Anal. Calcd. for $C_6H_{12}O_2$: C, 62.04; H, 10.42. Found: C, 62.35; H, 10.55.

Ditosylate of *cis*-1,3-Bis(hydroxymethyl)cyclobutane (16).—To a cold solution of 6.9 g. of *p*-toluenesulfonyl chloride in 20 ml. of pyridine was added 1.8 g. of diol **15**. After standing overnight at room temperature, the mixture was poured onto ice–water and the crystals of ditosylate were collected. Recrystallization from hexane–acetone yielded 4.2 g. (77%), m.p. 76.5–77.5°.

Anal. Calcd. for $C_{20}H_{24}O_6S_2$: C, 56.58; H, 5.70. Found: C, 56.66; H, 5.72.

***cis*-1,3-Dimethylcyclobutane (17).**—A solution of 4.2 g. of the ditosylate of *cis*-1,3-bis(hydroxymethyl)cyclobutane in 15 ml. of anhydrous ether was added dropwise to a stirred solution of 5.7 g. of lithium aluminum hydride in 50 ml. of anhydrous ether. Stirring was continued for 5 hr. and the solution was hydrolyzed with dilute hydrochloric acid. The ether layer was dried and most of the ether was carefully removed by slow distillation through a 14-cm. Vigreux column.

A sample consisting of a mixture of *cis*- and *trans*-1,3-dimethylcyclobutane was prepared in analogous fashion by utilizing a mixture of *cis*- and *trans*-dimethyl 1,3-cyclobutanedicarboxylate as starting material. This hydrocarbon mixture was found to be partially separated by v.p.c. (1,2,3-β-cyanoethoxypropane) at 25°. The material which was eluted first was found to be the *cis* isomer by comparison with that obtained in the previously described stereospecific syntheses. This indicates that the *cis*-1,3-dimethylcyclobutane is in fact the lower boiling isomer, and the previously reported *cis* and *trans* structures assigned earlier should be reversed. (Kazanskii and Lukina[9] give *trans*, b.p. 57.4–57.6°, $n^{20}D$ 1.3896, d^{20}_4 0.7016; *cis*, b.p. 60.5–60.6°, $n^{20}D$ 1.3933, d^{20}_4 0.7106.)

Acknowledgment.—The authors are indebted to Dr. E. R. Buchman for his kindness in furnishing details regarding some of the experimental procedures described herein, to Professor J. M. Conia for a sample of 3-methylcyclobutanecarboxylic acid, and to Professor K. Wiberg for a sample of 1,3-cyclobutanedicarboxylic acid.

Nucleophilic Ring-Opening Additions to 1,1-Disubstituted Cyclopropanes

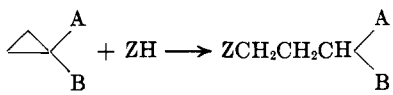
J. M. STEWART AND H. H. WESTBERG

Department of Chemistry, University of Montana, Missoula, Montana

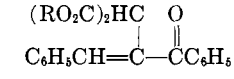
Received January 12, 1965

Ring-opening addition reactions have been found to take place between various nucleophilic reagents and a series of cyclopropane compounds substituted at one carbon of the ring by two electron-withdrawing groups. These reactions result in 1,1,3-trisubstituted propanes.

As part of a general study of the ring-opening addition reactions of nucleophilic reagents with cyclopropane compounds having one or more electron-withdrawing substituents on the ring, initial investigations were carried out with cyclopropanes substituted at the same ring carbon by *two* such groups. The cyclopropane ring behaves in a manner analogous to that of an alkene linkage substituted on one carbon by one or more electron-withdrawing groups; ring cleavage occurs adjacent to the substituted carbon, and addition of the nucleophile leads to 1,1,3-trisubstituted propanes as follows. Although a few isolated



instances of such behavior have been reported,[1-5] there have been no reported systematic studies of reactions of this type, and the universal nature of such reactions has not been recognized. Bone and Perkin,[1] in the preparation of diethyl cyclopropane-1,1-dicarboxylate by condensation of ethylene bromide and diethyl malonate in the presence of sodium ethoxide, demonstrated clearly that a by-product, tetraethyl 1,1,4,4-butanetetracarboxylate, was formed by a ring-opening reaction between the desired product and the malonate anion. Kierstad, *et al.*,[2] observed the same reaction and described an analogous reaction between diethyl 2-vinylcyclopropane-1,1-dicarboxylate and diethyl sodiomalonate. Kohler and Conant[3] reported that various anhydrous basic solutions reacted with compounds of the type, 1-$(CO_2R)_2$-2-C_6H_5-3-COC_6H_5-*c*-C_3H_2 (*c*-C_3H_n refers to a cyclopropane ring), to form the isomeric unsaturated structure that is shown.

