Synthesis of Methyl *N*-Acetyl-D,L-cysteinate. A solution of *N*-acetyl-D,L-cysteine (363 mg, 2.22 mmol), prepared in the same way as *N*-acetyl-D,L-β,β-dideuterocysteine outlined above, dissolved in methanol (3 mL) was added to an excess of freshly prepared diazomethane solution in diethyl ether cooled in a dry ice–acetone bath. The minimum amount of glacial acetic acid was added to discharge the yellow color. The resulting clear, colorless solution was concentrated with a rotary evaporator to an oil, which resisted crystallization (but whose spectra were identical with those of authentic crystalline methyl *N*-acetyl-L-cysteinate): IR (neat) 3279 (NH), 2563 (w, SH), 1736 (ester C=O), 1658 (amide C=O), 1537, 1216, 1042 cm^{-1}; ^1H NMR ($CDCl_3$, 250 MHz) δ 1.37 (1 H, t, J = 9.0 Hz, SH), 2.08 (3 H, s, CH_3CO), 3.02 (2 H, dd, J = 3.9, 9.1 Hz, β-CH_2S), 3.80 (3 H, s, CH_3O), 4.90 (1 H, dt, J = 3.9, 7.7 Hz, α-CH), 6.54 (1 H, br s, NH).

Synthesis of Seleno Sulfide 5, R = $CH_2CH(NHAc)CO_2Me$. To a stirred solution of Ebselen, 1 (115 mg, 0.42 mmol), dissolved in dichloromethane (7 mL) under an argon atmosphere, was added a solution of methyl *N*-acetyl-D,L-cysteinate (68 mg, 0.42 mmol) dissolved in dichloromethane (2 mL). The solvent was removed with a rotary evaporator to obtain a pale yellow oil, which was crystallized from ethyl acetate–hexanes to give seleno sulfide **5**, R = $CH_2CH(NHAc)CO_2Me$ (115 mg, 61%), as a white solid: mp 141–142 °C dec; IR (KBr) 3278 (NH), 1742, 1731 (ester C=O), 1648, 1632 (amide C=O), 1596, 1530, 1437, 1327, 783, 757 cm^{-1}; ^1H NMR ($CDCl_3$ with 20% CD_3CN, 250 MHz) δ 1.93 (3 H, s, CH_3CO), 3.23 (2 H, *AB*X, J_{AB} = 13.8 Hz, J_{AX} = 6.3 Hz, J_{BX} = 4.8 Hz, β-CH_2S), 3.69 (3 H, s, CH_3O), 4.72 (1 H, m, α-CH), 6.64 (1 H, d, J = 7.6 Hz), 7.16 (1 H, AA'BB'X, J_{BX} = 7.4 Hz, H4'), 7.37 (3 H, m, H5,3',5'), 7.56 (1 H, t, J = 7.9 Hz, H4), 7.66 (2 H, AA'BB'X, J_{AB} = 7.7 Hz, H2',6'), 7.85 (1 H, d, J = 7.9 Hz, H6), 8.24 (1 H, d, J = 7.9 Hz, H3). Anal. Calcd for $C_{19}H_{20}N_2O_4SSe$: C, 50.55; H, 4.47; N, 6.21. Found: C, 50.65; H, 4.35; N, 6.23.

Registry No. **1**, 60940-34-3; **2**, 104473-83-8; **5** (R = $PhCH_2$), 114744-69-3; **5** (R = $CH_2CH{=}CH_2$), 118398-38-2; **5** (R = $(CH_2)_6CH_3$), 118398-39-3; **5** (R = C_6H_{11}), 118398-40-6; **5** (R = *cis*-4-*tert*-butylcyclohexyl), 118398-41-7; **5** (R = *trans*-4-*tert*-butylcyclohexyl), 118398-42-8; **5** (R = $CD_2CH(NHAc)CO_2Me$), 118398-43-9; **5** (R = $CH_2CH(NHAC)CO_2Me$), 118398-44-0; *exo*-**7**, 95417-00-8; *endo*-**7**, 95416-99-2; **8**, 84040-16-4; **10**, 80028-57-5; **12**, 53273-25-9; **13**, 60260-88-0; **14**, 60305-05-7; **15**, 60260-89-1; **16**, 118398-45-1; **17** (diastereomer 1), 118398-46-2; **17** (diastereomer 2), 118456-63-6; $PhCH_2SH$, 100-53-8; $(PhCH_2)_2S_2$, 150-60-7; cyclopentadiene, 542-92-7; anthracene, 120-12-7; 2-propene-1-thiol, 870-23-5; 1-heptanethiol, 1639-09-4; diheptyl disulfide, 10496-16-9; cyclohexanethiol, 1569-69-3; dicyclohexyl disulfide, 2550-40-5; ethyl *N*-acetyl-*S*-benzyl-D,L-β,β-dideuterocysteinate, 118398-47-3; sodium α-toluenethiolate, 3492-64-6; diethyl α-acetamido-α-[(trimethylammonio)dideuteromethyl]malonate iodide, 57866-76-9; *N*-acetyl-*S*-benzyl-D,L-β,β-dideuterocysteine, 118398-48-4; ethyl *N*-acetyl-*S*-benzyl-D,L-cysteinate, 118456-64-7; *N*-acetyl-*S*-benzyl-D,L-cysteine, 19538-71-7; *N*-acetyl-D,L-cysteine, 7218-04-4; methyl *N*-acetyl-D,L-cysteinate, 118398-49-5.

