chemistry of the side chain (the three chiral centers) is still under investigation and the total synthesis of nucleoside Q should corroborate the tentative assignments reported in ref 1a and 1b.
(2) F. Harada and S. Nishimura, *Biochemistry*, **11**, 301 (1972).
(3) H. Kasai, Y. Kuchino, K. Nihei, and S. Nishimura, *Nucleic Acid Res.*, **2**, 1931 (1975).
(4) Y. Kuchino, H. Kasai, K. Nihei, and S. Nishimura, *Nucleic Acid Res.*, **3**, 393 (1976).
(5) R. J. Suhaldolnik, "Nucleoside Antibiotics", Wiley-Interscience, New York, N.Y. 1970, Chapter 8.
(6) (a) K. H. Schram and L. B. Townsend, *J. Chem. Soc., Perkin Trans. 1*, 1253 (1975); (b) R. L. Tolman, R. K. Robins, and L. B. Townsend, *J. Am. Chem. Soc.*, **91**, 2102 (1969), and references cited therein.
(7) Professor K. Nakanishi recently reported (presented at the Centennial American Chemical Society Meeting, New York, N.Y., April 1976, CARB 31) the structure of Q*. He indicated that Q* possessed a mixture of *O*-glycosides on the 4-position of the cyclopentenyl moiety. His data strongly suggested that the *O*-glycoside portion was a mixture of the following hexoses: β-D-mannosyl (~75%)/β-D-galactosyl (~25%); for complete details see H. Kasai, K. Nakanishi, R. D. MacFarlane, D. F. Torgerson, Z. Ohashi, J. A. McCloskey, H. J. Gross, and S. Nishimura, *J. Am. Chem. Soc.*, **98**, 5044 (1976).
(8) L. B. Townsend in "Handbook of Biochemistry and Molecular Biology", 3d ed, Nucleic Acids Vol. 1, G. D. Fasman, Ed., Chemical Rubber Co. Press, Cleveland, Ohio, 1975, p 390.
(9) H. Kawashima and I. Kumashiro, *Bull. Chem. Soc. Jpn.*, **40**, 639 (1967).
(10) Satisfactory analytical data (C, H, and N) were obtained for all compounds reported in this communication. A chlorine analysis was also obtained for compound **7**.
(11) B. C. Hinshaw, J. F. Gerster, R. K. Robins, and L. B. Townsend, *J. Org. Chem.*, **35**, 236 (1970).
(12) G. R. Revankar and R. K. Robins, *Ann. N.Y. Acad. Sci.*, **255**, 166 (1975).

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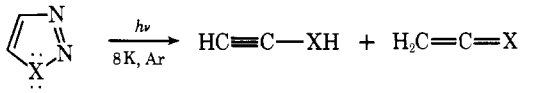
Photolysis of Isotopically Labeled 1,2,3-Selenadiazole and 1,2,3-Thiadiazole. Symmetry Properties of the Paths Leading to Ethynyl Mercaptan and Selenol. Evidence for Thiirene[1]

Sir:

We recently reported[2] on the irradiation with Pyrex-filtered mercury lamp light of matrix-isolated 1,2,3-thiadiazole (**1a**), whose photodecomposition appears to involve the potentially antiaromatic molecule, thiirene (**2**), as a transient species.[3,4]



1a, X = S
b, X = Se
3 **4**

In this communication we describe the photochemistry of matrix-isolated 1,2,3-selenadiazole[5] (**1b**), (which exhibits, in its details, behavior quite distinct from its sulfur analogue)[2] and further experiments with isotopically labeled **1a.** Irradiation with Pyrex-filtered mercury lamp light of argon or nitrogen matrix-isolated **1b** at 8 K ($M/R \sim 500$) gave ethynyl selenol **3b,** selenoketene **4b,** and acetylene (**5**) (a product not observed in the photolysis of **1a**).[6] It is noteworthy that **1b** is not interconverting with the more photostable 1,3,4-selenadiazole[7,8] (**6b**), since neither **6b** nor its major photoproduct, hydrogen cyanide, are observed during the photolysis of **1b.**