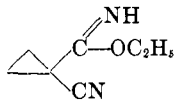


However, they described only a reaction involving sodium methoxide in methanol in which they proposed that an addition reaction first occurred, with ring opening between C-1 and 2, followed by loss of methyl alcohol to form the unsaturated product. (It has been pointed out by a referee, however, that this product could have been formed by an alternate route involving a base-catalyzed abstraction of a proton from position 3, followed by a conjugate shift of electrons from that position to position 1.) Truce and Lindy[4] reported ring opening of methyl cyclopropyl ketone by sodium benzene thiolate to give $C_6H_5SCH_2CH_2CH_2COCH_3$, and Regan[5] assigned the propenide structure, $[(CN)_2C{=}C(CO_2Et)C(CN)_2]^-NH_4$, to the product formed on reaction of diethyl 2,2,3,3,-tetracyanocyclopropane-1,1-dicarboxylate with ammonia in ether solution.

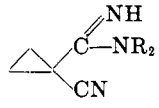
The cyclopropane compounds used in this investigation were diethyl cyclopropane-1,1-dicarboxylate, ethyl 1-cyanocyclopropane-1-carboxylate, 1-cyanocyclopropane-1-carboxamide, cyclopropane-1,1-dicarboxamide, and cyclopropane-1,1-dicarbonitrile. All are previously reported compounds except cyclopropane-1,1-dicarbonitrile, which was prepared by dehydration of either cyclopropane-1,1-dicarboxamide or 1-cyanocyclopropane-1-carboxamide with phosphorus pentoxide. A number of attempts were made to prepare cyclopropane-1,1-dicarbonitrile by a Perkin-type ring-closure condensation between malononitrile and ethylene bromide in the presence of the basic catalysts, sodium ethoxide or methoxide or sodium

(1) W. A. Bone and W. H. Perkin, *J. Chem. Soc.*, **67**, 108 (1895).
(2) R. W. Kierstad, R. P. Linstead, and B. C. L. Weedon, *ibid.*, 3616 (1952).
(3) E. P. Kohler and J. P. Conant, *J. Am. Chem. Soc.*, **39**, 1406 (1917).
(4) W. E. Truce and L. B. Lindy, *J. Org. Chem.*, **26**, 1463 (1961).
(5) T. H. Regan, *ibid.*, **27**, 2236 (1962).

hydride, and in a variety of solvents. Only a very low yield was obtained in any of these attempts. In experiments of this type in which ethylene bromide was added to a solution of the monosodium salt of malonitrile in absolute ethanol and the solution was then heated to boiling, the product formed in largest amount was ethyl 1-cyanocyclopropane-1-imidocarboxylate (I).



I would appear to have been formed either by intermediate formation of the desired cyclopropane-1,1-dicarbonitrile, followed by addition of a molecule of ethanol to one of the nitrile groups, or by addition of one molecule of ethanol to one of the nitrile groups of malonitrile to form ethyl cyanoimidoacetate, $NCCH_2C(OC_2H_5)=NH$, followed by condensation with ethylene bromide. Ethyl cyanoimidoacetate was indeed the second major product isolated from this reaction. Its structure was demonstrated by elemental analysis, infrared spectral evidence, and comparison of its physical properties to known values.[6] The structure, ethyl 1-cyanocyclopropane-1-imidocarboxylate, was assigned to I on the basis of its facile hydrolysis in dilute hydrochloric acid to ethyl 1-cyanocyclopropane-1-carboxylate, which in turn was readily converted by aqueous ammonia to 1-cyanocyclopropane-1-carboxamide. An infrared spectrum showed absorption peaks at 3.02 and 6.07 μ, characteristic of the >C=NH group; at 4.48 μ, characteristic of the nitrile group; and at 3.48, 9.78, and 10.31 μ, characteristic of cyclopropane rings. Compound I on mild treatment with the secondary amines, piperidine and dimethyl amine, was readily converted to amidines.



All of the listed cyclopropanes underwent ring-opening addition reactions when heated with secondary amines, either with or without solvents. For example, diethyl cyclopropane-1,1-dicarboxylate and piperidine, heated 20 hr. at 102°, gave diethyl 2-(piperidino)-ethylmalonate (II). To demonstrate unequivocally that ring opening had occurred, diethyl 2-(piperidino)-ethylmalonate was prepared from 2-(piperidino)ethyl chloride and diethyl malonate as described by Goldhahn,[7] and this product was compared to II. The two had very similar boiling points and refractive indices and identical infrared spectra. Each was converted to a diamide melting at 194–196° and a mixture melting point determination showed no depression. The same diamide, $c\text{-}C_5H_{10}N\text{-}CH_2CH_2CH(CONH_2)_2$ (where $c\text{-}C_5H_{10}N$ refers to a piperidinyl group), was also obtained by the direct ring-opening reaction between cyclopropane-1,1-dicarboxamide and piperidine, boiling in absolute ethanol for 100 hr. The structure of the product formed by reaction of ethyl 1-cyanocyclopropane-1-carboxylate and piperidine was also demonstrated unequivocally and shown to be ethyl 2-cyano-4-piperidinobutanoate by means of independent synthesis from 2-(piperidino)ethyl chloride and ethyl cyanoacetate in the presence of sodium ethoxide. The two products each formed 2-cyano-4-piperidinobutanamide on treatment with aqueous ammonia, and this same amide was also obtained by a direct ring-opening reaction between 1-cyanocyclopropane-1-carboxamide and piperidine.

