloride (520 mg., 3.25 mmoles/5.7 ml.). Sodium acetate (268 mg., 3.25 mmoles) was added to absorb any generated hydrobromic acid. The bromine was decolorized rapidly, and a white precipitate was formed. The carbon tetrachloride was extracted once with water, the solution was dried, and the solvent was evaporated on a rotary evaporator. The residue (700 mg.) was distilled (b.p. 100° at 9 mm.) yielding a colorless liquid (503 mg., 66%). It exhibited these spectra: infrared (neat film), 5.65 μ; p.m.r., a singlet at τ 7.9 (area 1 proton) and four peaks at 8.4–8.6 (12 protons), consistent with the assigned structure. On thin layer chromatography (pentane–ether, (10%) the bromo lactone moved as one spot.

Anal. Calcd. for $C_9H_{13}BrO_2$: C, 46.35; H, 5.62; Br, 34.3. Found: C, 46.60; H, 5.72; Br, 34.0.

2,2-Dimethyl-3-iodo-3-[1-hydroxy-1-methylethyl]cyclopropyl-1-carboxylic Acid Lactone (21).—To a solution of lead tetraacetate (376 mg., 1.0 mmole) and 2,2-dimethyl-3-isopropylidenecyclopropyl-1-carboxylic acid (200 mg., 1.3 mmoles) in carbon tetrachloride (10 ml.) was added dropwise a solution of iodine (330 mg., 1.3 mmoles) in carbon tetrachloride (50 ml.) under irradiation from a tungsten lamp. The solution was refluxed overnight and cooled, the solid was filtered, and the excess iodine was destroyed with 10% sodium thiosulfate solution. The carbon tetrachloride solution was washed once with water and dried, and the solvent was removed on a rotary evaporator. The residue was sublimed at 70° (1.5 mm.) and gave a yellow solid (200 mg., 52%, m.p. 67–68°). It exhibited the following spectra: infrared ($CHCl_3$), 5.68 μ; p.m.r., singlet at τ 8.0 (1 proton), singlet 8.33 (3 protons), singlet 8.53 (6 protons), and singlet 8.59 (3 protons), consistent with the above structure. Gas chromatography (5% SE 30, 220°) showed only one peak at 25 min.

Anal. Calcd. for $C_9H_{13}O_2I$: C, 38.59; H, 4.67; I, 45.3. Found: C, 38.96; H, 4.75; I, 44.84.

This lactone was also obtained using the following conventional technique. The unsaturated acid (1.54 g., 10 mmoles) was dissolved in 0.5 *N* sodium bicarbonate. A solution of iodine–potassium iodide, (2.54 g. of iodine, 10 mmoles; 1.66 g. of potassium iodide, 10 mmoles) was added, and the reaction mixture was kept for 24 hr. in the dark. The reaction mixture turned murky at the outset. The heterogeneous mixture was extracted with ether, and the ether was washed with water, 10% sodium thiosulfate, and water and dried over anhydrous sodium sulfate. The solvent was removed on a rotary evaporator. The residue solidified on cooling. The white crystalline material which formed (2.06 g., 73%, m.p. 69–71°) exhibited no depression in a mixture melting point with iodo lactone prepared by the previous procedure. Their infrared spectra were identical.

Reduction of 2,2-Dimethyl-3-iodo-3-[1-hydroxy-1-methylethyl]-cyclopropyl-1-carboxylic Acid Lactone to 2,2-Dimethyl-3-isopropylidenecyclopropyl-1-carboxylic Acid.—The iodo lactone (744 mg., 2.7 mmoles) was heated on a steam bath in glacial acetic acid (20 ml.) with zinc powder (1.3 g., 26 mmoles) for 1 hr. The zinc salts were filtered and the acetic acid was removed on a rotary evaporator. The residue was taken up in sodium bicarbonate and extracted with ether. Evaporation of the ether gave 340 mg. of unchanged iodo lactone, identified by superimposability of its infrared spectrum upon that of an authentic sample, and by mixture melting point. Neutralization and extraction of the aqueous layer gave 122 mg. of acid, which was sublimed to give 105 mg. (48% based on recovered iodolactone) of unsaturated acid **19**. A mixture melting point was undepressed.

