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Registry No. **1a**, 465-65-6; **1b**·HCl, 16676-29-2; **2b**, 123621-72-7; **3a**, 41135-96-0; **3b**, 121962-99-0; **4a**, 123621-70-5; **4b**, 123621-71-6.

Practical Synthesis of (3*S*,4*R*)-3-[(*R*)-1-(*tert*-Butyldimethylsiloxy)-ethyl]-4-(methylsulfonyl)-2-azetidinone from Dibromopenicillanic Acid *S*,*S*-Dioxide: A Penem Synthon

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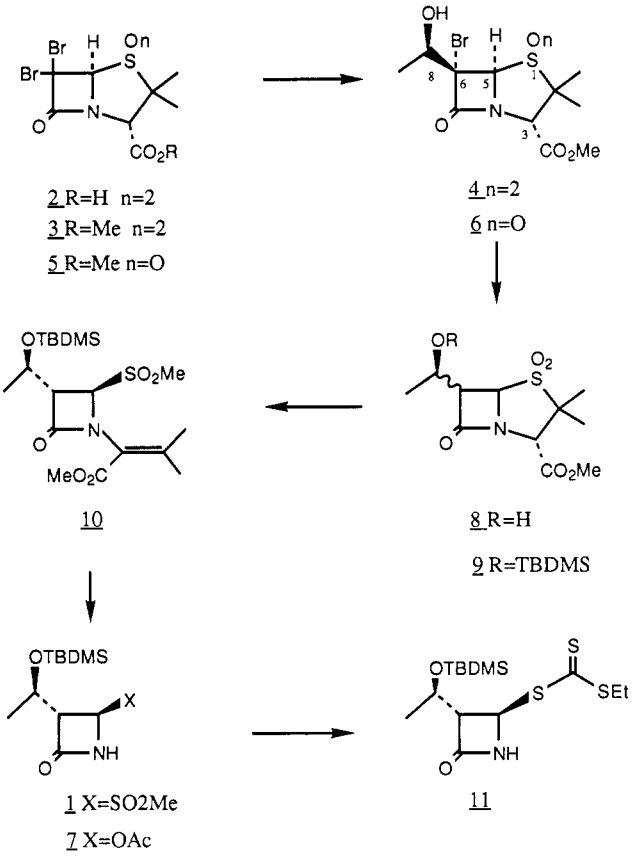
β-Lactams have intrigued chemists for decades.[1] The allurement has been the result of their labyrinthine chemical structure in tandem with their valuable biological activity. Woodward introduced a new dimension to β-lactam research by synthesizing the first penem and demonstrating the inherent antibacterial activity[2] present in this ring system. His pioneering strategy of thiazoline ring construction onto an appropriately substituted azetidinone is still the most commonly employed approach to penems.[3] Our penem research, as well as others, targeted 3,4-disubtituted azetidinones as key synthons.

6-Aminopenicillanic acid and other enantiomerically pure compounds have been converted into azetidinones of this type.[4] Two fundamental problems were persistent in the penicillin-based routes. Aldol reaction with the sulfide oxidation level of the penicillin gave a mixture of isomers that required crystallization and/or chromatography to isolate the desired 8R isomer.[5] Subsequent isomerization of the cis C_5–C_6 relationship, in the dominate 8*R* aldol isomer, to trans was not complete (91:9) and required chromatography to isolate the pure trans compound.[5b] Therefore, a penicillin-based azetidinone process was sought that did not necessitate chromatography. Recently, some researchers have found methods to overcome these two obstacles.[6] The subject of this note is an efficient route to sulfone **1** starting with 6,6-dibromopenicillanic acid *S*,*S*-dioxide.[7]