A detailed study was made of the effects of temperature and time of reaction and of the effects of various solvents on the rate of the reaction between piperidine and diethyl cyclopropane-1,1-dicarboxylate, and on the yields of addition compound. In all solvents used, the reaction rate increased markedly when the temperature was increased from 78 to 102°. The rate was much slower in nonpolar solvents such as benzene than in ethanol. Best results were obtained either with absolute ethanol as solvent or with no solvent. The best yield (73%) was obtained using a 100% molar excess of the amine, no other solvent, and a temperature of 102° for 20 hr. Longer reaction times in the presence of excess amine resulted in lower yields of the addition compound, apparently due to further reaction of piperidine with the ester groups to give piperidides. In one series of experiments in which dimethyl formamide was employed as solvent in this reaction, ring opening occurred, but a further exchange reaction apparently also took place between the amide structure of the solvent and the ester groups to give $c\text{-}C_5H_{10}N\text{-}CH_2CH_2CH(CO_2C_2H_5)CON(CH_3)_2$ and $c\text{-}C_5H_{10}N\text{-}CH_2CH_2CH[CON(CH_3)_2]_2$. The infrared spectrum of each exhibited an amide I band at 6.05 μ and the three absorption peaks between 3.5 and 3.6 μ exhibited by all products of ring-opening reactions between the substituted cyclopropanes and secondary amines. These are attributed to the $>N\text{-}CH_2\text{-}$ grouping. In addition a carboxyl absorption peak at 5.75 μ was found only in the compound assumed to contain an ester group. Elemental analyses confirmed these structures.

When cyclopropane-1,1-dicarbonitrile was treated with secondary amines, ring-opening addition was accomplished with a fair yield only when ethanol was used as solvent and at room temperature or below. It appears that with nonpolar solvents and at higher temperatures a different type of addition reaction may occur. Under the influence of the other electron-withdrawing group on the same carbon, one or both of the nitrile groups can add a molecule of amine to form amidine groups. This type of reaction has been previously demonstrated for malonitrile[8,9] and for cyanogen.[10] No simple amidine compounds were isolated during our investigation. Attempted distillations gave only resinous residues which may have resulted from polymerization of the initial amidine type of products. Further study of this type of addition reaction is in progress. The structure of the simple addition compounds formed in *ethanol* was clearly indicated to be the open-chain form, $R_2NCH_2CH_2CH(CN)_2$, and not an amidine, by their infrared spectra. There were no absorption peaks around 3.0

(6) S. M. McElwain and J. P. Schroeder, *J. Am. Chem. Soc.*, **71**, 40 (1949).

(7) H. Goldhahn, *Acta chim. Acad. Sci. Hung.*, **18**, 395(19 59); *Chem. Abstr.*, **54**, 550 (1960).

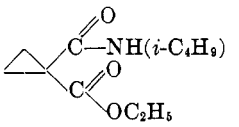
(8) Schmidtmann, *Ber.*, **29**, 1168 (1896).

(9) L. J. Exner, M. J. Hurwitz, and P. L. de Benneville, *J. Am. Chem. Soc.*, **77**, 1103 (1955).

(10) H. M. Woodburn, B. A. Morehead, and T. Bonner, *J. Org. Chem.*, **14**, 555 (1949).

μ, indicative of –C=NH groups, nor any around 6.1 μ, indicative of –C=N–. Three absorption peaks between 3.5 and 3.6 μ indicated the presence of a tertiary amine group.

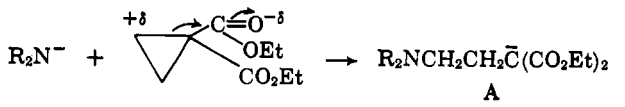
Primary amines, under the same conditions as described for secondary amines, did not give simple addition compounds with diethyl cyclopropane-1,1-dicarboxylate or ethyl 1-cyanocyclopropane-1-carboxylate. Use of excess amine, longer reaction time, and higher temperature (150°), or use of a basic catalyst, Triton B, did not result in any ring opening. Instead, preferential attack of the amine with the ester groups resulted, leading to N-substituted amides with retention of the cyclopropane ring. Refluxing the diester with isobutylamine for 20 hr. and distillation led to recovery of 50% of the starting diester and a higher boiling substance, shown to be as follows



by elemental and spectral analysis; the infrared spectrum shows two carbonyl absorptions, one for the ester (5.85 μ) and one for the amide (6.02 μ), together with an amide II band at 6.50 μ. From the reaction of the diester with cyclohexylamine, two products were finally isolated and identified by means of elemental analyses and infrared spectra as the mono- and the diamide, in which one or both ethoxy groups in the starting ester had been replaced by cyclohexylamine groups.