Similar treatment of 2,2-dimethyl-3-bromo-3-[1-hydroxy-1-methylethyl]cyclopropyl-1-carboxylic acid lactone gave the unsaturated acid **19** (18% based on recovered bromo lactone).

Hydroxy Lactone 22 from Ethyl 2,2-Dimethyl-3-isopropylidenecyclopropyl-1-carboxylate.—Ethyl 2,2-dimethyl-3-isopropylidenecyclopropyl-1-carboxylate (1.0 g., 0.55 mmole) was dissolved in carbon tetrachloride (15 ml.) and to it was added a solution of bromine in carbon tetrachloride (88 mg., 0.55 mmole of bromine from a stock solution) with cooling. After the bromine was added, the solution was stirred an additional 15 min., and the carbon tetrachloride was removed on a rotary evaporator leaving 1.59 g. of a yellow residue; infrared spectrum (neat film), 5.69, shoulder 5.75 μ. This residue was stirred with aqueous lithium hydroxide (25 mg., 0.6 mmole) at 60°. Within 1 hr., the solution was neutral. The solution was stirred overnight, partially evaporated on a rotary evaporator, and extracted with ether. The ether layer was dried, and the ether was removed. The residue (260 mg., m.p. 92–115°) was recrystallized from ether giving white crystals (111 mg., 12%, m.p. 114–118°). An analytical sample was recrystallized three times from ethyl acetate–hexane and sublimed (85° at 0.35 mm.) giving material of m.p. 123–124°. It exhibited these spectra: infrared ($CHCl_3$), 3.0, 5.75, 6.15, 8–8.5 μ; p.m.r., singlet at τ 4.17 with an area equivalent to 1 proton, singlet at 7.02 (area 1 proton), and 2 singlets at 8.30 and 8.42 (each equivalent to 6 protons). The singlet at τ 7.02 disappeared on the addition of deuterium oxide.

Anal. Calcd. for $C_9H_{14}O_3$: C, 63.51; H, 8.29. Found: C, 63.50; H, 8.31.

Hydroxy Lactone 22 from Bromo Lactone 20.—The bromo lactone **20** (140 mg., 0.6 mmole) was stirred with an aqueous lithium hydroxide solution [25 mg. (monohydrate), 0.6 mmole] for 2 hr. at 60°. The still basic solution was extracted with ether, the ether extract was washed with water and dried, and the ether was removed. The residue (60 mg.) crystallized. It was sublimed at 80° (2 mm.), giving white crystals (30 mg., 30%, m.p. 120–122°). The mixture melting point with the hydroxy lactone **22** was undepressed, and their infrared spectra were superimposable.

1,1-Dibromo-2,2-dimethyl-3-isopropylidenecyclopropane (23).—In a four-necked, 500-ml. flask equipped with mechanical stirrer, nitrogen inlet, condenser, thermometer, and Gooche tubing connected to a 125-ml. erlenmeyer flask was placed tetramethylallene (80 g., 0.83 mole), pentane (50 ml.), and bromoform (96 g., 0.38 mole). The solution was cooled in an ice–acetone bath. To the cold solution was added, through the Gooche tubing, potassium *t*-butoxide (43.1 g., 0.38 mole), keeping the temperature below −3° at all times. The solution turned dark brown as the reaction progressed. After the base was added, the reaction mixture was stirred for an additional hour, diluted with pentane, and extracted with water.

The resultant mixture was dried over sodium sulfate and the mixed solvent (ether–tetramethylallene) was removed on a rotary evaporator. The brownish crystalline mass which remained was sublimed (40° at 2 mm.) giving, after an oily first fraction, white crystals (48 g., 47%, m.p. 44.0–44.5°). The dibromocyclopropane **23** exhibited these spectra: infrared (melt), 3.4, 5.6, 7.0, 7.5, 10.0, 11.5, and 13.5 μ; p.m.r., only three absorptions at τ 8.1 (3 protons), 8.2 (3 protons), and 8.58 (6 protons) consistent with the structure assigned.