Scheme I



Results and Discussion

The synthesis commenced with Fisher esterification of 6,6-dibromopenicillanic acid *S*,*S*-dioxide (DBPAS, **2**), which afforded an 88% yield of the methyl ester **3** as a crystalline white solid,[8] Scheme I. Transmetalation of the DBPAS methyl ester **3** with methylmagnesium chloride at −85 °C and subsequent addition of acetaldehyde produced, after workup and aqueous trituration, exclusively **4** in 71% yield. The crude reaction mixture contained a mixture of three isomeric products, prior to aqueous trituration, in a ratio of 89:7:4.[9] For comparison, in the sulfide series, aldol reaction of **5** produced a mixture of all four possible diastereomers in the ratio of 72:19:5:3.[5b,9] The dominant sulfide aldol isomer **6** has been converted into acetoxyazetidinone **7** and methyl sulfone **1**.[5,10] Sulfide oxidation of this dominant aldol isomer **6**, methyl (3*S*,5*R*,6*S*)-6-bromo-6-[(*R*)-1-hydroxyethyl]penicillanate, with *m*-CPBA produced a compound identical with sulfone aldol adduct **4** by high-field proton and carbon NMR. The 6*S*,8*R* stereochemistry determined by chemical correlation in aldol **4** was confirmed by X-ray analysis, Figure 1.[11]

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0022-3263/90/1955-0367$02.50/0

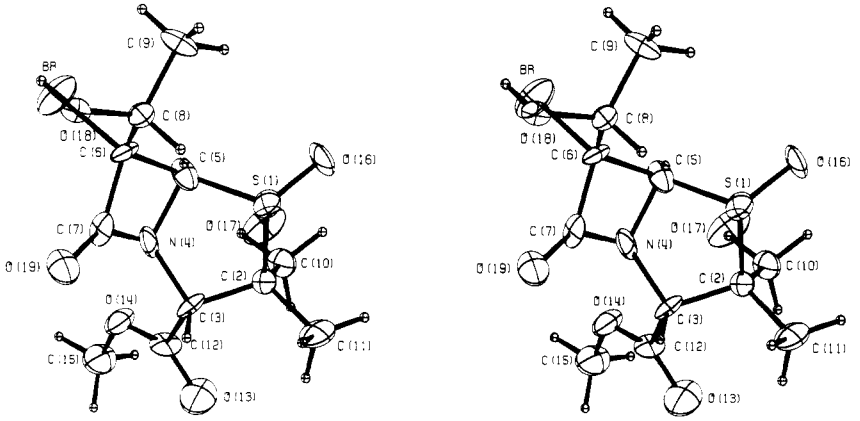

Figure 1. Stereoplot of compound 4.

Having established the correct $C_8(R)$ stereochemistry, attention was directed to epimerizing the C_6 center into the desired trans configuration.

Catalytic hydrogenation of aldol **4** employing palladium on carbon generated **8** with varying cis/trans ratios at C_5/C_6.[12] The mixture of isomers could be separated by crystallization or column chromatography; however, this was not necessary. Instead, the C_6 isomeric alcohol mixture was silylated in 86% yield under standard conditions with *tert*-butyldimethylsilyl chloride.[13] Under appropriate reaction conditions the lack of stereocontrol generated at C_6 during reduction of aldol **4** was of no consequence, as both cis and trans silylated isomers **9** were converted into unsaturated ester **10**.

In a previous synthesis of methyl sulfone **1**, **9** was converted into unsaturated ester **10** in two steps.[10] This had been achieved by catalytic 1,5-diazabicyclo[4.3.0]non-5-ene (DBN) isomerization of the hydroxyethyl substitutent in **9** to the trans configuration, which was subsequently treated with potassium *tert*-butoxide and methyl iodide to afford **10**. Our research sought conditions to transform **9** into **10** directly. Initial experiments with excess DBN and methyl iodide afforded the desired trans-unsaturated ester **10** contaminated with approximately 20% of the cis isomer.[14] Treatment of the mixture with additional DBN produced no change in the cis/trans ratio. Continued investigation revealed that reaction of the silylated isomer mixture **9** or the pure cis component with 1,8-diazabicyclo[5.4.0]undec-7-ene (DBU) rapidly isomerized the hydroxyethyl substituent completely trans (~1 min at 25 °C). Subsequently, the sulfone residue underwent β-elimination and was alkylated in situ with methyl iodide affording the trans-unsaturated ester **10** in 93% yield. Conventional oxidative cleavage of unsaturated ester **10** with sodium metaperiodate and catalytic potassium permanganate gave the target sulfone **1** in a 92% yield.[5,10,15]

