In contrast to our previous experience in determining 2-octanol optical purity by the gc-diastereomer method, the results in this run were imprecise. Thus, although the Xerox cut-outs of each of three traces were mutually consistent (four copies per trace, average deviations 1.30, 1.71, 1.13%), the final (uncorrected) optical purities obtained were 22.24, 32.72, and 26.94%. The average value was 27.30 ± 3.61%. The stereochemical course of the reaction was therefore 27.30/0.94 ~ 29% net inversion.

Although we cannot account for the poor precision in this stereochemical determination, we can show that the results in Table II, which partly rest upon this determination, are relatively unaffected. Thus, using the lower, uncorrected, net inversion limit of (27.30 − 3.61) = 23.69%, we calculate a final 2-octanol distribution of ex–ret, 20.00; ex–inv, 56.74; cons–ret, 17.40; and cons–inv, 5.85%. The final values corresponding to the higher, uncorrected, net inversion of 30.91% afford a distribution of 17.88, 60.21, 14.73, and 6.23%, respectively. These limiting values are very similar to the distribution shown in Table II, which is based on the average, uncorrected, net inversion of 27.30%.

Registry No.—I, 27850-48-2.

Acknowledgments.—We are grateful to the National Science Foundation (GP-12645) and to the National Institutes of Health (GM-13585) for financial support. A. W. F. thanks the National Science Foundation (GY-7556) for summer support. We also thank the Colgate-Palmolive Co. for making available its mass spectroscopy facilities, and Professor D. Denney for a helpful discussion.

Reactions of Diazo Compounds with Tetrasubstituted 1,3-Cyclobutanediones and the Corresponding Dithiones. Isolation of Bis-Δ^3-1,3,4-thiadiazolines from the Dipolar Addition of Diazomethane to the Dithiones and Their Thermal Decomposition into Diepisulfides

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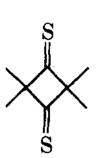
Received June 17, 1971

Tetramethyl-1,3-cyclobutanedithione (**1**), dispiro[4.1.4.1]dodecane-6,12-dithione (**2**, $n = 5$), and dispiro-[5.1.5.1]tetradecane-7,14-dithione (**2**, $n = 6$) on treatment with diazomethane at 0° lead to novel stereoisomeric bis-Δ^3-1,3,4-thiadiazolines **12**, **13** ($n = 5$), and **13** ($n = 6$), respectively. These bis adducts are reasonably stable and on thermolysis readily undergo loss of nitrogen to yield stereoisomeric mixtures of diepisulfides **17**, **18** ($n = 5$), and **18** ($n = 6$). Treatment of **1** with diphenyldiazomethane leads to the cis and trans diepisulfides **21**. Treatment of the diones **1** (S = O) and **2** ($n = 4$, 5, or 6; S = O) with ethanolic-ethereal diazomethane leads to the ring-expanded diones **22** and **23** ($n = 4$, 5, or 6), respectively. The relative ease of ring expansion stands in the order: **2** ($n = 4$; S = O) >>>> **2** ($n = 5$; S = O) > **1** (S = O) > **2** ($n = 6$; S = O). The possible reasons for this order are discussed.

As part of a program designed to contrast the chemistry of –C=O and –C=S linkages, we have recently begun a study of various reactions of tetrasubstituted 1,3-cyclobutanedithiones **1** and **2** ($n = 5$ or 6) and the corresponding diones **1** (S = O) and **2** ($n = 4$, 5, or 6; S = O). This report deals with the reaction of diazomethane with dithiones **1** and **2** ($n = 5$ or 6) and diones **1** (S = O) and **2** ($n = 4$, 5, or 6; S = O).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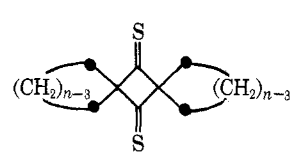

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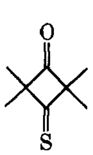
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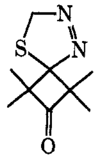
In general most simple aliphatic and alicyclic thiones are unstable in the monomeric state.[3] As a consequence, their chemistry and reactivity have not been fully investigated. The dithiones **1**[4] and **2** ($n = 6$)[5] and the monothione **3**[4a] have been prepared recently and join the ranks of such non-enethiolizable thiones as thiocamphor,[6] thiofenchone,[7] and adamantanethione[8] in possessing stable thione groups. Hexafluorothioacetone has been reported to undergo dimerization on standing for several hours.[9]

The reaction of several aliphatic thioketones with diazomethane (0°, ether) led to the corresponding episulfides along with methylthioalkenes (from the enethiol). In the case of diisopropyl thioketone only the episulfide was formed; in none of the cases was any thiadiazoline intermediate isolated.[10] Recently the reaction of **3** has been reported to lead to the unstable Δ^3-1,3,4-thiadiazoline **4** (tentatively characterized by ir and nmr spectroscopy).[11] The thiadiazoline **4** readily loses nitrogen to yield the episulfide **5**. Bis-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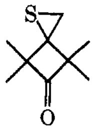
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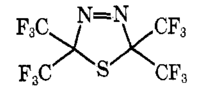

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[1] Fellow of the Humphrey Chemical Co., North Haven, Conn.

[2] Ethiopian Fellow of the African Graduate Fellowship Program (AFGRAD).

[3] (a) For a review see R. Mayer, J. Morgenstern, and J. Fabian, *Angew. Chem., Int. Ed. Engl.*, **3**, 277 (1964); (b) R. Mayer in "Organosulfur Chemistry," M. J. Janssen, Ed., Interscience, New York, N. Y., 1967, p 219; (c) R. Mayer and S. Bleisch, *Chem. Ber.*, **100**, 93 (1967); (d) E. Campaigne in "The Chemistry of the Carbonyl Group," S. Patai, Ed., Interscience, New York, N. Y., 1966, p 917; (e) M. Demuynck and J. Vialle, *Bull. Soc. Chim. Fr.*, 2748 (1967).