Ring-opening addition reactions of diethyl cyclopropane-1,1-dicarboxylate with *n*-butyl mercaptan, thiophenol, and phenol occurred only in the presence of a basic catalyst. Sodium ethoxide or commercial sodium methoxide (dissolved in absolute ethanol) and the reactants were sealed in test tubes under argon and heated at 110° for 20 hr. Best yields of the phenol and thiophenol products were obtained when a molar amount of catalyst equivalent to one-tenth that of the diester was used with a 50% molar excess of phenol or thiophenol. When butyl mercaptan was the nucleophile, the amount of catalyst could be varied from one-tenth to an equal molar amount compared to the diester with very little effect on yield. The products were known compounds and their structures were further confirmed by elemental analysis and by their infrared spectra.

A reasonable mechanism for these reactions might be postulated as involving an initial nucleophilic attack at one of the β-carbons of the ring and ring opening between this carbon and the α-carbon to form an open-chain anion. Hydrogen exchange could then occur between the nucleophile and this anion to give the observed product. For example in the reaction of a secondary amine and diethyl cyclopropane-1,1-dicarboxylate, these steps would be as follows.



$$A + R_2NH \longrightarrow R_2NCH_2CH_2CH(CO_2Et)_2 + R_2N^-$$

Table I lists the products of the reactions described above, their physical properties, and analytical data.

TABLE I

REACTIONS OF 1,1-DISUBSTITUTED CYCLOPROPANES AND NUCLEOPHILES

Reactants	Addition product	Formula	Yield, %	B.p. (mm.) or m.p., °C.	n_D (°C.)	Carbon, %[a] Calcd.	Carbon, %[a] Found	Hydrogen, %[a] Calcd.	Hydrogen, %[a] Found
c-C_3H_4-$(CO_2Et)_2$ + diethylamine	Diethyl 2-(diethylamino)ethylmalonate	$C_{13}H_{25}NO_4$	40	101 (0.3)[b]	1.4391 (20)	60.19	59.81	9.37	9.32
+ piperidine	Diethyl 2-(piperidino)ethylmalonate	$C_{14}H_{23}NO_4$	73	132–134 (1.5)[b]	1.4595 (20)				
+ *n*-butyl mercaptan	Diethyl 2-(butylthio)ethylmalonate	$C_{13}H_{24}O_4S$	58	127–129 (0.6)[c]	1.4602 (25)	56.49	56.35	8.76	8.84
+ thiophenol	Diethyl 2-(phenylthio)ethylmalonate	$C_{15}H_{20}O_4S$	54	153–154 (0.3)[d]	1.5158 (29)	60.78	60.67	6.80	6.59
+ phenol	Diethyl 2-(phenoxy)ethylmalonate	$C_{15}H_{20}O_5$	60	141–142 (0.3)[e]	1.4862 (27)	64.27	64.10	7.18	7.36
c-C_3H_4-$(CN)_2$ + dimethylamine	2-(Dimethylamino)ethylmalononitrile[f]	$C_7H_{11}O_2$	30	69–70 (0.5)	1.4420 (25)	61.28	61.12	8.08	8.14
+ piperidine	2-(Piperidino)ethylmalononitrile[g]	$C_{10}H_{15}N_3$	36	102–103 (0.5)	1.4675 (28)	67.76	67.62	8.48	8.70
c-C_3H_4-1-CN-1-CO_2Et + piperidine	Ethyl 2-cyano-4-piperidinobutanoate	$C_{12}H_{20}N_2O_2$	43	109–111 (0.3)	1.4668 (20)	64.24	64.29	9.00	9.21
c-C_3H_4-1-CN-1-$CONH_2$ + piperidine	2-Cyano-4-piperidinobutanamide	$C_{10}H_{17}N_3O$	49	128–130		61.49	61.25	8.79	8.61
c-C_3H_4-$(CONH_2)_2$ + piperidine	2-(Piperidino)ethylmalonamide	$C_{10}H_{19}N_3O_2$	45	194–196		56.30	56.36	8.98	9.01

[a] Analyses were by Galbraith Laboratories, Knoxville, Tenn. [b] Ref. 7. [c] K. Hagashi [*Chem. Pharm. Bull.* (Tokyo), **8**, 177 (1963); *Chem. Abstr.*, **55**, 7304 (1961)] reported b.p. 185° (20 mm.). [d] S. Lamdan and D. Albarracin [*Safybi*, **1**, 41 (1959); *Chem. Abstr.*, **54**, 14234 (1960)] reported b.p. 180–195° (3 mm.). [e] H. Leuchs [*Ber.*, **44**, 1509 (1911)] reported b.p. 193–195° (12 mm.). [f] Hydrochloride m.p. 160–162°. [g] Hydrochloride m.p. 191–192°.