Displacement of the sulfone **1** with sodium alkyltrithiocarbonate has been reported to give a complex mixture.[5a] However, preparation of the ethyl trithiocarbonate analogue **11** from sulfone **1** proceeded cleanly in a biphasic solution with sodium ethyltrithiocarbonate, producing **11** as a yellow solid.[16] Recrystallization from hexane gave pure **11** in 67% yield, 24% overall yield, from DBPAS. Trithiocarbonate **11** has been utilized as an intermediate to prepare penem analogues and transformed into Schering 29482 employing the oxalimide cyclization reaction of azetidinone trithiocarbonates.[17]

Summary

An efficient synthesis of methyl sulfone **1** has been described. In the process, 6,6-dibromopenicillanic acid *S,S*-dioxide (**2**) was transformed into methyl sulfone **1** over six steps in 35% overall yield without chromatography. Furthermore, the ability of the methyl sulfone to function as a penem synthon was demonstrated by conversion to the ethyl trithiocarbonate **11**. Except for the final recrystallization, no other purification was required for the process.

Experimental Section

Melting points were determined with a Thomas-Hoover capillary melting point apparatus and were uncorrected. NMR spectra were recorded on either a Varian T-60 or Bruker WM250 spectrometer in $CDCl_3$ with Me_4Si as an internal standard. Infrared solution spectra were recorded on a Perkin-Elmer 283B spectrophotometer in $CHCl_3$. Microanalyses were performed by the Pfizer Analytical Department.

Single-Crystal X-Ray Analysis. A representative crystal was surveyed, and a 1-Å data set (maximum sin $B/\lambda = 0.5$) was collected on a Syntex P1 diffractometer. The diffractometer was equipped with a graphite monochromator and molybdenum radiation ($\lambda = 0.71069$ Å). The crystal belonged to the monoclinic space group $P2_1$ with $a = 6.938$ (2) Å, $b = 7.847$ (5) Å, $c = 13.418$ (8) Å, and $\beta = 91.10$ (4)°. Atomic scattering factors were taken from the International Tables for X-ray Crystallography,[18] except hydrogen, which was taken from Stewart et al.,[19] and bromine, which was taken from Cromer and Mann.[20] All crystallographic calculations were facilitated by the CRYM[21] system. All diffractometer data were collected at room temperature.

A trial structure was obtained by conventional Patterson and Fourier techniques. This trial structure refined routinely. Hydrogen positions were calculated wherever possible. The methyl hydrogens and the hydrogen on the oxygen were located by

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difference Fourier techniques. The hydrogen parameters were added to the structure factor calculations but were not refined. The shifts calculated in the final cycle of least-squares refinement were all less than 0.2 of their corresponding standard deviations. The final R index was 0.071. A final difference Fourier revealed no missing or misplaced electron density.

The refined structure was plotted by using the ORTEP plotting package of Johnson[22] (Figure 1). Coordinates, distances and angles are available as supplementary material (Tables I and II; see the paragraph at the end of the paper).

Methyl 6,6-Dibromopenicillanate *S,S*-Dioxide (3). Acetyl chloride (92.5 mL, 1.30 mol) was added dropwise to methanol (2000 mL) at 0 °C. Ten minutes later 6,6-dibromopenicillanic acid *S,S*-dioxide (500 g, 1.28 mol) was added in one portion. The acid dissolved within 5 min. Three hours later methyl ester began crystallizing out of solution. The mixture was stirred overnight, filtered, and washed with 300 mL of 1:1 methanol/water. DBPAS methyl ester **3** was thus obtained in 88% yield (456 g) decomposition point 182 °C: IR ($CHCl_3$) 2953, 1824, 1765, 1439, 1344, 1286, 1122 cm^{-1}; ^1H NMR (250 MHz) δ 5.02 (s, 1 H), 4.52 (s, 1 H), 3.85 (s, 3 H), 1.62 (s, 3 H), 1.41 (s, 3 H). Anal. Calcd for $C_9H_{11}NO_5SBr_2$: C, 26.69; H, 2.74; N, 3.46; S, 7.92. Found: C, 26.65; H, 2.71; N, 3.42; S, 7.86.