[4] (a) E. U. Elam and H. E. Davis, *J. Org. Chem.*, **32**, 1562 (1967). (b) R. D. Lipscomb (to E. I. du Pont de Nemours and Co., Inc.), U. S. Patent 3,297,767 (Jan 10, 1967); *Chem. Abstr.*, **66**, 65180r (1967).

[5] E. U. Elam (to Eastman Kodak Co.), British Patent 1,137,377 (Dec 18, 1968); *Chem. Abstr.*, **70**, 96253d (1969).

[6] D. C. Sen, *J. Indian Chem. Soc.*, **12**, 647 (1935).

[7] (a) D. C. Sen, *ibid.*, **14**, 214 (1937); (b) C. N. R. Rao and R. Venkataraghavan, *Spectrochim. Acta*, **18**, 541 (1962).

[8] (a) J. W. Greidanus and W. J. Schwalm, *Can. J. Chem.*, **47**, 3715 (1969); (b) J. W. Greidanus, *ibid.*, **48**, 3530, 3593 (1970).

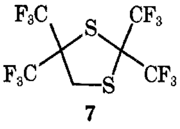
[9] (a) W. J. Middleton, E. G. Howard, and W. H. Sharkey, *J. Org. Chem.*, **30**, 1375 (1965); (b) W. J. Middleton, *ibid.*, **34**, 3201 (1969).

[10] D. Paquer and J. Vialle, *Bull. Soc. Chim. Fr.*, 3327 (1969).

[11] C. E. Diebert, *J. Org. Chem.*, **35**, 1501 (1970).

(trifluoromethyl)diazomethane reacts with hexafluorothioacetone to yield the Δ^3-1,3,4-thiadiazoline **6**, which is stable at room temperature and on thermolysis yields the corresponding episulfide.[9b]

Treatment of hexafluorothioacetone with diazomethane yields 1,3-dithiolane **7**.[12] Schönberg and coworkers have described reactions between diazoalkanes and several diaryl thioketones and have isolated either 1,3-dithiolanes **8** or episulfides **9** (R_2 and R_3 from the diazoalkane).[13]



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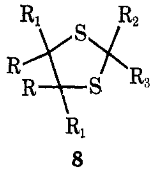

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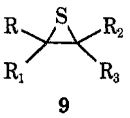

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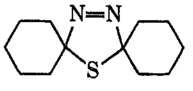
A synthetic route to Δ^3-1,3,4-thiadiazolines has recently been developed which involves dehydrogenation of 1,3,4-thiadiazolidines.[14] The Δ^3-1,3,4-thiadiazolines **10**,[14a,c] **11** ($R = R_2 =$ *tert*-Bu, $R_1 = H$),[14b] **11** ($R = R_1 = Et$; $R_2 = H$),[14a,b] and **11** ($R = R_2 = Et$; $R_1 = H$)[14a,b] have been prepared, the latter two compounds being isolated at −10°. The thermolysis of these thiadiazolines led to the corresponding episulfides. The thiadiazoline **10** is the first reported example of an exceptionally stable system of this structure, mp 80° (without decomposition).[14a,c]



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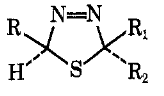

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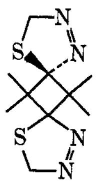

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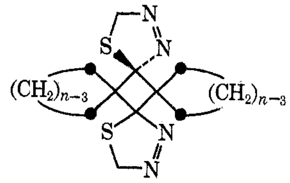

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Results and Discussion

Reaction of the 1,3-Dithiones with Diazomethane.—Tetramethyl-1,3-cyclobutanedithione (**1**),[4] dispiro[5.1.5.1]tetradecane-7,14-dithione (**2**, $n = 6$),[5] and dispiro[4.1.4.1]dodecane-6,12-dithione (**2**, $n = 5$) were prepared in excellent yields by treatment of the corresponding diones with H_2S in the presence of HCl and zinc chloride in a cold methanol solution.[4b] The three dithiones are pleasant smelling, red-colored compounds which can be stored for long periods without appreciable decomposition.[15]

Treatment of **1** and **2** ($n = 5$ or 6) in ethereal solutions at 0° with ethereal diazomethane (0°) led to the immediate discharge of the red coloration of the dithione solutions with no evolution of nitrogen. Removal of the excess diazomethane and ether at 0° under vacuum led to quantitative yields of white solids. On dissolving in ether and cooling to −25° beautiful colorless crystals were obtained. The bis adducts from **1** and **2** ($n = 5$ or 6) can be formulated as the stereoisomeric bis-Δ^3-1,3,4-thiadiazolines **12** and **13** ($n = 5$ or 6), respectively. These structural assignments are based on analytical and spectroscopic data.

The infrared spectra of **12** and **13** ($n = 5$ or 6) exhibited absorptions at 1570 cm^{-1} (–N=N–).[16,17] The nmr absorptions for these thiadiazolines are tabulated in Table I.

TABLE I

NMR ABSORPTIONS FOR THE BIS-Δ^3-1,3,4-THIADIAZOLINES 12 AND 13

Δ^3-1,3,4-Thiadiazolines[a]	δ, CH_3 or ring CH_2	δ, $SCH_2N{=}N$
12	0.95 (s), 1.25 (s), 1.34 (s)	5.82 (s)[b]
13 ($n = 6$)	1.25 (broad), 1.85 (broad)	5.82 (s), 5.85 (s)[c,d]
13 ($n = 5$)	1.45 (complex m), 2.0 (complex m)	5.79 (s), 5.75 (s)[c,e]

[a] $CDCl_3$ as solvent. [b] The cis and trans bis adducts are obtained with the approximate composition being 70% of one isomer and 30% of the other. No definite stereochemical assignments can be presently made. Attempts to separate the isomers have been unsuccessful. [c] The cis and trans bis adducts exhibit different field positions for the δ $SCH_2N{=}N$ resonances. [d] The areas of the δ 5.85 and 5.82 peaks (3:1 ratio) indicate 75% of one isomer and 25% of the other. [e] The peak heights of the δ 5.79 and 5.75 peaks (~1:2 ratio) indicate 67% of one isomer and 33% of the other.