Selenol **3b** possesses key bands at 3318 (≡CH str), 2050 (C≡C str), and 581 cm^{-1} (≡CH in-plane bend), virtually identical with those observed for the corresponding modes in **3a**[2] and ethynyl selenoethers.[9] The assignment of an extremely intense band at 1695 cm^{-1} in the spectrum of photolysate to the C=C stretch of **4b** is reasonable, in light of the value of the corresponding mode in thioketene (1755 cm^{-1}). This band

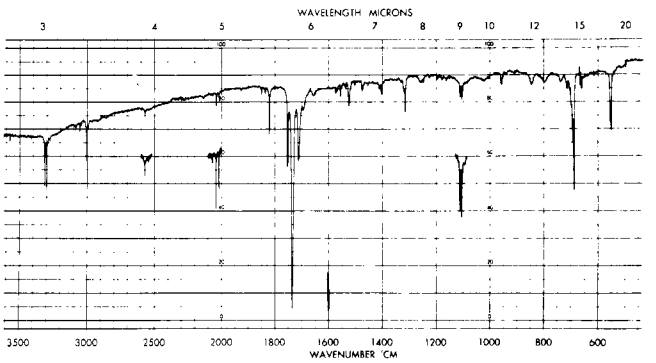


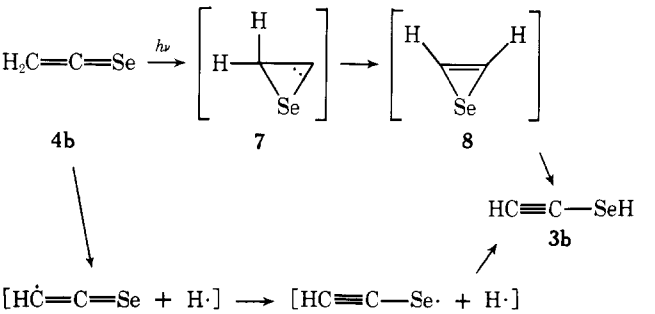
Figure 1. Spectrum of argon matrix-isolated 1,2,3-thiadiazole-*4*-^{13}C (90% isotopically pure) (M/R = 500) photolyzed at 8 K for 105 min with Pyrex-filtered light. Starting thiadiazole has been destroyed. Pairs of bands due to isomeric ^{13}C ethynyl mercaptans are seen at 3307 and 3325 (CH str), 2025 and 2045 (C≡C str), and 552 and 555 cm^{-1}. There is a 10% contribution from the carbon-12 spectrum.

displays, on substitution of **1b** with deuterium, behavior typical of parent cumulenes:[10] ν_{d_0} = 1699, ν_{d_1} = 1698, ν_{d_2} = 1681 cm^{-1}. Detection of selenoketene represents one of the few documented examples of a species possessing a C=Se double bond.[11-13]

Photolysis with Pyrex-filtered light of argon matrix-isolated 4-deuterio-1,2,3-selenadiazole[5] ($M/R \sim 400$) gives product spectra containing absorption characteristic of ≡C-H (3318 cm^{-1}) and ≡C-D (2580 cm^{-1}) stretches in the ratio of ca. 0.2; under identical conditions the 5-deuterio isomer gives these bands in an approximately inverse ratio of 3.5! Whereas the hydrogens of the thiadiazole framework become equilibrated through a symmetrical species en route to ethynyl mercaptan **3a,** it is clear from the foregoing labeling experiments that the major portion of ethynyl selenol **3b** is not formed via a pathway which equilibrates the hydrogens.

If the Pyrex filter is removed after monodeuterated selenadiazole has been fully photodecomposed, and the "Pyrex" photolysate is then irradiated with a bare lamp (λ > 200 nm), the selenol increases at the expense of both acetylene **5** and selenoketene **4b,** with the ratio ≡CH/≡C-D(str) of the selenols converging to 1.0.