Experimental

Diethyl Cyclopropane-1,1-dicarboxylate.—The most successful preparations followed the method described by Dox and Yoder[11] and resulted in yields of 40–50% of product after two distillations, b.p. 201–203° (690 mm.) and 111–115° (20 mm.), $n^{20}D$ 1.4315 [lit.[11] b.p. 214–215° (748 mm.)]. This product, however, proved to contain still some diethyl malonate and a new method of purification was developed to remove it. The impure material was mixed with an amount of *n*-butylamine calculated to provide a slight molar excess over the amount of diethyl malonate estimated to be present. This mixture was heated at reflux temperature for 2 hr. and then cooled in a refrigerator overnight. A crystalline solid which had precipitated was removed by filtration and found to be N,N'-dibutylmalonamide, m.p. 131–133° after recrystallization from ethyl acetate (lit.[12] m.p. 130°). The filtrate was then distilled to give diethyl cyclopropane-1,1-dicarboxylate, b.p. 122–125° (22 mm.), $n^{20}D$ 1.4350.

Ethyl 1-Cyanocyclopropane-1-carboxylate.—A number of modifications of the reaction of ethyl cyanoacetate with ethylene bromide in the presence of sodium ethoxide were tried but the most successful were those following the procedure developed by Jones and Scott.[13] The product, obtained in 80% yields, b.p. 115–118° (15 mm.), $n^{20}D$ 1.4339, was found to contain unreacted starting ester as in the case of the preparation of diethyl cyclopropane-1,1-dicarboxylate. It was removed by reaction with *n*-butylamine as described above to form N-butylcyanoacetamide, m.p. 70–71° after recrystallization from carbon tetrachloride (lit.[14] m.p. 73°). The purified ethyl 1-cyanocyclopropane-1-carboxylate distilled at 110° (10 mm.), $n^{20}D$ 1.4380.

Cyclopropane-1,1-dicarboxamide was prepared by shaking a mixture of diethyl cyclopropane-1,1-dicarboxylate and five times its volume of concentrated aqueous ammonia for 24 hr., following the method of Dox and Yoder.[11] One recrystallization from water gave colorless crystals, m.p. 194–195° (lit.[11] m.p. 192–194°).

1-Cyanocyclopropane-1-carboxamide was prepared from ethyl 1-cyanocyclopropane-1-carboxylate and concentrated aqueous ammonia,[15] and one recrystallization from water gave colorless crystals, m.p. 158–160° (lit.[15] m.p. 160°).

Cyclopropane-1,1-dicarbonitrile. A. By Dehydration of Cyclopropane-1,1-dicarboxamide.—A mixture of 8.6 g. (0.067 mole) of cyclopropane-1,1-dicarboxamide and 10 g. (0.07 mole) of phosphorus pentoxide was mixed throughly by shaking and heated in a 125-ml. Claisen distilling flask at 20-mm. pressure. At about 180° a sudden reaction began and a colorless liquid distilled. Extreme swelling of the reaction mixture forced cessation of the process. The distillate was redistilled to give 2 g. (33%) of product, b.p. 103° (20 mm.), $n^{25}D$ 1.4463.

Anal. Calcd. for $C_5H_4N_2$: C, 65.20; H, 4.37. Found: C, 65.42; H, 4.46.

The infrared spectrum of cyclopropane-1,1-dicarbonitrile in carbon tetrachloride solution showed peaks at the following wave lengths in μ: 3.22 (w), 4.45 (m–s), 7.0 (m), 7.83 (m), 7.98 (w), 9.20 (m), 9.46 (m), 10.32 (s), 10.44 (m–s).

B. By Dehydration of 1-Cyanocyclopropane-1-carboxamide.—A mixture of 7.3 g. (0.066 mole) of the amide and 10 g. (0.07 mole) of phosphorus pentoxide was shaken well and then heated in a 125-ml. Claisen flask at 20-mm. pressure. At 160° a reaction began and a colorless liquid distilled. The mixture in the flask was raised to a final temperature of 210°. About 3 g. (50%) of crude product was obtained. Redistillation gave 2.3 g. (38%) of cyclopropane-1,1-dicarbonitrile, b.p. 90° (10 mm.), $n^{20}D$ 1.4491.