It can be noted from the nmr data presented in Table I that the resonances at δ 5.75–5.85 ppm are only consistent with the formulation of the adducts as bis-Δ^3-1,3,4-thiadiazolines rather than the alternative formulation as Δ^2-1,2,3-thiadiazolines ($SN{=}NCH_2$). Compound **4** exhibits a singlet at δ 5.70 and a discussion is presented for favoring this structural assignment.[11] Indeed the recent unambiguous synthesis and nmr data for **11** ($R = R_2 =$ *tert*-Bu; $R_1 = H$) and **11** ($R = R_2 = Et$; $R_1 = H$) offer support to these assignments. The former compound exhibits absorptions at δ 5.9–6.25 (m) and the latter compounds absorb at δ 5.62 (s), these absorptions being assigned to the protons on the ring carbon adjacent to the sulfur and the –N=N– bond.[14a,b]

The bis-Δ^3-1,3,4-thiadiazolines **12** and **13** ($n = 5$ or 6) are stable for short periods at room temperature in the solid state. On standing for longer periods (few days) they slowly lose nitrogen. When a 0.5-g sample of **12** was heated in an oil bath, at about 60°, the compound *exploded* and shattered the flask. The compounds can be stored for long periods at −25° without appreciable decomposition. This report along with the previous work of Diebert[11] appears to be the only case in which Δ^3-1,3,4-thiadiazolines have been obtained from the dipolar addition of diazomethane to a thioketone. The bis-Δ^3-1,3,4-thiadiazolines **12** and **13** ($n = 5$ or 6) are considerably more stable than **4**.[11]

The addition of diazomethane to the dithiones **1** and **2** ($n = 5$ or 6) leads exclusively to the diadducts in

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(12) W. J. Middleton and W. H. Sharkey, *J. Org. Chem.*, **30**, 1384 (1965).

(13) A. Schönberg, B. Konig, and E. Singer, *Chem. Ber.*, **100**, 767 (1967), and references therein cited.

(14) (a) R. M. Kellogg and S. Wassenaar, *Tetrahedron Lett.*, 1987 (1970); (b) R. M. Kellogg, S. Wassenaar, and J. Buter, *ibid.*, 4689 (1970); (c) D. H. R. Barton, E. H. Smith, and B. J. Willis, *Chem. Commun.*, 1226 (1970).

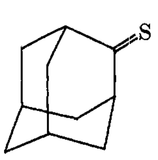
(15) We wish to express our appreciation to Dr. E. U. Elam (Eastman Kodak Co., Kingsport, Tenn.) for generous samples of **1** and **2** ($n = 6$) for our initial studies (Dec 1969).

(16) Reference 11 reports absorption at 1565 cm^{-1} for compound **4**. References 14a and 14c report absorption for **10** at 1579 and 1575 cm^{-1} (KBr), respectively.

(17) For other reports of systems with –N=N– absorptions in this region, see (a) E. L. Allred and J. C. Hinshaw, *J. Amer. Chem. Soc.*, **90**, 6885 (1968); (b) R. J. Crawford, A. Mishra, and R. J. Dummel, *ibid.*, **88**, 3959 (1966).

which the nitrogen end of the diazomethane has bonded to the carbon of the thione link. The intimate details of the cycloaddition mechanism are left unanswered. However, because of the steric barrier of the bulky groups surrounding the C=S bonds in **1** and **2** (n = 5 or 6), it is possible that approach of the nitrogen end of the diazomethane to the carbon of the thione link is sterically more favorable in comparison to the approach of the carbon end (with the two hydrogens) to the carbon of the thione link. It is perhaps of interest to report some preliminary data on the cycloaddition of diazomethane with adamantanethione (**14**),[7] a molecule in which the thione grouping is not so sterically inaccessible as in the cases of the dithiones reported above.

Treatment of **14** with ethereal diazomethane (0°) led to the immediate discharge of the orange coloration of the solution. Concentration of the solution at 0° led to an oil which solidified in the freezer (−25°). Nmr examination of the crude product ($CDCl_3$) revealed absorptions at δ 1.9 (broad d), 2.7 (two broad peaks), 5.0 (s), and 5.82 ppm (s). The peak at δ 5.82 can be assigned to the protons of the Δ^3-1,3,4-thiadiazoline ring in **15** and the δ 5.0 peak to the protons of the Δ^2-1,2,3-thiadiazoline ring in **16**, the percentages of **15** and **16** in the reaction mixture being 75 and 25%, respectively (area integration of the singlets). The infrared spectrum of the mixture (neat) exhibited –N=N– stretching frequencies at 1575 (**15**) and 1515 cm^{-1} (**16**) of about equal intensities. Thus in the case of adamantanethione cycloaddition occurs *via* the two possible modes. This reaction is under further investigation.



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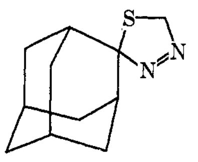

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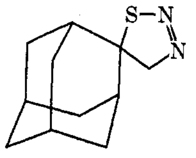

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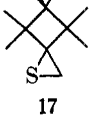
Diepisulfide Formation. Thermal Decompositions of the Bis-Δ^3-1,3,4-thiadiazolines.—The bis-Δ^3-1,3,4-thiadiazolines **12** and **13** (n = 5 or 6) on refluxing in chloroform or carbon tetrachloride–hexane solutions (2–3 hr) readily lost nitrogen and were quantitatively converted into stereoisomeric mixtures of the diepisulfides **17** and **18** (n = 5 or 6), respectively. The nmr data for these diepisulfides are tabulated in Table II.



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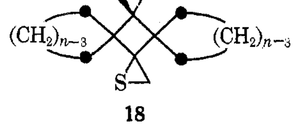

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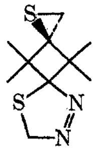

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On repeated crystallization of the crude diepisulfide mixture **17** from pentane–benzene the pure trans diepisulfide **17** could be isolated. It exhibited resonances in the nmr at δ 2.59 (s, SCH_2, 4 H) and 1.05 ppm (s, CH_3, 12 H). The decomposition of the bis-Δ^3-1,3,4-thiadiazoline **12** leads to 70% *trans*-**17** and 30% *cis*-**17** [CH_3 resonances at 1.26 (s) and 0.90 (s)].