A possible mechanism for the loss of acetylene could involve the addition of photochemically excited selenium atoms to neighboring acetylene molecules.[15] Plausible explanations for the trade-off of selenoketene **4b** for selenol **3b** include (1) conversion of **4b** to the carbene **7,** which could, in turn, isom-

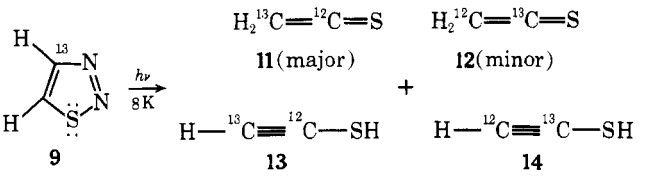


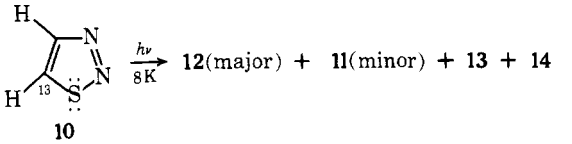
erize to predominantly the selenol through selenirene **8,** or (2) a reaction mediated by a hydrogen radical cleaved from the carbon end of **4b,** which then readds to the selenium terminus. Support for the latter alternative is derived from the observation that irradiation (λ > 200 nm) of the photolysate from **1b** isolated in a carbon monoxide host at 8 K produces absorptions [ν = 1865 (s), 1093 cm^{-1} (m)] in the infrared, indicative of the formyl radical.[16,17]

The results of irradiating 1,2,3-thiadiazole-*4*-^{13}C (**9**) (90% isotopically pure) in solid argon are pictured in Figure 1. Pairs

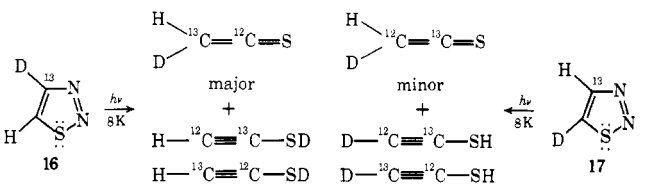
of bands at 3307 and 3325 (CH str), 2025 and 2045 (C≡C str), and 552 and 555 cm^{-1} signal the formation of two isomeric ^{13}C-ethynyl mercaptans, which are almost completely equilibrated as judged by the relative intensities of the aforementioned bands. Inspection of the bands due to thioketene indicate that one isotopic form ($H_2{}^{13}C{=}{}^{12}C{=}S$) dominates the spectrum. The latter point is apparent from a comparison of the intensity of the band at 1737 cm^{-1} due to $H_2{}^{13}C{=}{}^{12}C{=}S$, with the corresponding mode at 1713 cm^{-1} belonging to $H_2{}^{12}C{=}{}^{13}C{=}S$. It seems likely that a major path to ethynyl mercaptan **3a** involves a species with equivalent carbons, whereas the major portion of the thioketene product is not formed via a pathway which equilibrates carbon atoms.[18]

The validity of this argument, which is based on relative intensities, is unambiguously supported by the course of photolysis of 1,2,3-thiadiazole-*5*-^{13}C (**10**) (90% isotopically pure). Whereas ethynyl mercaptans are again substantially equilibrated, the preference exhibited for thioketene **11** over **12** in the case of **9**, is reversed in the photolysis of **10**. With the proviso that a degenerate rearrangement equilibrating the carbon atoms of ethynyl mercaptan is not involved, the major portion of the thioketene and ethynyl mercaptan product cannot be born from a common intermediate.



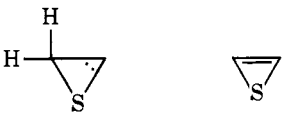


A most dramatic consequence of the mechanistic pathway is uncovered by comparison of the infrared spectrum of photolyzed 1,2,3-thiadiazole-*4-d-4*-^{13}C (**16**) with that of its 5-*d* isomer **17**. The spectra are very similar and indicate the formation of all four isomeric, monodeuterated, ^{13}C-labeled ethynyl mercaptans. Hence, the carbon-bound hydrogen of ethynyl mercaptan **3a** is not necessarily bound to that carbon atom to which it was originally attached in thiadiazole **1a.** To satisfy the data, at least one interchange involving "hydrogen swapping" between carbon atoms must occur. A careful kinetic analysis of the photolysate from the irradiation of either 1,2,3-thiadiazole-*4*- or -*5*-^{13}C (**9** or **10,** respectively) (1000-W Hg–Xe lamp fitted with a 3000-Å interference filter) indicates that the minor thioketene in each case is formed by a different path than the primary thioketene product. A process producing ethynyl mercaptan (apart from one leading to fully equilibrated **13** and **14**) favoring **13** in the case of **9,** and **14** in the case of **10,** can also be observed early in the photolysis.