Ethyl 1-Cyanocyclopropane-1-imidocarboxylate (I). Condensation of Malononitrile and Ethylene Bromide in the Presence of Sodium Ethoxide.—To a cooled solution of 15 g. (0.65 g.-atom) of sodium in 270 ml. of absolute ethanol in a 1-l. three-necked flask equipped with stirrer, condenser, and dropping funnel was added dropwise with stirring a solution of 41 g. (0.62 mole) of malononitrile in 65 ml. of absolute ethanol. This solution was again cooled, and 69.5 g. (0.37 mole) of ethylene bromide was added rapidly through the dropping funnel. The mixture was then heated rapidly by a preheated water bath with stirring and at 70° an exothermic reaction began. After the reaction had subsided, the mixture was heated at reflux temperature for an hour. It was then cooled and filtered to remove precipitated sodium bromide. Most of the ethanol was removed by distillation with stirring, the residue was cooled, 250 ml. of ether was added, and a further precipitate of sodium bromide was removed by filtration. Stripping of the ether under reduced pressure left 51 g. of red liquid and distillation gave 23 g. of colorless distillate, b.p. 87–90? (12 mm.). When this distillate was cooled overnight in the refrigerator, a precipitate formed which after filtration and drying yielded 7 g. of colorless crystals. After two recrystallizations from benzene, this product melted at 77–78.5° and was proved to be ethyl cyanoimidoacetate by comparison with the reported melting point of this compound (lit.[8] m.p. 78–79°) and its elemental analysis.

Anal. Calcd. for $C_5H_8N_2O$: C, 53.57; H, 7.14. Found: C, 53.51; H, 7.22.

It readily hydrolyzed in cold 1 *N* hydrochloric acid to give ethyl cyanoacetate, which in turn was converted by aqueous ammonia to cyanoacetamide.

The liquid portion of the product mixture was redistilled and five arbitrary distillation fractions were taken, all b.p. 84–85° (10 mm.), but varying in refractive index. The three middle fractions were again distilled with similar results. A center fraction from this distillation, $n^{22}D$ 1.4645, proved to be slightly impure on the basis of elemental analysis (*Anal.* Calcd. for $C_7H_{10}N_2O$: C, 60.86; H, 7.29; N, 20.30. Found: C, 59.94; H, 7.15; N, 21.24.) and was assumed to contain still some ethyl cyanoimidoacetate. However, it was shown to be ethyl 1-cyanocyclopropane-1-imidocarboxylate (I) by hydrolysis in cold 1 *N* hydrochloric acid to give ethyl 1-cyanocyclopropane-1-carboxylate, which was converted by aqueous ammonia to 1-cyanocyclopropane-1-carboxamide, m.p. 158–159° after recrystallization from water. A mixture melting point determination of this amide and an authentic sample of 1-cyanocyclopropane-1-carboxamide showed no depression.

The infrared spectrum of I in carbon tetrachloride solution showed peaks at the following wave lengths in μ: 3.02 (m), 3.48 (m), 4.48 (m), 4.59 (w), 6.07 (s), 6.32 (m), 6.78 (m), 6.94 (m), 7.11 (m), 7.29 (s), 7.49 (s), 7.90 (s), 8.18 (s), 8.53 (m), 9.2 (s, broad), 9.55 (m), 9.78 (m), 10.31 (s), 11.65 (m), 14.23 (m).

General Procedure for Reaction of 1,1-Disubstituted Cyclopropanes with Amines.—A mixture of the cyclopropane compound and the amine in varying molar ratios (but generally with the amine in 2:1 molar excess) and with or without various solvents was heated for a usual 20-hr. period. The temperature was determined by the reflux temperature of the solvent or amine or, if higher temperatures were desired, the reactions were carried out in a hydrogenation-type bomb and heater. The products were purified by several distillations.

Table I lists the compounds and their physical properties and analytical data obtained from ring-opening addition reactions of secondary amines and various 1,1-disubstituted cyclopropanes.

A. Reaction of Piperidine with Diethyl Cyclopropane-1,1-dicarboxylate in Dimethylformamide (DMF).—A mixture of 4.2 g. (0.023 mole) of diethyl cyclopropane-1,1-dicarboxylate, 3.9 g. (0.046 mole) of piperidine, and 15 ml. of DMF was heated at reflux temperature for 20 hr. Following removal of DMF by distillation under reduced pressure, two higher boiling fractions were collected. Fraction 1 was assumed to be *c*-$C_5H_{10}N$-CH_2-$CH_2CH(CO_2C_2H_5)CON(CH_3)_2$, b.p. 72–73° (1 mm.), $n^{20}D$ 1.4777.

Anal. Calcd. for $C_{14}H_{26}N_2O_3$: C, 62.18; H, 9.71. Found: C, 61.93; H, 9.78.

Fraction 2 was assumed to be *c*-$C_5H_{10}N$-$CH_2CH_2CH[CON(CH_3)_2]_2$, b.p. 178–182° (1 mm.), $n^{20}D$ 1.4872.

Anal. Calcd. for $C_{14}H_{27}N_3O_2$: C, 62.40; H, 10.12. Found: C, 63.17; H, 9.80.

Further evidence for the indicated structures of these two products is based on their infrared absorption spectra as described in the discussion section of this paper.