Table II

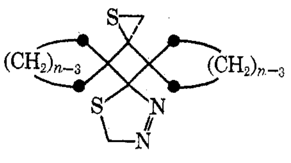
Nmr Spectral Data for the Stereoisomeric Diepisulfides 17 and 18

Diepisulfides[a]	δ, CH_3 or ring CH_2	δ, CH_2S[b]
17	0.90 (s), 1.05 (s), 1.26 (s)	2.59 (s)
18 (n = 6)	1.26 (broad m), 1.57 (broad m)	2.68 (s), 2.61 (s)
18 (n = 5)	1.40 (complex m), 1.80 (complex m)	2.62 (s), 2.55 (s)

[a] $CDCl_3$ as solvent. Area integrations are in agreement with the structural assignments. [b] Reference 11 reports δ 2.55 (s) for the corresponding protons in **19**. Reference 10 lists several episulfides with resonances at δ 2.1–2.4 ppm.

When a solution of **12** ($CDCl_3$) was allowed to stand at room temperature for 24 hr, the nmr pattern became complex as about nine distinct CH_3 singlets appeared in the δ 0.8–1.5 ppm region and singlets appeared at δ 2.55 and 2.59 ppm. The singlet originally present at δ 5.82 ppm diminished in intensity and a new singlet appeared at δ 5.75. The new absorptions δ 2.55 and 5.75 (not present in the product diepisulfides **17** or the starting thiadiazolines **12**) are consistent with the formation of the Δ^3-1,3,4-thiadiazoline intermediate **19** as a transient in the decomposition pathway to **17**.

On the basis of the areas of the protons of the episulfide rings, the stereoisomeric composition of the diepisulfides **18** (n = 5) was 67% of one isomer and 33% of the other (no definite stereochemical assignment could be made). The thermal decomposition of **13** (n = 5) was monitored in the nmr tube (CCl_4). After 2 hr singlets appeared at δ 2.37 and 2.85 ppm [probably SCH_2 of the stereoisomeric Δ^3-1,3,4-thiadiazolines **20** (n = 5)] and δ 2.50 and 2.57 [SCH_2 of the diepisulfides **18**, n = 5)]. In addition the singlet at δ 5.75 diminished in intensity. After 8 hr the signals at δ 2.37, 2.85, 2.57, and 2.50 ppm increased in intensity and the singlet at δ 5.75 decreased. After warming the tube, the singlets δ 2.50 and 2.57 remained.



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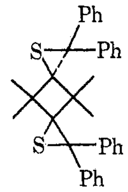

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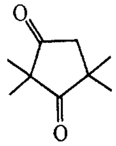
On the basis of the singlets at δ 2.62 and 2.55 (SCH_2) the diepisulfide composition for **18** (n = 6) was about 70% of one isomer and 30% of the other isomer. The decomposition of bis adduct **13** (n = 6) was monitored in the nmr tube (CCl_4). After 3 hr a new singlet appeared at δ 5.80 ppm (in addition to the singlets at δ 5.75 and 5.78 ppm) and additional singlets appeared at δ 2.74 and 2.44 (equal intensity) and δ 2.64 and 2.56 (different intensity, SCH_2). After about 4 hr at room temperature the intensity of the δ 2.64 and 2.56 peaks increased and the δ 5.75 peak of the original bis-Δ^3-1,3,4-thiadiazoline decreased as the δ 5.80 peak increased in intensity. After 7 hr the diepisulfide peaks intensified (δ 2.64 and 2.55) and the peaks at δ 2.74 and 2.44 diminished in intensity. The nmr data are consistent with the buildup of the stereoisomeric Δ^3-1,3,4-thiadiazoline **20** (n = 6), followed by a slower decomposition to the diepisulfides.

The bis-Δ^3-1,3,4-thiadiazoline **13** (n = 5) (nmr studies) is the most stable and undergoes the slowest decomposition, and the bis adduct **12** undergoes the fastest decomposition. This is perhaps suggestive of a release of steric compression in the decomposition of **12** in comparison to **13** ($n = 5$). Kellogg has previously discussed the mechanism of thermolysis of several Δ^3-1,3,4-thiadiazolines as proceeding *via* thiocarbonyl ylides.[14]

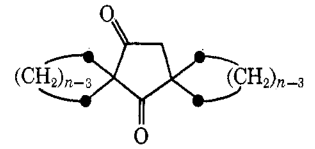
The thermal decomposition of the adducts obtained from **14** was also monitored in the nmr tube ($CDCl_3$). After about 0.5 hr at 60° the absorption at δ 5.82 disappeared but the peak at δ 5.0 remained. A new peak appeared at δ 2.4 (episulfide protons). At 85° for 3 hr the δ 5.0 peak disappeared but the nmr pattern in the δ 1.7–2.3 region was drastically changed and indicated decomposition of the episulfide. Apparently **15** (*via* a thiocarbonyl ylide[14]) undergoes loss of nitrogen more readily than **20**. These points are under further investigation.

Diphenyldiazomethane Reaction with 1.—The addition of an ethereal solution of diphenyldiazomethane to an ether solution of dithione **1** led to the immediate evolution of nitrogen. After 1 hr the nitrogen evolution ceased and on evaporation of the ether a quantitative yield of the stereoisomeric diepisulfides **21** was obtained. The nmr ($CDCl_3$) showed resonances at δ 7.80 (aromatic complex m), 7.2 (aromatic complex m), 1.42 (s), 0.77 (s), and 0.53 ppm (s). Treatment of the crude diepisulfide mixture with warm acetone left an insoluble white residue which exhibited resonances at δ 7.8 (aromatic complex m), 7.2 (aromatic complex m), and 0.77 ppm (s) and can be assigned the transoid structure **21**. The acetone-soluble portion on cooling led to the cis diepisulfide **21** which exhibited nmr peaks at ($CDCl_3$) δ 7.8 (aromatic complex m), 7.2 (aromatic complex m), 1.42 (s), and 0.53 ppm (s). The original diepisulfide mixture consisted of 67% *cis*-**21** and 33% *trans*-**21**.