One way to rationalize these results is to assume that one set of products (with non-equilibrated label) stems from a single C_2H_2S isotopic species (perhaps the diradical $H^{13}\dot{C}{=}C(H)\dot{S}$ in the case of **9**), whereas the other set (with equilibrated label) is derived from thiirene **2.**[21]

Support for a thiirene *intermediate* stems from the observation that irradiation (1000-W Hg–Xe lamp fitted with a 3000-Å interference filter) of either thiadiazole **9** or **10** leads to a species with bands at 3163, 3158, 1634, 910, and 558 cm^{-1} that is photochemically converted to ethynyl mercaptan and thioketene, both with equilibrated label. The species derived from **1a** has bands located at 3169, 3166, 1663, 912, and 563 cm^{-1}. The singly labeled monodeuterated variant exhibits absorption at 3181, 3175, 2420, 2415, 1611, 892, and 467 cm^{-1}. Such behavior is precisely the kind that would be expected for thiirene.



The relevance of these observations involving matrix-isolated species, to mechanistic photochemistry in other phases, is being studied. In particular, the possibility that the three-member cyclic carbene **18** or any other precursor is being diverted to thiirene because of slow vibrational energy transfer in inert gas matrices is currently under intensive investigation.[23,24]

Acknowledgment. We gratefully acknowledge support of this research from grants made available by the National Science Foundation, The Research Foundation, SUNY, and the donors of the Petroleum Research Fund, administered by the American Chemical Society.

References and Notes

(1) Presented in part at the First Chemical Congress of the North American Continent, Mexico City, Mexico, Dec 4, 1975, Paper ORG 132.
(2) A. Krantz and J. Laureni, *J. Am. Chem. Soc.*, **96,** 6768 (1974).
(3) Thiirene and related three-membered heterocycles have been implicated as transients in a number of previous reports: see O. P. Strausz, J. Font, E. L. Dedio, P. Kebarle, and H. E. Gunning, *J. Am. Chem. Soc.*, **89,** 4805 (1967); D. E. Thornton, R. K. Gosavi, and O. P. Strausz, *ibid,* **92,** 1768 (1970); I. G. Csizmadia, J. Font, and O. P. Strausz, *ibid,* **90,** 7360 (1968); J. Fenwick, G. Frater, K. Ogi, and O. P. Strausz, *ibid,* **95,** 124 (1973); T. L. Gilchrist, G. E. Gymer, and C. W. Rees, *Chem. Commun.*, 1519 (1971); P. S. Mente and C. W. Rees, *J. Chem. Soc., Chem. Commun.*, 418 (1972); S. A. Matlin and P. S. Sammes, *ibid.*, 11 (1972); O. P. Strausz, *IUPAC, Suppl.,* **4,** 186 (1971).
(4) We have recently observed a partial equilibration of the ^{13}C label in product dimethyl ketene formed on photolysis of matrix-isolated 3-diazo-2-propanone-*2*-^{13}C: B. Hoppe and J. Laureni, unpublished results.
(5) I. Larezari, A. Shafill, and M. Yalpani, *J. Org. Chem.*, **36,** 2836 (1971).
(6) (a) An identical experiment performed in a carbon monoxide host gives rise to absorption at 2021 cm^{-1}, indicative of carbonyl selenide,[6b] which can be viewed as evidence for trapping of selenium atoms by the matrix host. (b) T. Wentink, Jr., *J. Chem. Phys.*, **30,** 105 (1959).
(7) R. U. Kendall and R. A. Olofson, *J. Org. Chem.*, **35,** 806 (1970).
(8) G. Lipkowitz and A. Krantz, unpublished results.
(9) L. Brandsma, *Recl. Trav. Chim. Pays-Bas,* **83,** 307 (1964).
(10) The corresponding values for thioketene (**4,** X = S) are ν_{d_0} = 1760,[25] ν_{d_1} = 1755, and ν_{d_2} = 1735 cm^{-1}. For ketene,[14] ν_{d_0} = 2142, ν_{d_1} = 2132, and ν_{d_2} = 2113 cm^{-1}.
(11) T. G. Bank, D. H. R. Barton, M. R. Britten-Kelly, and F. S. Guzieck, Jr., *J. Chem. Soc., Chem. Commun.*, 539 (1975).
(12) K. A. Jensen, L. Henriksen, and P. H. Nielsen in "Organic Selenium Compounds: Their Chemistry and Biology", D. L. Klayman and W. H. H. Gunther, Ed., Wiley, New York, N.Y., 1973, p 843.
(13) D. H. Reid, *J. Chem. Soc. C,* 3187 (1971).
(14) C. B. Moore and G. C. Pimentel, *J. Chem. Phys.*, **38,** 2824 (1963).
(15) The reduction in acetylene may be due to the formation of carbon diselenide (carbon disulfide is formed when thioketene is photodecomposed with λ > 200 nm, vide infra) and its subsequent breakdown and reaction with acetylene.
(16) D. E. Milligan and M. E. Jacox, *J. Chem. Phys.*, **51,** 277 (1969); G. E. Ewing, W. E. Thompson, and G. C. Pimentel, *ibid,* **32,** 927 (1960).
(17) All these proposals must presently be regarded as speculative; the experiments described for the selenium system were developed for comparison purposes with **1a,** and are to be regarded as indicative of the be-