Methyl (3*S*,5*R*,6*S*)-6-Bromo-6-[(*R*)-1-hydroxyethyl]-penicillanate *S,S*-Dioxide (4). DBPAS methyl ester **3** (100 g, 0.247 mol) and THF (500 mL) were combined at 25 °C in a three-neck round-bottom flask equipped with a low-temperature thermometer. Upon cooling to −90 °C, methylmagnesium chloride (88 mL, 3.09 M in THF, 0.272 mol) was added dropwise, maintaining the temperature below −75 °C. Thirty minutes after Grignard addition, distilled acetaldehyde (42 mL, 0.741 mol) was added over 10 min and stirred 30 min. The reaction was quenched by dropwise addition of acetic acid (14.8 mL, 0.247 mol) in THF (15 mL). After the solution warmed to 20 °C, ethyl acetate (250 mL) and water (350 mL) were added. The layers were separated, and the aqueous layer was extracted with ethyl acetate (150 mL). The organic layers were combined and washed with saturated $NaHCO_3$ (250 mL) and brine (250 mL). Treatment of the organic layer with Na_2SO_4 and removal of solvent under vacuum produced an off-white solid. The product was repulped in water (400 mL) for 5 h. The solids were filtered and dried in a vacuum oven. Aldol **4** (64.6 g) was produced in 71% yield, decomposition point 158 °C; IR ($CHCl_3$) 3570, 1807, 1765, 1601, 1333, 1120 cm^{-1}; ^1H NMR (250 MHz) δ 4.82 (s, 1 H), 4.81 (q, J = 6 Hz, 1 H), 4.52 (s, 1 H), 3.85 (s, 3 H), 2.29 (d, J = 6 Hz, 1 H), 1.61 (s, 3 H), 1.42 (s, 3 H), 1.36 (d, J = 6 Hz, 3 H). Anal. Calcd for $C_{11}H_{16}NO_6SBr$: C, 35.69; H, 4.35; N, 3.78; S, 8.66. Found: C, 35.48; H, 4.23; N, 3.78; S, 8.72.

Methyl (3*S*,5*R*,6*R*)-6-[(*R*)-1-Hydroxyethyl]penicillanate *S,S*-Dioxide (*cis*-8) and Methyl (3*S*,5*R*,6*S*)-6-[(*R*)-1-Hydroxyethyl]penicillanate *S,S*-Dioxide (*trans*-8). A 2-L Parr bottle was charged with 50% water, wet 5% Pd/C (15.6 g) and a solution of aldol **4** (62.5 g, 0.169 mol), ethyl acetate (690 mL), and triethylamine (34.4 mL, 0.247 mol). The solution was hydrogenated at 50 psi for 1 h and subsequently filtered through a pad of Celite, and the cake washed with ethyl acetate (250 mL). The filtrate was washed with water (500 mL), and the layers were separated. The aqueous layer was extracted with ethyl acetate (2 × 150 mL), and the organic layers were combined, dried with Na_2SO_4, and stripped under vacuum, affording white crystals 37.98 g (77%). The mixture of alcohols was used directly in the next step. They could be separated by column chromatography, 50% ethyl acetate/hexane with 40-μm silica, and their individual characteristics are listed below.

Cis isomer: decomposition point 160–161 °C; IR ($CHCl_3$) 3581, 2956, 1798, 1761, 1460, 1439, 1329, 1160, 1119 cm^{-1}; ^1H NMR (250 MHz) 4.88 (m, 1 H), 4.66 (d, J = 5 Hz, 1 H), 4.48 (s, 1 H), 3.82 (s, 3 H), 3.78 (dd, J = 5 Hz, J = 7 Hz, 1 H), 2.55 (d, J = 3 Hz, 1 H), 1.59 (s, 3 H), 1.40 (s, 3 H), 1.32 (d, J = 6 Hz, 3 H). Anal. Calcd for $C_{11}H_{17}NO_6S$: C, 45.35; H, 5.88; N, 4.81; S, 11.01. Found: C, 45.07; H, 5.70; N, 4.71; S, 11.02.