Anal. Calcd. for $C_8H_{12}Br_2$: C, 35.83; H, 4.51; Br, 59.66. Found: C, 35.66; H, 4.63; Br, 59.54.

1-Bromo-2,2-dimethyl-3-isopropylidenecyclopropane (24).—In a 100-ml., three-necked flask equippped with thermometer, mechanical stirrer, nitrogen flow, and pressure-equalized dropping funnel was placed 1,1-dibromo-2,2-dimethyl-3-isopropylidenecyclopropane (13.4 g., 0.05 mole) in ether (50 ml.). To this solution was added, over a 1-hr. period, keeping the temperature below 40°, tri-*n*-butyltin hydride[27] (14.5 g., 0.05 mole) in ether (25 ml.). The mixture was stirred for an additional hour, the ether was removed on a rotary evaporator, and the residue was distilled to give a colorless liquid (6.94 g., 86%). Larger runs gave 80–90% yields. The monobromocyclopropane **24** was stored in sealed ampoules in the refrigerator. It quickly turned black when stored in the air at room temperature. It was unstable to silicic acid chromatography, turning black the moment it touched the column. It exhibited these spectra: infrared (neat film), 3.4, 5.59, 7.1, 7.5, 13.7, and 14.8 μ; p.m.r., multiplet at τ 6.7 (area 1 proton), doublet 8.2 (6 protons), and a doublet at 8.75 (area 6 protons) consistent with the above structure.

Anal. Calcd. for $C_8H_{13}Br$: C, 50.78; H, 6.92; Br, 42.2. Found: C, 50.55; H, 7.11; Br, 42.27.

The Reaction of 1-Bromo-2,2-dimethyl-3-isopropylidenecyclopropane with Silver Propionate.—1-Bromo-2,2-dimethyl-3-isopropylidenecyclopropane (1.27 g., 6.7 mmoles) was dissolved in carbon tetrachloride (15 ml.) and to the solution was added silver propionate[45] (1.21 g., 6.7 mmoles). The reaction mixture was refluxed in the dark for 5 hr. and allowed to cool. The silver bromide was filtered and washed with ether, and the solvent was removed on a rotary evaporator. The residue (1.25 g., 100%) exhibited infrared absorption (neat film) at 3.4, 5.1, 5.76, 8.4, and 9.0 μ.

Chromatography on activity III alumina gave 750 mg. of a sweet-smelling, colorless liquid with essentially the same infrared spectrum. It exhibited these additional spectra: p.m.r., multiplet at τ 4.70 (area 1 proton), quartet 7.85 (2 protons), doublet 8.32 (6 protons), doublet 8.58 (6 protons), and a triplet at 8.95 (3 protons); ultraviolet, λ_{max}^{EtOH} 230 sh mμ (ϵ 1100).

Anal. Calcd. for $C_{11}H_{18}O_2$: C, 72.49; H, 9.96. Found: C, 71.99; H, 9.92.

The absorption at 5.10 μ in the infrared is characteristic of allenes.[30] On the basis of this absorption and the additional spectral data, this compound is assigned the structure 2,5-dimethyl-5-propionoxy-2,3-hexadiene (**25**).

(45) A. Vogel, ref. 40, p. 376.

Displacements with silver propionate in acetonitrile, tetrahydrofuran, toluene, benzene, as well as displacements with sodium iodide–potassium propionate in acetone or acetone–dimethoxyethane gave the same product in poorer yields. Reaction with propionic acid–potassium propionate gave a complex mixture. No trace of 2,2-dimethyl-3-isopropylidenecyclopropyl propionate was found under any of these conditions.

An earlier fraction eluted from alumina (60 mg., b.p. 80° at 35 mm.) when the displacement was carried out in acetonitrile exhibited the following spectra: infrared (neat film), 6.15, 7.0, 7.3, 9.3, 9.9, 11.8, and 13.5 μ; p.m.r., singlet at τ 4.3 (area 1 proton) and 4 sharp peaks at 8.1–8.4 (area 12 protons); ultraviolet, λ_{max}^{EtOH} 210 mμ (ϵ 11,500).

