The homolytic reaction between thiocyanogen and olefin (1.2 mole ratio) was carried out under nitrogen for 24 h by irradiation with a 300-W incandescent bulb.

Control Experiments. The following experiments were carried out on the products **1a** and **2a** from *trans*-3-hexene to demonstrate the resistance of the products to isomerization under the experimental conditions employed. A sample of 3,4-dithiocyanatohexane **1a** was added to unfiltered thiocyanogen in benzene solution and stirred in the dark for 24 h. The crude reaction mixture showed only **1a** by GLC analysis. Repetition of the experiment with the corresponding **2a** similarly demonstrated that **2a** was not isomerized.

The effect of added salts on the product composition of the thiocyanation of *trans*-3-hexene was determined in the following manner. A benzene solution of thiocyanogen was prepared, filtered, and delivered into four flasks each containing a mixture of 0.01 mol of *trans*-3-hexene in 10 mL of benzene. Lead thiocyanate (2.0 g) was freshly prepared and added to flask a, freshly prepared lead bromide (2.0 g) was added to flask b, a mixture of 2.0 g of lead thiocyanate and 2.0 g of lead bromide was added to the contents of flask c, and 2.0 g of the crude salts obtained from the filtration of thiocyanogen solution was added to flask d. The above four mixtures were stirred in the dark under nitrogen for 24 h. Analysis of the contents of flasks a, b, c, and d by GLC showed nearly identical chromatographic traces for all four mixtures, essentially unchanged from a trace obtained from the filtered thiocyanation additions carried out in benzene.

Registry No.—*trans*-3-Hexene, 13269-52-8; *cis*-3-hexene, 7642-09-3; $(SCN)_2$, 505-14-6.

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Thiocyanations. 3.[1] Preparation of 2-Imino-1,3-dithiolane Salts by Cyclization of *vic*-Dithiocyanates

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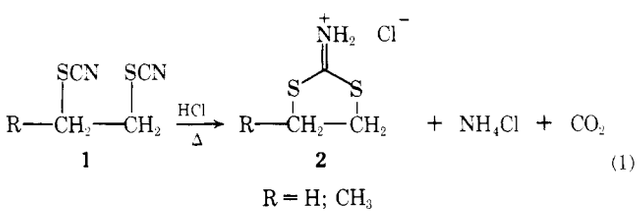
A series of 2-imino-1,3-dithiolane salts has been formed stereospecifically through the cyclization of *vic*-dithiocyanate derivatives of alkenes and unsaturated fatty acids. This cyclization has been accomplished using methanesulfonic acid as both coreactant and solvent. Methods of isolation of the product salts are briefly described.

Derivatives of 2-imino-1,3-dithiolane salts[3,4] demonstrate synthetic utility as intermediates in the preparation of pesticidally active compounds.[5–7] Although the heterocyclic structure was initially derived by cyclization of *vic*-dithiocyanates of ethane and propane by Miolati in 1891,[8] the method has received little attention since that time. Iminodithiolane derivative were subsequently prepared by reaction of *vic*-dithiols and cyanogen chloride[4–7] and by acid-catalyzed cyclization of allylic[6a,9] or β-hydroxyalkyl[10] esters of dithiocarbamic acid.

The alkyl substituted iminodithiolanes that had been prepared previously[4–10] were short-chain species of fewer than seven carbon atoms. Our efforts to obtain new long-chain aliphatic substituted compounds by incorporation of the heterocyclic structure into unsaturated fatty acids were precluded by difficulties encountered in the preparation of *vic*-dithiols[11] and by the indirect syntheses required for dithiocarbamate derivatives. As a result of our recent studies on the elucidation of olefin thiocyanations,[12] the *vic*-dithiocyanates that were readily obtainable presented the opportunity to study their chemistry as an essentially unexplored route to the titled compounds.

The 2-imino-1,3-dithiolane hydrochlorides (**2**) were first prepared by Miolati[8] from *vic*-dithiocyanates (**1**) in refluxing hydrochloric acid (eq 1). This technique required prolonged

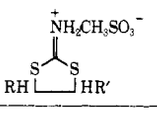
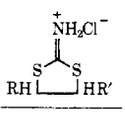
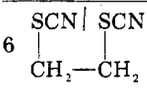
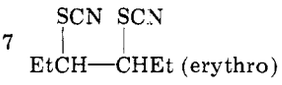
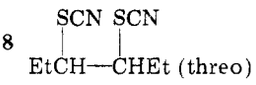
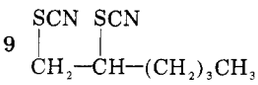
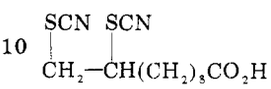
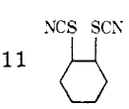