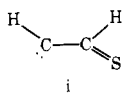
havior of a photofragmentable C_2H_2X species. On the other hand, the C_2H_2S fragment from **1a** appears to be generated and to remain intact at least during photoirradiation with Pyrex-filtered light.

(18) Further irradiation of the photolysate of **9** with the bare lamp results in the destruction of the thioketene and the appearance of bands at 1530 and 1485 cm^{-1}, perhaps due to carbon disulfide[19,20] or some other polysulfide. The course of this photodecomposition appears to be sensitive to traces of oxygen, and is concentration dependent.

(19) D. F. Smith, Jr., and J. Overend, *Spectrochim. Acta, Part A*, **26**, 2269 (1970).

(20) A. Krantz and J. Laureni, *J. Am. Chem. Soc.*, **97**, 6606 (1975).

(21) A mechanism involving the thiocarbene i could be responsible for the formation of a single isotopic thioketene species.[22]



i

(22) Dewar has predicted that the thiocarbene i would collapse without activation energy to thioketene: M. J. S. Dewar and C. A. Ramsden, *J. Chem. Soc., Chem Commun.*, 688 (1973).

(23) The ratio **3a/4a** appears to decrease in the series argon (highest value), nitrogen, carbon monoxide, and acetylene (lowest value) matrices. When methyl and dimethyl thiadiazoles are photolyzed, thioketenes are detectable. The formation of ethynyl sulfides and mercaptans may be suppressed by methyl substituents.

(24) All new infrared values reported for the thiadiazole system were recorded on a Perkin-Elmer Model 180 spectrometer.

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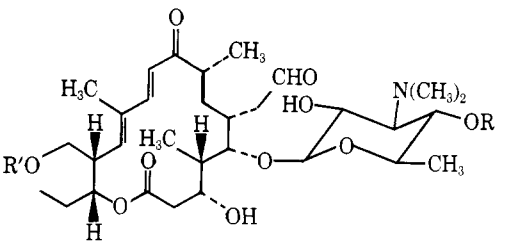
Tylonolide Hemiacetal, the Aglycone of Tylosin, and Its Partial Synthesis

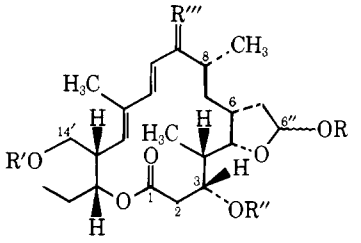
Sir:

Tylosin (**1**)[1] is one of the structurally most complex 16-membered macrolides[2] and has been widely used therapeutically as well as nutritionally.[3] We wish to describe herein (i) an efficient preparation of tylonolide hemiacetal (**2**) (the intact aglycone of **1**) which is demanded for biosynthetic modification of the macrolide,[4] and (ii) a partial synthesis of **2.** An adequate supply of **2** has permitted us to characterize **2** fully, accordingly to modify the structure previously proposed.[5b] Conversion of **2** into a seco-acid derivative (**3**) and subsequent cyclization to form the original ring system have also been achieved. This transformation represents the first successful lactonization of an authentic[6] 16-membered macrolide seco-acid. In addition, problems associated with the presence of the β-hydroxy group in **3** have led to the discovery of an efficient synthetic method for the preparation of β-lactones,[7] versatile intermediates often utilized for the introduction of other functional groups.