Trans isomer: decomposition point 146.5 °C; IR 3587, 2976, 1797, 1764, 1460, 1439, 1175, 1156, 1119 cm^{-1}; ^1H NMR (60 MHz) 4.83 (d, J = 2 Hz, 1 H), 4.50 (s, 1 H), 4.48 (m, 1 H), 3.91 (s, 3 H), 3.78 (dd, J = 2, J = 5.6 Hz, 1 H), 3.18 (bs, 1 H), 1.62 (s, 3 H), 1.44 (s, 3 H), 1.40 (d, J = 6 Hz, 3 H). Anal. Calcd for $C_{11}H_{17}NO_6S$: C, 45.35; H, 5.88; N, 4.81; S, 11.01. Found: C, 45.52; H, 5.65; N, 4.78; S, 11.41.

Methyl (3*S*,5*R*,6*S*)-6-[(*R*)-1-(*tert*-Butyldimethylsiloxy)-ethyl]penicillanate *S,S*-Dioxide (*trans*-9) and Methyl (3*S*,5*R*,6*R*)-6-[(*R*)-1-(*tert*-Butyldimethylsiloxy)ethyl]-penicillanate *S,S*-Dioxide (*cis*-9). The mixture of alcohols **6** (31.33 g, 0.108 mol) was dissolved in dimethylformamide (100 mL) at 20 °C. Imidazole (14.73 g, 0.215 mol) was added, followed by *tert*-butyldimethylsilyl chloride (17.9 g, 0.119 mol). The reaction was stirred for 3 h and then poured into hexanes (750 mL)/water (500 mL). The organic layer was separated and washed with water (4 × 250 mL). Treatment with Na_2SO_4 and solvent removal under vaccuum produced a fluffy white solid (37.65 g, 86%). The mixture of silyl ethers was employed directly in the next reaction. However, the isomers could be separated by column chromatography, 20% ethyl acetate/hexane with 40-μm silica, and their individual characteristics are as follows:

Cis isomer: mp 98–99 °C; IR ($CHCl_3$) 2951, 2930, 2886, 2856, 1805, 1761, 1461, 1438, 1326, 1117 cm^{-1}; ^1H NMR (250 MHz) 4.78 (m, 1 H), 4.61 (d, J = 5 Hz, 1 H), 4.43 (s, 1 H), 3.80 (s, 3 H), 3.77 (m, 1 H), 1.58 (s, 3 H), 1.39 (s, 3 H), 1.27 (d, J = 6 Hz, 3 H), 0.88 (s, 9 H), 0.11 (s, 3 H), 0.07 (s, 3 H). Anal. Calcd for $C_{17}H_{31}NO_6SSi$: C, 50.34; H, 7.70; N, 3.45; S, 7.91. Found: C, 50.53; H, 7.66; N, 3.33; S, 7.86.

Trans isomer: mp 97–98 °C; IR ($CHCl_3$) 2952, 2932, 2885, 2858, 1798, 1765, 1739, 1462, 1438, 1327, 1118 cm^{-1}; ^1H NMR (250 MHz) 4.62 (d, J = 1.9 Hz, 1 H), 4.38 (m, 1 H), 4.36 (s, 1 H), 3.78 (s, 3 H), 3.65 (dd, J = 1.9 Hz, J = 2.3 Hz, 1 H), 1.59 (s, 3 H), 1.41 (s, 3 H), 1.25 (d, J = 6 Hz, 3 H), 0.89 (s, 9 H), 0.07 (s, 6 H). Anal. Calcd for $C_{17}H_{31}NO_6SSi$: C, 50.34; H, 7.70; N, 3.45; S, 7.91. Found: C, 50.39; H, 7.50; N, 3.43; S, 8.01.