Cycloadditions of Isoquinolinium Salts: Vinyl Sulfide Dienophiles for the Syntheses of 1-Naphthaldehydes and Tetralins

Ram B. Gupta,[†] Richard W. Franck,*[,†] Kay D. Onan,[‡,§] and Clifford E. Soll[†]

Department of Chemistry, Hunter College/CUNY 695 Park Ave., New York, New York 10021, and Department of Chemistry, Northeastern University, 360 Huntington Ave., Boston, Massachusetts 02115

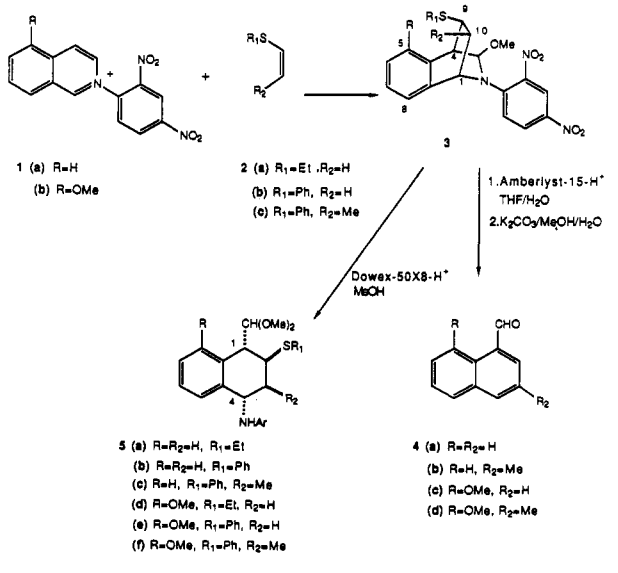
Received May 17, 1988

Vinyl sulfides are used as dienophiles in the Bradsher cycloaddition reaction. Processing of the cycloadducts leads to either tetralins or naphthaldehydes. The tetralins are formed with high stereoselectivity. The configuration of the products is confirmed by an X-ray structure determination. Removal of sulfur from the tetralin products affords materials that are the equivalent of having used simple alkenes as dienophiles.

Vinyl sulfides have emerged as versatile substrates in synthetic methodology.[1] Of particular significance is their ability to participate as electron-rich alkenes in cycloaddition reactions.[2] Recently, Denmark[3] reported their use in the intramolecular inverse-electron-demand (IED) Diels–Alder reactions of α,β-unsaturated aldehydes, and Posner[4] has used these sulfur dienophiles in cycloadditions to pyrones.

The IED reactions of two closely related systems, acridizinium and isoquinolinium ions, discovered by Bradsher,[5] have been the subject of extensive investigation.[6] Dienophiles shown to participate in these reactions include alkenes, dienes, styrenes, benzyne, vinyl ethers, vinyl silyl ethers, enamines, ynamines, ketene acetals, and ketene aminals. Conspicuous by their absence, however, are reports on the use of vinyl sulfides in the Bradsher cycloaddition. We now describe our results, which remedy the omission and which have significance for the synthetic community.

Scheme I



Thus, when isoquinolinium salt **1** was treated with vinyl sulfide **2** in anhydrous methanol containing calcium car-

[†] Hunter College/CUNY.
[‡] Northeastern University.
[§] Correspondence concerning the X-ray crystallography should be addressed to K.D.O.