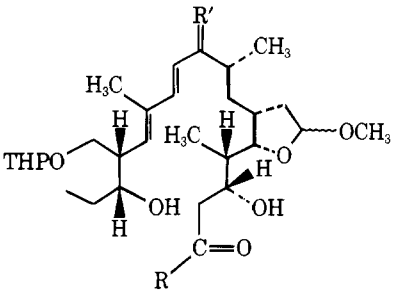
The glycoside linkage of an amino-sugar resists acid hydrolysis much more than that of a neutral sugar. Therefore, conditions normally required for the removal of an amino-sugar from a macrolide antibiotic induce extensive destruction of the aglycone.[8] Devices to secure the intact aglycone, therefore, involve conversion of the amino group into its *N*-oxide which is in turn eliminated from the sugar moiety (prior to or during the following milder acid hydrolysis) via a Cope elimination[9] or Polonovski reaction.[10] Thus conversion of *O*-mycaminosyl tylonolide (OMT)[5a,11] into its tetra(trifluoroacetate) and subsequent oxidation with *m*-chloroperoxybenzoic acid yielded the *N*-oxide which was again trifluoroacetylated. Refluxing a sodium acetate buffered aqueous tetrahydrofuran solution of this last compound effected hydrolysis of both the glycoside and trifluoroacetate groups. Column chromatography (Woelm Silica Gel) provided, in as high as 50% yield, tylonolide hemiacetal (**2**), mp 147–148 °C,



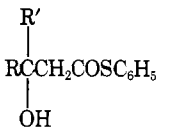
1, R = mycarosyl; R′ = mycinosyl
OMT, R = R′ = H



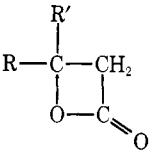
2, R = R′ = R″ = H; R‴ = O
4, R = R′ = R″ = $COCH_3$; R‴ = O
5, R = CH_3; R′ = R″ = H; R‴ = O
6, R = CH_3; R′ = THP; R″ = H; R‴ = H, OH



3, R = SC_6H_5; R′ = O
7, R = OH; R′ = H, OH



8, R, R′ = C_5H_{10}
9, R = n-C_8H_{17}; R′ = H



10, R, R′ = C_5H_{10}
11, R = n-C_8H_{17}; R′ = H

$C_{23}H_{36}O_7$ (elemental analysis and accurate mass).[12] The presence of a hemiacetal group rather than the previously reported acetal[5b] in **2** was shown by the formation of the triacetate (**4**) (rather than the monoacetate) and of a mixed acetal (**5**) with an alcohol (vide infra). All attempts to prepare the corresponding tylonolide acetal (with C(3)-O-) have failed. These results provide (synthetically important) information concerning the conformation of **2,** accepting the Celmer model[2b] for this aglycone. The C-3 OH group must be remotely located from the C-6″ OH in the actual conformer and its conversion into another conformational isomer in which the (intramolecular) acetal formation is likely to proceed must encounter a high energy barrier. Inspection of the CPK atomic model of **2** supports this supposition.

The methyl ether (acetal) (**5**) of **2** (trimethyl orthoformate), after the protection of its primary hydroxy group at the C-14′ position as a tetrahydropyranyl ether (dihydropyran, 5 min, room temperature), was reduced with $NaBH_4$ to afford the isomeric allylic alcohols **6.** The alkaline hydrolysis of **6** proceeded under reasonably mild conditions (1 N NaOH, 60 °C, 2 h) apparently due to the assistance of the C-3 hydroxy group.[13] The overall conversion of **2** into the β-hydroxycar-