1 **2** (1)

R = H; CH_3

heating and resulted in diminished yields. Miolati[8] improved the yield of **2** by a method using the tin and hydrochloric acid

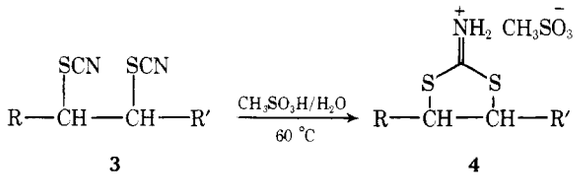
Table I. Methanesulfonates and Hydrochlorides from the Cyclization of Some 1,2-Dithiocyanates

	Starting dithiocyanate	Yield, %	Reaction time, h	Mp,[a] °C: 	Mp,[a] °C: 
6		70	4	155–157[c]	
7		85	2	132–134 (cis)[d]	
8		80	4	122–124 (trans)[e]	
9		70	8		159–161[f]
10		90	12	90–95[g]	
11		90	6.5		238–240[b,h]

[a] Melting points were usually accompanied by decomposition. [b] Addor reported mp 243–246 °C (ref 4). [c] Registry no., 61522-05-2. [d] Registry no., 61521-98-0. [e] Registry no., 61522-00-7. [f] Registry no., 49549-01-1. [g] Registry no., 61522-07-4. [h] Registry no., 61522-08-5.

reduction of **1** followed by treatment of the resultant tin–hydrochloride double salt with hydrogen sulfide. Both methods, however, resulted in the formation of a nearly inseparable mixture of **2** and the coproduct ammonium chloride. We have reexamined these procedures with the model compounds (**1**, eq 1) and longer chain dithiocyanates. It was found that solubilities of the longer chain compounds in this medium in comparison to ethylene dithiocyanate are greatly diminished and conversions to adduct **2** are negligible. We therefore attempted to modify the Miolati method with cosolvents such as tetrahydrofuran, dioxane, and dimethyl sulfoxide to solubilize the dithiocyanate adducts in concentrated hydrochloric acid. None of these attempts lead to cyclization to the desired products. These failures led to the conclusion that cyclization would occur effectively only in the presence of a concentrated strong acid medium. Among the acids examined, namely phosphoric, trifluoroacetic, and methanesulfonic acids, cyclization was accomplished only with the latter, which served in the dual role of catalyst and solvent.

The dithiocyanates dissolved in methanesulfonic acid containing a small amount of water and cyclized smoothly at 60 °C within 1–8 h (eq 2). This cyclization does not involve the



3 **4**

$$+ CH_3SO_3NH_4 + CO_2 \quad (2)$$

5

asymmetric vicinal carbon atoms so that the method is advantageous for the stereospecific formation of the adducts **4**.[14] The rate of disappearance of dithiocyanate was easily monitored by infrared spectroscopy using the following technique. Samples of the reaction mixture were neutralized with aliquots of 1,2-epoxybutane. This mild reaction converted the methanesulfonic acid to neutral hydroxybutylmethanesulfonate esters with no effect on unreacted dithiocyanate. Completion of the cyclization reaction was indicated by the absence of the strong infrared band for –SCN at 2150 cm^{-1}.

The difficulties encountered by Miolati in separating **2** from ammonium chloride were not experienced in the methanesulfonic acid experiments. Dilution of the product mixture with chloroform resulted in the precipitation of the comparable ammonium methanesulfonate (**5**). Removal of excess methanesulfonic acid from the product **4** was first attempted by neutralization with mild base. This method failed owing to the instability of the free iminodithiolanes formed in this process. Less drastic techniques used to isolate **4** achieved the desired results. In one method the aqueous methanesulfonic acid was removed from the product **4** using ethyl ether in a continuous extraction apparatus. Although this method required several days for completion, satisfactory yields of the product salts **4** were obtained. A second, more rapid method of product recovery involved the use of ion exchange chromatography. After removal of ammonium methanesulfonate the crude product mixture was passed through a chloride anion exchange column resulting in the recovery of the product as the hydrochloride salt **2**. The yields and melting points for both classes of iminodithiolane salts prepared in this study are listed in Table I. The desired products were obtained for all of the dithiocyanates cyclized except for those adducts derived from oleic and elaidic acids. Both of these dithiocyanates were consumed in the reaction forming a water-soluble mixture, but attempts to isolate the products were unsuccessful. Identical spectral and NMR data for both products suggest that a possible zwitterionic structure is formed between the polar groups in these compounds enhancing their solubility in the aqueous reaction medium.