(3*S*,4*R*)-4-(Methylsulfonyl)-3-[(*R*)-1-(*tert*-butyldimethylsiloxy)ethyl]-1-(1-(methoxycarbonyl)-2-methyl-1-propenyl)-2-azetidinone (10). To a solution of the *tert*-butyldimethylsilyl ethers **9** (34.9 g, 0.086 mol) in methylene chloride (200 mL) at ambient temperature was added 1,8-diazabicyclo-[5.4.0]undec-7-ene (DBU 17.02 g, 0.112 mol) dropwise over 5 min. The reaction was then stirred for 90 min and cooled to 0 °C, and methyl iodide (53.5 g, 0.375 mol) added over 10 min. Stirring was continued at 0 °C for 16 h. The reaction was diluted with methylene chloride (200 mL) and washed with pH 3 water (2 × 400 mL), water (250 mL), and saturated $NaHCO_3$ (250 mL). Treatment of the organic extract with Na_2SO_4 and removal of the solvent produced a viscous oil, 33.6 g, 93%; IR ($CHCl_3$) 2953, 2930, 2887, 2857, 1778, 1715, 1624, 1437, 1383, 1321, 1144 cm^{-1}; ^1H NMR (250 MHz) 5.29 (d, J = 2.4 Hz, 1 H), 4.34 (dq, 1 H), 3.79 (s, 3 H), 3.61 (dd, J = 2.4 Hz, J = 3.1 Hz, 1 H), 2.86 (s, 3 H), 2.24 (s, 3 H), 2.06 (s, 3 H), 1.30 (d, J = 6 Hz, 3 H), 0.86 (s, 9 H), 0.10 (s, 3 H), 0.06 (s, 3 H). Anal. Calcd for $C_{18}H_{33}NO_6SSi$: C, 51.52; H, 7.93. Found: C, 51.41; H, 7.99.

(3*S*,4*R*)-3-[(*R*)-1-(*tert*-Butyldimethylsiloxy)ethyl]-4-(methylsulfonyl)-2-azetidinone (1). Phosphate buffer (pH 7, 680 mL), potassium permanganate (0.98 g, 0.006 mol), sodium periodate (87.3 g, 0.41 mol), and acetone (320 mL) were combined at ambient temperature and then cooled to 0 °C. Over 8 min, unsaturated ester **10** (33.6 g, 0.08 mol) in acetone (320 mL) was added. The reaction was stirred for 30 min at 0–5 °C and then allowed to warm to ambient temperature. Over 1 h of reaction time the purple solution had changed to a pink color, and 30 mL of aqueous potassium permanganate ($KMnO_4$ (15 g, 0.095 mol) in 500 mL water) was added. At 1-h intervals, two more portions (50 and 75 mL) of aqueous potassium permanganate were added. The reaction was complete after 6 h. Water (500 mL) and ethyl acetate were added, and the phases separated. The aqueous phase was extracted ethyl acetate (3 × 250 mL). The combined organic layers were washed with water (2 × 500 mL) and dried with sodium sulfate, and solvent was removed under vacuum yielding 22.7 g (92%) of a thick colorless oil. Crystals formed on standing at 0 °C, mp 101–102 °C; IR ($CHCl_3$) 3404, 2950, 2930, 2886, 2856, 1793, 1463, 1321, 1145, 1128 cm^{-1}; ^1H NMR (250 MHz) 6.53 (b s, 1 H) 4.74 (d, J = 2.1 Hz, 1 H), 4.32 (m, 1 H), 3.56 (t, J = 2.5 Hz, 1 H), 2.96 (s, 3 H), 1.26 (d, J = 6 Hz, 3 H), 0.86 (s, 9 H), 0.07 (s, 3 H), 0.05 (s, 3 H). Anal. Calcd for $C_{12}H_{25}NO_4SSi$: C, 46.87;

(22) Johnson, C. K., ORTEP, Report ORNL-3794, Oak Ridge National Laboratory, TN, 1965.

H, 8.20; N, 4.56; S, 10.43. Found: C, 46.83; H, 8.15; N, 4.33; S, 10.36.