B. Reactions of Diethyl Cyclopropane-1,1-dicarboxylate with Primary Amines.—Very little reaction of any sort took place if solvents were used in these reactions. When the amine and the ester were heated without solvent for 20 hr. at reflux temperatures, small amounts of amides formed by reaction of the amine with one or both of the ester groups were obtained. No ring-opened products were isolated.

(1) **Product with isobutylamine** was assumed to be 1-$CO_2C_2H_5$-1-CON-*i*-C_4H_9-*c*-C_3H_4, b.p. 105–108° (1 mm.), $n^{27}D$ 1.4572.

(11) A. W. Dox and L. Yoder, *J. Am. Chem. Soc.*, **43**, 2097 (1921).
(12) E. A. Pauw, *Rec. trav. chim.*, **55**, 215 (1936).
(13) L. W. Jones and A. W. Scott, *J. Am. Chem. Soc.*, **44**, 413 (1922).
(14) K. G. Naik and L. D. Shah, *J. Indian Chem. Soc.*, **8**, 29 (1931); *Chem. Abstr.*, **25**, 3619 (1931).
(15) W. H. Perkin and H. C. H. Carpenter, *J. Chem. Soc.*, **75**, 925 (1899).

Anal. Calcd. for $C_{11}H_{19}NO_3$: C, 61.93; H, 8.98. Found: C, 61.90; H, 9.05.

(2) **Product with *n*-butylamine** was assumed to be 1-$CO_2C_2H_5$-1-CONH-*n*-C_4H_9-*c*-C_3H_4, b.p. 115–120° (1 mm.), $n^{24}D$ 1.4572.

Anal. Calcd. for $C_{11}H_{19}NO_3$: C, 61.93; H, 8.98; N, 6.57. Found: C, 60.42; H, 8.93; N, 6.31.

(3) **Products with Cyclohexylamine.** (a) **Monoamide** was assumed to be 1-$CO_2C_2H_5$-1-$CONHC_6H_{11}$-*c*-C_3H_4, b.p. 165–172° (1 mm.), $n^{24}D$ 1.4944.

Anal. Calcd. for $C_{13}H_{21}NO_3$: C, 65.23; H, 8.86. Found: C, 65.11; H, 8.96.

(b) **Diamide** was assumed to be *c*-C_3H_4-$(CONHC_6H_{11})_2$, m.p. 130–132° (from 3:1 water–ethanol).

Anal. Calcd. for $C_{17}H_{28}N_2O_2$: C, 69.80; H, 9.67. Found: C, 69.76; H, 9.46.

Further evidence for the indicated structures of these products from primary amines is based on their infrared absorption spectra as described in the discussion section of this paper.

Reactions of Diethyl Cyclopropane-1,1-dicarboxylate with *n*-Butylmercaptan, with Thiophenol, and with Phenol.—These reactions were all performed in essentially the same way. A solution of sodium ethoxide was prepared from an amount of sodium equivalent to from 0.1 molar to an equimolar amount compared to the amount of ester used. To this solution was added an excess of the mercaptan, thiophenol, or phenol, and then the diester. The mixture was then heated at reflux for 7 hr. in the case of *n*-butyl mercaptan and thiophenol, and in a sealed tube at 110° for 24 hr. in the case of phenol. Best results were obtained with an equimolar amount of sodium for the butyl mercaptan reaction and with a 0.1 molar equiv. of sodium in the other two reactions. Ethanol was stripped from the product mixtures, and the residue was cooled and dissolved in ether. The ether solution was washed twice with water, twice with 5% sodium hydroxide, and once more with water, and dried over anhydrous magnesium sulfate. The product was obtained pure after two distillations. Physical properties and analytical data for these compounds are listed in Table I.

The infrared spectra of these compounds in carbon tetrachloride solution showed the following peaks with wave lengths in μ: (1) diethyl 2-(butylthio)ethylmalonate, 3.4 (s), 5.75 (s, br), 6.82 (m), 6.91 (m), 7.19 (w), 7.30 (m), 7.47 (m), 7.70 (s), 8.07 (s), 8.23 (s), 8.48 (s), 8.70 (s), 9.10 (m), 9.62 (s), 11.60 (w); (2) diethyl 2-(phenylthio)ethylmalonate, 3.25 (w), 3.35 (s), 5.75 (s, br), 6.3 (m), 6.75 (s), 6.93 (s), 7.18 (m), 7.30 (s), 7.47 (s), 7.7–8.8 (s, br), 8.95 (m), 9.11 (s), 9.65 (s, br), 10.28 (w), 11.60 (m), 13.64 (m–s), 14.50 (s); (3) diethyl 2-(phenoxy)ethylmalonate, 3.46 (m), 5.75 (s, br), 6.25 (s), 6.78 (s), 6.80 (s), 6.92 (m), 7.20 (m), 7.30 (s), 7.50 (s), 7.69 (s), 8.16 (s, br), 8.5–8.7 (s, br), 9.12 (s), 9.25 (s), 9.50 (s), 9.70 (s), 10.72 (w), 11.34 (w), 11.62 (m), 14.50 (s).