Anal. Calcd. for $C_8H_{13}Br$: C, 50.78; H, 6.92; Br, 42.28. Found: C, 51.06; H, 7.06; Br, 42.35.

Chromatography of the crude reaction mixture on silicic acid with pentane–ether (5%) gave a different ester which exhibited these spectra: infrared (neat film), 3.4, 5.71, 6.0 (w), 7.0, 8.8 μ; p.m.r., multiplet at τ 4.45 (1 proton), quartet 7.7 (2 protons), 3 peaks at 8.25–8.5 (12 protons), and a triplet at 8.88 (3 protons); ultraviolet, λ_{max}^{EtOH} 220 mμ (ϵ 4500). This material was unstable to gas chromatography and recoveries were poor when it was rechromatographed on silicic acid.

Anal. Calcd. for $C_{11}H_{18}O_2$: C, 72.49; H, 9.96. $C_{11}H_{18}O_3$: C, 66.69, H, 9.09. Found: C, 65.29, 66.93, 70.92; H, 9.02, 9.18, 9.25.

This ester could also be prepared by chromatographing 2,5-dimethyl-5-propionoxy-2,3-hexadiene (**25**) on silicic acid and by heating this allenic ester in a sealed tube (excluding oxygen) at 100° for 5 hr. Although the analytical figures point to an empirical formula of $C_{11}H_{18}O_3$, the only structure that is consistent with this formula and the p.m.r. spectrum is that of 2,5-dimethyl-3-peroxypropionoxy-2,4-hexadiene. This unknown ester did not give values which differed significantly from the blank when it was titrated as a perester by the method of Sibert and Swern.[46] Peroxy esters are also known to absorb at 5.63 μ in the infrared.[47] These data indicate that the ester may be 2,5-dimethyl-3-propionoxy-2,4-hexadiene (**26**), the Cope rearrangement product of 2,5-dimethyl-5-propionoxy-2,3-hexadiene (**25**).

Lead Tetraacetate Oxidation of 22.—To a solution of 0.63 g. (0.004 mole) of acid **19** in 16 ml. of dry benzene and 0.48 (0.006 mole) of dry pyridine under nitrogen was added 3.29 g. (0.008 mole) of lead tetraacetate. The mixture was stirred and refluxed under nitrogen for 4 hr. The resulting yellow reaction mixture was cooled, filtered through a column of 54 g. of alumina (activity II, prepared in ether), and eluted with 150 ml. of ether. The total eluent was washed with 1 *N* sodium hydroxide, saturated aqueous sodium chloride, 1 *N* hydrochloric acid, and saturated aqueous sodium chloride and dried over sodium sulfate.

After evaporation of the solvent, the residue was chromatographed through a column of 30 g. of Woelm alumina (activity I). The first fraction obtained was eluted wth petroleum ether–benzene (3:1), and consisted of 0.10 g. of a yellow oil: infrared spectrum (CCl_4), 5.71 μ; p.m.r., τ 8.07, 8.27, 8.88, and 8.97 (1:2:1:1) compatible with the five methyl groups of the desired product. However, further purification of this oil was unsuccessful.

The major fraction, 0.24 g. of oily solid isolated from the benzene–ether (3:1) eluate, was the acetate of lactone **22** (35% yield): infrared spectrum (CCl_4), 5.71 and 5.78 μ; p.m.r., identical with that of the hydroxy lactone **22** with the additional acetoxyl resonance at τ 8.05. In a similar experiment, lead tetrapropionate[48] was used in place of lead tetraacetate. No identifiable product was isolated.

(46) L. S. Silbert and D. Swern, *Anal. Chem.*, **30**, 385 (1958).

(47) L. J. Durham, L. Glover, and H. S. Mosher, *J. Am. Chem. Soc.*, **82**, 1509 (1960); P. D. Bartlett and R. R. Hiatt, *ibid.*, **80**, 1398 (1958).

(48) R. Criegee, *Ann.*, **481**, 263 (1930).