Dione–Diazomethane Ring Expansions.—Treatment of the diones **1** (S = O) and **2** (n = 4, 5, or 6; S = O) with an ethereal–ethanolic solution of diazomethane led to the ring-expanded diones **22** and **23** (n = 4, 5, or 6), respectively. The dione **22** was obtained quantitatively by allowing the reaction mixture to stand at room temperature for about 3 days. Shorter reaction periods led to incomplete reaction. The dione **22** exhibited resonances in the nmr at (CCl_4) δ 1.10 (s), 1.21 (s), and 2.55 ppm (s). The nmr data for the diones **23** (n = 4, 5, or 6) are tabulated in Table III.



22



23

TABLE III

NMR SPECTRAL DATA FOR THE DIONES **23** (n = 4, 5, OR 6)

Dione **23**[a]	δ, $CH_2C{=}O$	δ, ring CH_2
4	2.84 (s)	1.8–2.6 (complex m)
5	2.70 (s)	1.84 (broad peak)
6	2.63 (s)	1.60 (broad peak)

[a] $CDCl_3$ as solvent.

The slowest ring expansion occurred with dione **2** (n = 6; S = O). After 2 days at room temperature with excess diazomethane only a 30% yield of pure **23** (n = 6) could be obtained. The dione **2** (n = 4; S = O) reacted instantaneously on addition of the diazomethane solution. Nitrogen was evolved and a quantitative yield of **23** (n = 4) could be obtained. The order of reactivity with ethanolic–ethereal diazomethane is dione **2** (n = 4; S = O) >>>> dione **2** (n = 5; S = O) >> dione **1** (S = O) > dione **2** (n = 6; S = O). No epoxide products were detectable. The mechanism of diazoalkane ring expansions have been discussed in several reviews and papers.[18]

One can perhaps explain the rapid rate of ring expansion of **2** (n = 4; S = O) on the basis of a synchronous addition–rearrangement mechanism.[18d] The internal angle strain of the cyclobutane ring holding the carbonyl groups could be considerable because of the external angles (about 90°) of the spirocyclobutane rings. Release of this internal angle strain would be expected to lead to a facile ring expansion process. In so far as release of internal angle strain, the order of reactivity for the spiro systems would be **2** (n = 4; S = O) >> **2** (n = 5; S = O) > **2** (n = 6; S = O). One must also consider the steric accessibility of the carbonyl group. The dione **1** (S = O) would probably be the most sterically crowded around the carbonyl group for approach of the diazomethane molecule while the dione **2** (n = 4; S = O) would be least hindered by the adjacent spiro methylene groups. Thus utilizing angle strain and steric accessibility arguments, the order of the reactivity of the diones can be adequately rationalized. The question of whether a discrete intermediate is involved in the ring expansion processes is unanswered.

Experimental Section

Melting points are uncorrected; elemental analyses were performed by Robertson Laboratory, Florham Park, N. J. 07932. Nmr spectra were recorded on a Varian Associates Model A-60 spectrometer using tetramethylsilane as an internal standard. Infrared spectra were recorded on a Perkin-Elmer Model 21 spectrometer or a PE 237B spectrometer.

Materials.—Diazomethane was generated from Diazald (*N*-methyl-*N*-nitroso-*p*-toluenesulfonamide, Aldrich Chemical Co.).[19]

Dithione Syntheses. A. 2,2,4,4-Tetramethyl-1,3-cyclobutanedithione (1).—The procedure was adapted from the Lipscomb patent and is documented here for reference.[4b] A solution of 2,2,4,4-tetramethyl-1,3-cyclobutanedione (25.0 g, 0.18 mol) and freshly fused zinc chloride (12.5 g, 0.092 mol) in methanol (200 ml) was placed in a 500-ml three-necked round-bottom flask equipped with a gas inlet tube, a gas outlet tube, and a thermometer. The solution was cooled to −5° and hydrogen chloride gas was bubbled through the reaction mixture for 1 hr. During this period the temperature of the solution rose and then dropped back to −5°. Hydrogen sulfide was then bubbled through the mixture for 14 hr at 0°. The red crystalline product which separated was filtered and washed with cold methanol (10–15 ml), wt 20 g. The crude dithione was crystallized from methanol (50 ml) to yield 16.0 g (52%) of pure dithione **1** as red platelets, mp 124–125° (lit.[4b] mp 125–126°). The dithione **1** could also be readily purified by sublimation.

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[18] (a) C. D. Gutsche, *Org. React.*, **8**, 364 (1954); (b) C. D. Gutsche and D. Redmore, "Carbocyclic Ring Expansion Reactions," Academic Press, New York, N. Y., 1968; (c) J. A. Marshall and J. J. Partridge, *J. Org. Chem.*, **33**, 4090 (1968); (d) N. J. Turro and R. B. Gagosian, *J. Amer. Chem. Soc.*, **92**, 2036 (1970); (e) G. W. Cowell and A. Ledwith, *Quart. Rev., Chem. Soc.*, **24**, 119 (1970), for a review and mechanistic discussion.

[19] (a) H. B. Hopps, *Aldrichimica Acta*, **3**, 9 (1970); (b) T. J. de Boer and H. J. Backer, "Organic Syntheses," Collect. Vol. IV, Wiley, New York, N. Y., 1963, p 250.

The nmr (CCl_4) exhibited a singlet at 1.40 ppm (lit.[4a] 1.40 ppm).

B. Dispiro[4.1.4.1]dodecane-6,12-dithione (2, *n* = 5).—Following the procedure described above, dispiro[4.1.4.1]dodecane-6,12-dione[20] (5.0 g, 0.026 mol) was converted into 4.5 g (78%) of crude dithione **2** (*n* = 5). The product was crystallized from cold methanol to yield orange-red platelets which melted at room temperature (22°), nmr (CCl_4) δ 1.95 ppm (m).