3(*S*)-[1(*R*)-(*tert*-Butyldimethylsiloxy)ethyl]-4-(*R*)-[[(ethylthio)thiocarbonyl]thio]-2-oxoazetidinone (11). Sodium hydroxide (11.8 g, 0.296 mol) was dissolved in water (170 mL) and cooled to 2 °C. Ethanethiol (24.5 mL, 0.318 mol) was added over 5 min, and the solution stirred for 30 min. Carbon disulfide (26.7 mL, 0.444 mol) was then rapidly charged, and the yellow solution stirred for 60 min. Sulfone **1** (22.7 g, 0.074 mol) in methylene chloride (340 mL was added in one portion to the rapidly stirring 0 °C solution which was allowed to warm to 20 °C. After 18 h the reaction was complete, and the phases were separated. The aqueous layer was extracted with methylene chloride (2 × 125 mL). The combined organic extracts were washed with water (2 × 125 mL) and dried over Na_2SO_4. A yellow solid (24.1 g) was obtained upon solvent removal under vacuum. Recrystallization from hexane (410 mL) afforded yellow "cottonlike" crystals (18.15 g, 67%), mp 122–123 °C; IR ($CHCl_3$) 3411, 2950, 2928, 2857, 1776, 1462, 1083 cm^{-1}; ^1H NMR (250 MHz) 6.59 (b s, 1 H), 5.67 (d, J = 2.5 Hz, 1 H) 4.29 (m, 1 H), 3.37 (q, J = 7.4 Hz, 2 H), 3.21 (t, J = 3 Hz, 1 H), 1.37 (t, J = 7.4 Hz, 3 H), 1.21 (d, J = 6.2 Hz, 3 H), 0.88 (s, 9 H), 0.08 (s, 6 H). Anal. Calcd for $C_{14}H_{27}NO_2S_3Si$: C, 45.99; H, 7.44; N, 3.83; S, 26.31. Found: C, 46.05; H, 7.21; N, 3.82; S, 26.83.

Supplementary Material Available: Coordinates and bond distances and angles for **1** (1 page). Ordering information is given on any current masthead page.

Rearrangements of Azidoquinones. Generation of a Benzyne Intermediate

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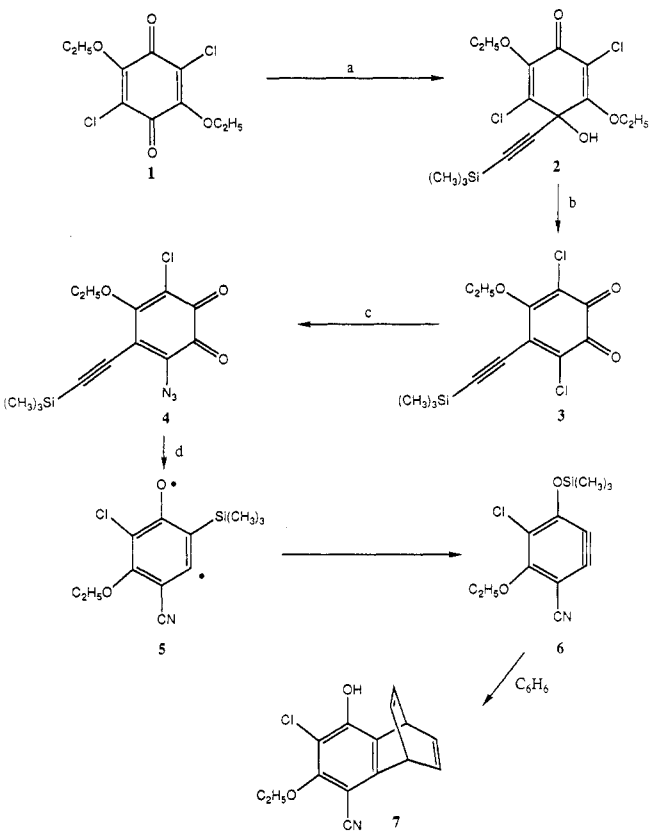
Reported here is a rearrangement envisaged to involve the unique generation of a benzyne intermediate from an azidoquinone precursor.[1] Specifically, 3-azido-6-chloro-5-ethoxy-4-[(trimethylsilyl)ethynyl]-1,2-benzoquinone (**4**) was prepared as outlined in Scheme I (**1** → **2** → **3** → **4**) and subjected to thermolysis in refluxing benzene; the bicyclic compound **7** was thus obtained in 38% isolated yield.[2] This unusual transformation is considered to proceed via the diradical intermediate **5**, which suffers a trimethylsilyl shift from carbon to oxygen to give the benzyne **6**. This then undergoes a Diels–Alder cycloaddition to the solvent resulting in adduct **7**.