Addor[4] has observed that two characteristic infrared frequencies are assignable to the 2-imino-1,3-dithiolane hydrochlorides, which exhibit an absorption for the >C=N group at 1560 cm^{-1} and a band for the $-NH_2$ bending vibra-

tions at 1488 cm^{-1}. Replacement of chloride ion for the methanesulfonate group did not result in any significant shifts in the positions of these two bands. Infrared spectra of the hydromethanesulfonate salts[3] as KBr pellets showed an absorption band at 1570 cm^{-1} for the >C=N group and at 1480 cm^{-1} for the $-NH_2$ group. A detailed analysis of the ^1H NMR spectra of the 2-imino-1,3-dithiolane hydromethanesulfonates is described in part 5 of this series.[14]

Experimental Section

Reagents. The *vic*-dithiocyanate adducts were prepared by thiocyanogen addition to the olefinic compounds as described in previous reports.[1,12] Ethylene dithiocyanate was a commercial sample supplied by Eastman Kodak.[15] Anion ion exchange resin AG 1-X4 (Bio-Rad Laboratories) was obtainable in analytical grade for the interchange of methanesulfonate and chloride anions.

Procedure. Examples of the Preparation of 2-Imino-1,3-dithiolane hydrogen Methanesulfonates and Chlorides. *cis*-4,5-Diethyl-1,3-ditholane-2-iminium Methanesulfonate from *erythro*-3,4-Dithiocyanatohexane 7. Compound **7** (1.0 g, 5.0 mmol) was added to a solution of 100 mg of water in 5 g of freshly distilled methanesulfonic acid. Upon heating the mixture to 60 °C the solid dithiocyanate dissolved and a vigorous evolution of carbon dioxide occurred. Aliquots were removed at frequent intervals as described in the text to test for completion of reaction. Upon completion of the reaction, coproduct **6** was removed as described below. The reaction mixture was then diluted with water and placed in a continuous extraction apparatus using ethyl ether as the extracting solvent. The product was extracted into ether which upon evaporation left a solid residue. The recovered salt was purified by recrystallization from methanol/ether and gave 1.15 g (85%): mp 132–134 °C dec; IR (KBr pellet) 2850, 1540, 1460, 1200, and 1050 cm^{-1}. Anal. Calcd for $C_8H_{17}NO_3S_3$: C, 35.4; H, 6.35; N, 5.15; S, 35.4. Found: C, 35.23; H, 6.34; N, 5.14; S, 35.7.

On the basis of this procedure, the hydromethanesulfonate salts of compounds **6, 8, 9,** and **11** were isolated and satisfactory spectral data and elemental analyses were obtained.

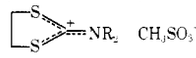
***trans*-4,5-Hexahydrobenzo-1,3-dithiolane-2-iminium Methanesulfonate from *trans*-1,2-Dithiocyanatocyclohexane 11.** Using the same procedure as described above, **11** was cyclized in 6.5 h to the title compound. However, the product could not be removed from the excess methanesulfonic acid by continuous extraction with ether. Exchange of methanesulfonic acid for volatile hydrochloric acid was simply attained by aqueous dilution of the crude methanesulfonic acid mixture after cyclization and elution through a column of AG 1-X4 resin (chloride form) and evaporation of the eluates. Comparison of the melting point and published spectral data[4] established the structure of this compound. By a similar technique the dithiocyanate **9** was also converted to the hydrochloride salt.

Ammonium methanesulfonate (**5**) precipitated upon addition of chloroform to the crude reaction mixture. The compound was isolated as a white, crystalline solid, purified by repeated washings with chloroform (mp 198–201 °C dec), and identified by IR (KBr pellet): 3100, 1920, 1200, 1050, 780, and 560 cm^{-1}. Anal. Calcd for CH_7NO_3S: C, 10.62; H, 6.19: N, 12.4; S, 28.5. Found: C, 11.04; H, 6.26; N, 12.38; S, 28.9.

Registry No.—**5,** 22515-76-0; **6,** 629-17-4; **7,** 30647-63-3; **8,** 61521-96-8; **9,** 61522-04-1; **10,** 55602-15-8; **11,** 30647-66-6.