Reaction of Ethyl 1-Cyanocyclopropane-1-imidocarboxylate (I) with Piperidine. Preparation of 1-Cyanocyclopropane-1-imidopiperidide.—A mixture of 6 g. (0.065 mole) of I and 7.9 g. (0.093 mole) of piperidine was warmed on a steam bath for 0.5 hr. and then allowed to stand at room temperature for 17 hr. in a corked erlenmeyer flask. Volatile materials were stripped under reduced pressure and the residual liquid (8 g.) was then distilled. A colorless liquid distillate, b.p. 122–123° (0.5 mm.), solidified in the receiver to give 4 g. (36%) of colorless crystals which, after two recrystallizations from ether, melted at 76–77°.

Anal. Calcd. for $C_{10}H_{15}N_3$: C, 67.76; H, 8.53. Found: C, 67.64; H, 8.59.

Part of this product, 1-cyanocyclopropane-1-imidopiperidide, 1-CN-1-C(*c*-$C_5H_{10}N$)=NH-*c*-C_3H_4, was converted to a hydrochloride salt by passing hydrogen chloride gas through an ethanol solution and precipitating the salt by addition of ether. It was recrystallized once from absolute ethanol and a second time from chloroform to give colorless needles, m.p. 159–160°.

The infrared spectrum of 1-cyanocyclopropane-1-imidopiperidide in carbon tetrachloride solution showed peaks at the following wave lengths in μ: 3.35 (w), 3.43 (m–s), 3.54 (m), 4.49 (w–m), 6.28 (s), 7.15 (s, sh at 6.95), 7.30 (w–m), 7.40 (w), 7.70 (m), 7.82 (w), 7.95 (w), 8.15 (m), 8.29 (w–m), 8.51 (m), 9.13 (s), 9.30 (w), 9.58 (w), 9.97 (m), 10.40 (w), 11.72 (w–m).

Reaction of Ethyl 1-Cyanocyclopropane-1-imidocarboxylate (I) with Dimethylamine.—A mixture of 2 g. (0.015 mole) of I and 2.25 g. (0.05 mole) of dimethylamine in 20 ml. of absolute ethanol was sealed in a pressure bottle and let stand for 2 days at room temperature. The excess amine and the alcohol were then stripped at reduced pressure, leaving 2 g. of red liquid. Distillation gave 1.5 g. of colorless liquid, b.p. 108–112° (1 mm.), $n^{22}D$ 1.5006. This product, assumed to be N,N-dimethyl-1-cyanocyclopropane-1-carboxamidine, 1-CN-1-C[$N(CH_3)_2$]=NH-*c*-C_3H_4, slowly crystallized on standing in the refrigerator and turned brown. It was converted to a hydrochloride salt by passing hydrogen chloride gas through an ether–chloroform solution. The precipitated salt was recrystallized twice from absolute ethanol, m.p. 151.5°.

Anal. Calcd. for $C_7H_{12}ClN_3$: C, 48.42; H, 6.97. Found: C, 48.75; H, 7.17.

Preparation of Ethyl 2-Cyano-4-piperidinobutanoate by Condensation of 2-(Piperidino)ethyl Chloride with Ethyl Cyanoacetate.—In a three-necked flask equipped with a stirrer, reflux condenser, dropping funnel, and argon inlet was prepared under argon atmosphere a solution of 0.5 g. (0.022 g.-atom) of sodium in 25 ml. of absolute ethanol. After cooling this solution, 2.8 g. (0.025 mole) of ethyl cyanoacetate was added dropwise with stirring, followed immediately by the dropwise addition of 3.2 g. (0.022 mole) of 2-(piperidino)ethyl chloride. The mixture was heated at reflux temperature for 2 hr., followed by distillation of most of the alcohol under slightly reduced pressure. Sufficient water was added to dissolve the precipitated sodium chloride, and the product was extracted with ether, water washed twice, and dried over calcium chloride. Ether was removed under reduced pressure and the residue was distilled to give 1.5 g. (30%) of ethyl 2-cyano-4-piperidinobutanoate, b.p. 138° (2 mm.), $n^{20}D$ 1.4637. This ester was converted to 2-cyano-4-piperidinobutanamide by shaking with concentrated aqueous ammonia for 0.5 hr., followed by filtration of the precipitated solid. Recrystallization from ethyl acetate gave colorless crystals, m.p. 126–128°. A mixture melting point determination with this amide and the product of addition of piperidine to 1-cyanocyclopropane-1-carboxamide showed no depression.

Acknowledgment.—This research was supported in part by a grant from the Petroleum Research Fund administered by the American Chemical Society. Grateful acknowledgment is made to the donors of this fund.