The structure of **7** is based upon its characteristic spectral properties. Of particular importance is the ^1H NMR and ^{13}C NMR data. The former shows absorptions due to the two bridgehead and four vinyl protons as two symmetrical multiplets at 5.25–5.29 and 5.36–5.39 and as a multiplet at 6.89–6.91 ppm, and the latter showed two vinyl carbon absorptions as required by the symmetry of structure **7**. Thus, the [4 + 2] cycloaddition of **6** to benzene rather than a [2 + 2] mode is established.

The mechanism suggested above for the conversion of **4** to **7** finds precedence with respect to the formation of the diradical **5** and the cycloaddition of benzynes to benzene.[3,4] However, to our knowledge, formation of benzyne **6** from the diradical **5** is unique.

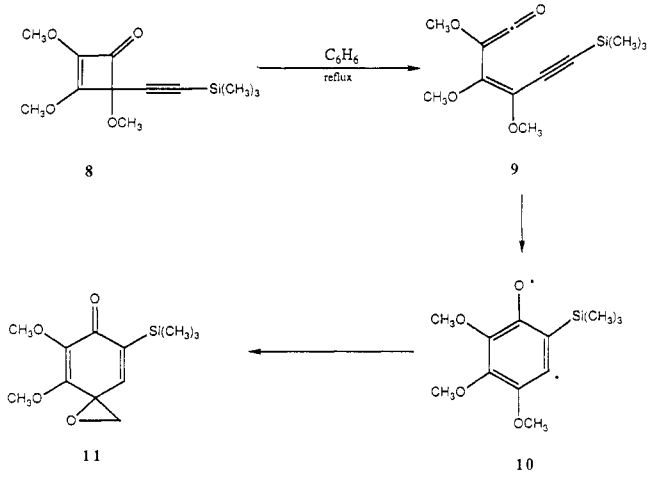
For comparison, it is of interest to note that the related diradical **10** (Scheme II) does not rearrange to a benzyne intermediate.[3] This diradical was generated from the cyclobutenone **8**, which upon electrocyclic ring opening gives ketene **9**, and this subsequently leads to the diradical **10**. Rather than silyl migration to a benzyne, this diradical undergoes an intramolecular hydrogen atom transfer and

Scheme I



[a] Lithium (trimethylsilyl)acetylide, THF, −78 °C. [b] TFAA, H_2SO_4, ambient temperature. [c] Na N_3, acetone, −78 °C. [d] Refluxing benzene.

Scheme II



(1) Azidoquinones have received extensive study and have been observed to function as precursors to a variety of other products. However, no example of their conversion to benzynes has been reported. For reviews of azidoquinone chemistry see: (a) Moore, H. W. *Chem. Soc. Rev.* **1973**, *2*, 415. (b) Moore, H. W.; Decker, O. H. W. *Chem. Rev.* **1986**, *86*, 821.

(2) Synthesis of substituted quinones by this method has been reported previously. See: Moore, H. W.; Sing, Y. L.; Sidhu, R. S. *J. Org. Chem.* **1980**, *45*, 5057.

(3) Foland, L. D.; Karlsson, J. O.; Perri, S. T.; Schwabe, R.; Xu, S. L.; Patil, S.; Moore, H. W. *J. Am. Chem. Soc.* **1989**, *111*, 975.

(4) For an example of the [4 + 2] cycloaddition of benzyne to benzene see: Friedman, L.; Lindow, D. F. *Ibid.* **1968**, *90*, 2329.

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