Anal. Calcd for $C_{12}H_{16}S_2$: C, 64.27; H, 7.19; S, 28.54. Found: C, 63.95; H, 7.50; S, 28.30.

C. Dispiro[5.1.5.1]tetradecane-7,14-dithione (2, *n* = 6).—Following the procedure described above with the exception that ethanol (150 ml) and methanol (50 ml) was used as the solvent, dispiro[5.1.5.1]tetradecane-7,14-dione[20] (10 g, 0.046 mol) yielded 10.0 g (86%) of crude dithione **2** (*n* = 6). The dithione was recrystallized from methanol, mp 119–120°, nmr (CCl_4) δ 1.77 ppm (broad peak).

Anal. Calcd for $C_{14}H_{20}S_2$: C, 66.64; H, 7.99; S, 25.37. Found: C, 66.50; H, 8.00; S, 25.32.

Diazomethane Additions to the Dithiones. General Procedure.—A slight excess of alcohol-free ethereal diazomethane at 0° was added to an ethereal solution of the dithione at 0°. Nitrogen evolution did not occur and the addition was continued until the red color disappeared and the yellow color persisted. The ether and excess diazomethane were removed at 0° using a slow nitrogen stream and then the last traces of ether were removed under vacuum. The white solids were stable at 0° and could readily be recrystallized from ether at low temperature.

A. Bis-Δ³-1,3,4-thiadiazolines 12.—Treatment of **1** (3.4 g, 0.02 mol) with excess diazomethane led to a quantitative yield of crude **12**. The compound was recrystallized from ether at −25°, mp 58° (decomposition starts), white solid fills tube, 180–195° to clear melt. The following spectral data were obtained for **12**: ir (CCl_4) 1570 cm⁻¹ (N=N); nmr ($CDCl_3$) δ 0.95, 1.25, 1.34 (all singlets, combined area for 12 H, CH_3), and 5.82 ppm (singlet, 4 H, $SCH_2N{=}N$).

Anal. Calcd for $C_{10}H_{16}N_4S_2$: C, 46.87; H, 6.29; N, 21.87. Found: C, 46.88; H, 6.03; N, 21.70.

B. Bis-Δ³-1,3,4-thiadiazoline 13 (*n* = 5).—Treatment of **2** (*n* = 5) with excess diazomethane led to a quantitative yield of the stereoisomers **13**: ir (CCl_4) 1570 cm⁻¹ (N=N); nmr ($CDCl_3$) δ 5.79, 5.75 (both singlets, combined area for 4 H, $SCH_2N{=}N$), 1.45 and 2.0 ppm (complex multiplets, combined area for 16 H, ring CH_2).

Anal. Calcd for $C_{14}H_{20}N_4S_2$: C, 54.53; H, 6.54; N, 18.17. Found: C, 54.55; H, 6.29; N, 18.07.

C. Bis-Δ³-1,3,4-Thiadiazolines 13 (*n* = 6).—Treatment of **2** (*n* = 6) with excess diazomethane led to a quantitative crude yield of the stereoisomers **13** (*n* = 6): ir (CCl_4) 1570 cm⁻¹ (N=N); nmr ($CDCl_3$) δ 5.85, 5.82 (both singlets, combined area for 4 H, $SCH_2N{=}N$), 1.85 and 1.25 ppm (broad patterns, combined area for 20 H, ring CH_2).

Anal. Calcd for $C_{16}H_{24}N_4S_2$: C, 57.13; H, 7.19; N, 16.66. Found: C, 57.41; H, 7.25; N, 16.79.

Thermolyses of the Stereoisomeric Bis-Δ³-1,3,4-thiadiazolines.—The bis adducts were refluxed in chloroform or carbon tetrachloride–hexane solutions for 2–4 hr (until the evolution of nitrogen ceased). On evaporation of the solvent the crude diepisulfides could be obtained.

A. Diepisulfides 17.—The bis adducts **12** (1.3 g) on refluxing in chloroform (10 ml) for 4 hr yielded 1.0 g (96%) of the stereoisomeric mixture of diepisulfides **17**, mp 150–185°. The crude product showed nmr absorptions at ($CDCl_3$) δ 0.90, 1.05, 1.26 (all singlets, combined total area for 12 H, CH_3), and 2.59 ppm (singlet, 4 H, SCH_2). On crystallization from pentane the intensities of the singlets at δ 0.90 and 1.26 diminished and the melting point was raised to 195–199°. Several recrystallizations from benzene–pentane yielded the pure trans diepisulfide: mp 207–208°; nmr ($CDCl_3$) δ 1.05 (s, 12 H, CH_3) and 2.59 ppm (s, 4 H, SCH_2).

Anal. (once crystallized from pentane). Calcd for $C_{10}H_{16}S_2$: C, 59.98; H, 8.05; S, 31.92. Found: C, 60.22; H, 8.09; S, 31.70.

B. Diepisulfides 18 (*n* = 5).—The bis adducts **13** (*n* = 5) were refluxed in a carbon tetrachloride–hexane solution until the evolution of nitrogen ceased. A quantitative yield of the diepisulfides **18** (*n* = 5) was obtained. The following nmr data were obtained ($CDCl_3$): δ 1.40, 1.80 (broad complex m, combined area for 16 H, ring CH_2), 2.62 and 2.55 ppm (both singlets, combined area for 4 H, SCH_2).

The analytical sample was crystallized from pentane, mp 65–71°.

Anal. Calcd for $C_{14}H_{20}S_2$: C, 66.64; H, 7.98; S, 25.37. Found: C, 66.74; H, 8.01; S, 25.58.

C. Diepisulfides 18 (*n* = 6).—The bis adducts **13** (*n* = 6) (0.9 g) in chloroform (10 ml) were refluxed for 1 hr. On evaporation of the chloroform a quantitative yield of the diepisulfides **18** (*n* = 6) was obtained, mp 87–97°. On crystallization from pentane the mixture melted at 99–102° (little change in the nmr spectrum).

The following nmr data were recorded ($CDCl_3$): δ 1.26, 1.57 (broad m, combined area for 20 H, ring CH_2), 2.61 and 2.68 ppm (both singlets, combined area for 4 H, SCH_2).