References and Notes

(1) Part 2: R. J. Maxwell, L. S. Silbert, and J. R. Russell, *J. Org. Chem.*, preceding paper in this issue.
(2) Agricultural Research Service, U.S. Department of Agriculture.
(3) The *Chemical Abstracts* systematic name for structure **2** (R = H) is "cyclic ethylene dithioimidocarbamate hydrochloride". A convenient, acceptable name for 2,2-imino-1,3-dithiolane (ref 4) was adapted to the compounds reported in this paper. The methanesulfonate salts are accordingly termed hydromethanesulfonates. The alternative name applicable to the methanesulfonate of **4**, 2-imino-1,3-dithiolinium methanesulfonate, is descriptive of the carbonium ion (structure below) and reflects the reactivity toward



nucleophiles [see T-L. Ho, *Chem. Rev.*, **75,** 1 (1975); T. Nakai and M. Okawara, *Bull. Chem. Soc. Jpn.*, **43,** 1864 (1970); J. L. Richards, D. S. Tarbell, and E. H. Hoffmeister, *Tetrahedron*, **24,** 6485 (1968)].
(4) R. W. Addor, *J. Org. Chem.*, **29,** 738 (1964).
(5) R. W. Addor, *J. Agric. Food Chem.*, **13,** 207 (1965).
(6) (a) R. W. Addor, U.S. Patent 3 281 430 (1966); *Chem. Abstr.*, **66,** 65483s (1967); (b) U.S. Patent 3 197 481 (1965); *Chem. Abstr.*, **64,** 2088*f* (1966); (c) U.S. Patent 3 193 561 (1965); *Chem. Abstr.*, **63,** 11577*a* (1965).
(7) J. B. Lovell, U.S. Patent 3 197 365 (1965); *Chem. Abstr.*, **66,** 37931t (1967).
(8) A. Miolati, *Justus Liebigs Ann. Chem.*, **262,** 61 (1891).
(9) T. A. Lies, U.S. Patent 3 389 148 (1968); *Chem. Abstr.*, **69,** 77268a (1968).
(10) S. D. Levy, U.S. Patent 3 364 231 (1968); *Chem. Abstr.*, **69,** 2950h (1968).
(11) Preparations of *vic*-dithiols to be reported in a subsequent publication.
(12) L. S. Silbert, J. R. Russell, and J. S. Showell, *J. Am. Oil. Chem. Soc.*, **50,** 415 (1973).
(13) Dry hydrochloric acid dissolved in nonpolar solvents also failed to effect cyclization of adduct **1.** Under these conditions hydrochloric acid may be too weak an acid to function effectively as a catalyst or requires the presence of water to bring about cyclization.
(14) Part 5: R. J. Maxwell, P. Pfeffer, and L. S. Silbert, *J. Org. Chem.*, accompanying paper in this issue.
(15) Reference to brand or firm name does not constitute endorsement by the U.S. Department of Agriculture over others of a similar nature not mentioned.
(16) Infrared spectra were recorded on a Perkin-Elmer Model 457 spectrophotometer.

Thiocyanations. 4. Cyclization of 1-Isothiocyanato-2-thiocyanates. A Stereospecific Route to the Preparation of 4,5-Thiazolidine-2-thiones[1,2]

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When 1-isothiocyanato-2-thiocyanates **2** are heated in ethanolic potassium hydroxide, they cyclize to 4,5-thiazolidine-2-thiones. It was found that 4,5-thiazolidine-2-thiones prepared in this manner are formed stereospecifically. The representative examples of adducts **2** cyclized to the heterocyclic derivatives are discussed and a mechanism based on the experimental observations is proposed.

vic-Dithiocyanates **1,** which are obtained by the trans addition[4,5] of thiocyanogen to olefins (eq 1), have long been useful intermediates for the preparation of thiiranes[6] **3** (eq 2) and, more recently, were effectively cyclized to 2-imino-1,3-dithiolane salts **4** (eq 3).[2] The isomeric adduct, 1-isothiocyanato-2-thiocyanate **2,** has been identified and isolated as a minor product of the thiocyanation reaction.[4,7] However, studies in this laboratory[8] have shown that the relative amounts of the two isomers **1** and **2** formed are solvent dependent so that either isomer may be prepared as the primary product (eq 1). The versatility of this reaction provides isomer **2** as a potential intermediate which could extend the utility of the thiocyanation reaction to other heterocyclic preparations.

In contrast to the known base-induced cyclization of *vic*-dithiocyanates to form the three-membered thiirane ring[6] (eq