Anal. Calcd for $C_{16}H_{24}S_2$: C, 68.54; H, 8.63; S, 22.83. Found: C, 68.69; H, 8.25; S, 23.03.

Isolation of *cis*- and *trans*-21. Addition of Diphenyldiazomethane to 1.—To a solution of 2,2,4,4-tetramethyl-1,3-cyclobutanedithione (0.4 g, 0.0023 mol) in ether a solution of diphenyldiazomethane (1.2 g, 0.006 mol) in ether was added slowly at room temperature. The reaction mixture was allowed to stand until the evolution of nitrogen ceased (1 hr). The solid which separated was filtered and washed with cold pentane. The filtrate was concentrated and pentane was added to the residue. The red solution was decanted from the white crystalline solid: total wt 1.15 g (quantitative); mp 235–240°; nmr ($CDCl_3$) δ 7.80 (aromatic complex m), 7.2 (aromatic complex m), 1.42, 0.77, and 0.53 ppm (all singlets, SCH_2). The product was recrystallized from benzene–hexane and the isomer composition changed.

Anal. Calcd for $C_{34}H_{32}S_2$: C, 80.90; H, 6.39; S, 12.71. Found: C, 81.02; H, 6.56; S, 12.99.

Treatment of the isomeric mixture (cis:trans 67:33) with warm acetone left an insoluble white residue, mp 256–257° The nmr ($CDCl_3$) showed peaks at δ 7.8 (broad multiplet), 7.25 (broad m), and 0.79 ppm (s), which is the *trans*-**21**. The acetone washings were combined and the solvent was removed. The residual solid was taken up in cold acetone and filtered from the insoluble material. The filtrate was partially concentrated and cooled to yield *cis*-**21**: mp 252–253°; nmr δ ($CDCl_3$) 7.8 (broad m), 7.2 (broad m), 1.43 (s), and 0.53 ppm (s).

Diazomethane Ring Expansions. Preparation of 22.—Treatment of tetramethyl-1,3-cyclobutanedione (2.8 g, 0.02 mol) with excess ethanolic–ethereal diazomethane (−25° for 21 hr and room temperature for 3 days) followed by removal of the ether left a low-melting solid in quantitative yield. Crystallization from pentane yielded 2.97 g (96%) of pure product: mp 22–23°; ir (neat) 1725 (s), 1760 and 1695 cm⁻¹ (sh); nmr (CCl_4) δ 1.10 (s, 6 H, CH_3), 1.21 (s, 6 H, CH_3), and 2.55 ppm (s, 2 H, $CH_2C{=}O$).

Anal. Calcd for $C_9H_{14}O_2$: C, 70.10; H, 9.15. Found: C, 70.10; H, 9.26.

Preparation of 23 (*n* = 4).—Treatment of dione **2** (*n* = 4; S = O) (0.14 g, 0.85 mol) in ether with excess ethanolic–ethereal diazomethane led to the instantaneous evolution of nitrogen. The solution was cooled to −25° and the solid which separated was collected, wt 0.052 g, mp 50–52°. On removal of the ether a second crop was obtained (total yield 99%) of the same melting point. The analytical sample was prepared by sublimation: mp 51–52.5°; ir ($CHCl_3$) 1712 (s) and 1752 cm⁻¹ (shoulder); nmr ($CDCl_3$) δ 1.8–2.6 (complex m, 12 H, ring CH_2) and 2.84 (s, 2 H, $CH_2C{=}O$).

Anal. Calcd for $C_{11}H_{14}O_2$: C, 74.13; H, 7.92. Found: C, 73.83; H, 8.18.

Preparation of 23 (*n* = 5).—Excess ethanolic–ethereal diazomethane was added to **2** (*n* = 5) (2.0 g, 0.011 mol) in ether. The solution was kept at −25° for 18 hr, 8 hr at 0°, and at room temperature for 24 hr. On removal of the excess diazomethane and ether an oil was obtained in a quantitative yield. This product was essentially pure and could be crystallized at low temperature from pentane and melted slightly below room temperature: ir (neat) 1710 (s), 1750 cm⁻¹ (sh); nmr ($CDCl_3$) δ 1.84 (broad peak, 16 H, ring CH_2) and 2.70 ppm (s, 2 H, $CH_2C{=}O$).

Anal. Calcd for $C_{13}H_{18}O_2$: C, 75.69; H, 8.80. Found: C, 75.65; H, 9.03.

Preparation of 23 (*n* = 6).—Dione **2** (*n* = 6) (4.0 g, 0.018 mol) was treated with excess ethanolic–ethereal diazomethane and kept at −25° for 18 hr, 0° for 8 hr, and at room temperature for 2

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[20] J. L. E. Erickson, F. E. Collins, Jr., and B. L. Owen, *J. Org. Chem.*, **31**, 480 (1966).

days. On removal of the excess diazomethane and ether, a large amount of starting material was present. By repeated crystallization from pentane the starting material could be removed and 1.3 g (31%) of crude dione **23** ($n = 6$) was obtained, mp 63–69°. The analytical sample was prepared by sublimation, mp 74–75°. The dione **23** ($n = 6$) had the following spectral properties: ir ($CHCl_3$) 1725 (s), 1725 and 1784 cm^{-1} (sh); nmr ($CDCl_3$) δ 1.6 (broad absorption, 20 H, ring CH_2), and 2.63 ppm (s, 2 H, $CH_2C{=}O$).

Anal. Calcd for $C_{15}H_{20}O_2$: C, 76.88; H, 9.46. Found: C, 76.75; H, 9.70.

Registry No.—2 ($n = 5$), 31934-25-5; 2 ($n = 6$), 22502-49-4; *cis*-**12**, 31934-27-7; *trans*-**12**, 31934-28-8; *cis*-**13** ($n = 5$), 31934-29-9; *trans*-**13** ($n = 5$), 31934-30-2; *cis*-**13** ($n = 6$), 31934-31-3; *trans*-**13** ($n = 6$), 31934-32-4; **15**, 31934-33-5; **16**, 31934-34-6; *cis*-**17**, 31934-35-7; *trans*-**17**, 31934-36-8; *cis*-**18** ($n = 5$), 31981-32-5; *trans*-**18** ($n = 5$), 31934-37-9; *cis*-**18** ($n = 6$), 31934-38-0; *trans*-**18** ($n = 6$), 31934-39-1; *cis*-**21**, 31934-40-4; *trans*-**21**, 31934-41-5; **22**, 31934-42-6; **23** ($n = 4$), 31934-43-7; **23** ($n = 5$), 31934-44-8; **23** ($n = 6$), 31934-45-9; diazomethane, 334-88-3.

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6-Acyl-5*H*-1-pyrindine-5,7(6*H*)-diones and Their Reaction with Hydrazine

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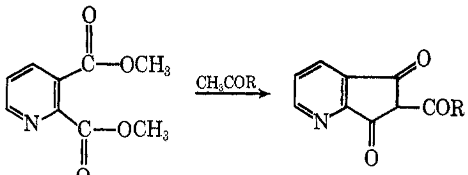
A series of 6-acyl-5*H*-1-pyrindine-5,7(6*H*)-diones (**1**) was prepared by condensing dimethyl 2,3-pyridinedicarboxylate with various methyl ketones. Depending upon the conditions, reaction of compounds **1** with hydrazine gave 3-substituted 1,4-dihydropyrazolo[3′,4′:3,4]cyclopenta[1,2-*b*]pyridines (**6**), 3-substituted pyrazolo[3′,4′:3,4]cyclopenta[1,2-*b*]pyridin-4(1*H*)-ones (**2**), or a mixture of the hydrazones of the two isomeric 3-substituted pyrazolo[3′,4′:3,4]cyclopentapyridin-4(1*H*)-ones (**4** and **5**).

Our interest in 2-acyl-1,3-indandiones and their reaction products with hydrazine[1-3] prompted us to prepare the structurally related compounds, the 6-acyl-5*H*-1-pyrindine-5,7(6*H*)-diones (**1a–o**) and to study their reaction with hydrazine. 6-Alkyl- and 6-aryl-5*H*-1-pyrindine-5,7(6*H*)-diones are reported in the literature[4,5] but no reference was found concerning the 6-acyl derivatives **1**.

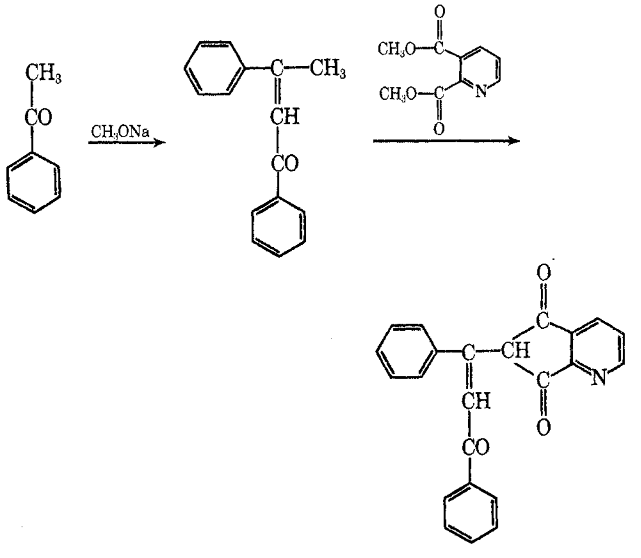
The structural analogy with the 6-acyl-1,3-indandiones suggested the preparation of **1** by a method similar to that used to prepare the acylindandiones.[1] Yields varying from 8 to 69% were obtained by reacting dimethyl 2,3-pyridinedicarboxylate with the appropriate methyl ketone in the presence of sodium methoxide.



1a–o

When R is an aryl group instead of an alkyl, the reaction is slower and it is accompanied by side reactions. Thus, in the condensation of dimethyl 2,3-pyridinedicarboxylate with acetophenone to form compound **1m**, 6-(α-phenacylidenebenzyl)-5*H*-1-pyridine-5,7(6*H*)-dione was isolated as the by-product.

The structures of the acylpyrindinediones **1a–o** are based upon the elemental analyses and are consistent with the infrared spectra.



The addition of hydrazine to a hot solution of 6-acetyl-5*H*-1-pyrindine-5,7(6*H*)-dione (**1a**) in ethanol, followed by rapid cooling in ice, gave the corresponding monohydrazone with the hydrazono group on the side chain. This structural assignment was based on the similarities of the spectral and chemical properties of this hydrazone with those of the known α-hydrazone of 2-acetyl-1,3-indandione.[1] Several attempts to prepare the monohydrazones of other 6-acyl-5*H*-1-pyrindine-5,7(6*H*)-diones were unsuccessful. The products obtained were generally the ring-closed compounds **2**.

In the reaction of the acylpyrindinediones **1m** and **1n** with 1 equiv of hydrazine in refluxing ethanol, only one of the two possible isomers, 3-substituted pyrazolo[3′,4′:3,4]cyclopenta[1,2-*b*]pyridin-4(1*H*)-one (**2**, Scheme I) or 3-substituted pyrazolo[3′,4′:3,4]cyclopenta[2,1-*b*]pyridin-4(1*H*)-one (**3**), was isolated. Structure **2** was assigned to the isolated isomer, since the hydrazones of compounds **2** were found identical

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[1] R. A. Braun and W. A. Mosher, *J. Amer. Chem. Soc.*, **80**, 2749 (1958).

[2] R. A. Braun and W. A. Mosher, *J. Org. Chem.*, **24**, 648 (1959).

[3] W. A. Mosher and W. E. Meier, *ibid.*, **35**, 3685 (1970).

[4] B. M. Bain and J. E. Saxton, *J. Chem. Soc.*, 5216 (1961).

[5] L. E. Neiland and G. Ya. Vanag, *Khim. Geterotsikl. Soedin.*, **1**, 114 (1967); *Chem. Abstr.*, **67**, 64269*k* (1967).