0022-3263/89/1954-1097$01.50/0

Table I. Products from the Cycloadditions of Vinyl Sulfides to Isoquinolinium Salts

entry	isoquinolinium salt	vinyl sulfide	product 1-naphthaldehyde[a]	% yield[b]	product tetralin[a]	% yield[b]
i	**1a**: R = H	**2a**: R_1 = Et; R_2 = H	**4a**: R = R_2 = H	91	**5a**: R = R_2 = H; R_1 = Et	93
ii	**1a**	**2b**: R_1 = Ph; R_2 = H	**4a**	90	**5b**: R = R_2 = H; R_1 = Ph	91
iii	**1a**	**2c**: R_1 = Ph; R_2 = Me	**4b**: R = H; R_2 = Me	66	**5c**: R = H; R_1 = Ph; R_2 = Me	70
iv	**1b**: R = OMe	**2a**	**4c**: R = OMe; R_2 = H	90	**5d**: R = OMe; R_1 = Et; R_2 = H	90
v	**1b**	**2b**	**4c**	88	**5e**: R = OMe; R_1 = Ph; R_2 = H	90
vi	**1b**	**2c**	**4d**: R = OMe; R_2 = Me	74	**5f**: R = OMe; R_1 = Ph; R_2 = Me	72

[a] Products characterized by high-field ^{1}H NMR decoupling experiments. [b] Yields based on isoquinolinium salt.

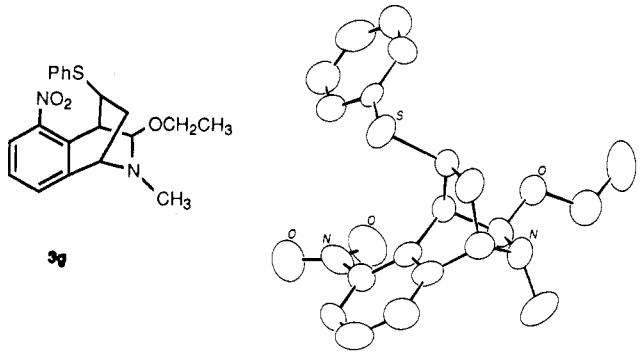
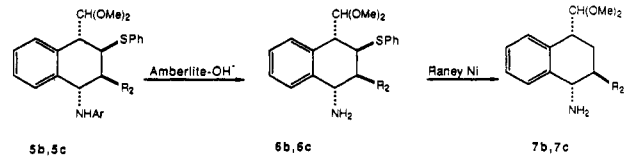


Figure 1. An ORTEP perspective diagram of **3g**. The substituents at N(2) and C(3) are anti with respect to one another and the ethoxy group is syn to the bridge. The sulfur of the thio ether group lies over the phenylene ring. The nitro group forms an angle of 33.6° with respect to the phenylene ring. Hydrogen atoms have been omitted for clarity.

bonate at room temperature over a period of 1–3 days, tricyclic adduct **3** was obtained in high yields. Further transformations of adduct **3** were effected by the following two methods. In method a, **3** was treated with Amberlyst-15-H^+ in aqueous tetrahydrofuran, followed by aromatization of the resulting product with K_2CO_3/MeOH/H_2O to yield the aromatic aldehyde **4** and 2,4-dinitroaniline.[7] Whereas method b, which involves treatment of **3** with Dowex-50X-8 H^+ in anhydrous methanol, produces tetralin **5**.[6] The results with different isoquinolinium salts and vinyl sulfides are summarized in Table I.

The stereochemical outcome of the above reaction is identical with that obtained in the case of analogous vinyl ethers, viz., cycloadducts result from predominant exo addition. Confirmation of our assignments, routinely done by ^{1}H NMR spectroscopy, was obtained by an X-ray crystal structure determination of tricyclic adduct **3g** as illustrated in Figure 1. The compound **3g** was obtained from the cycloaddition of phenyl vinyl sulfide to 2-methyl-5-nitroisoquinolinium iodide, followed by the recrystallization of the adduct from EtOH. The NMR parameters for **3g** correlated well with those of the other members of our series. The isolation of only cis products (entries iii and vi) is perhaps due to faster addition of *cis*-vinyl sulfide than the trans isomer (and facile isomerization of *trans*/*cis*-vinyl sulfides[1e]). The tetralins, e.g., **5b**, can be obtained in a one-pot procedure simply by stirring the salt **1a** and vinyl sulfide **2b** in methanol with no added $CaCO_3$, in almost identical yields with the two-step method. The acid generated during cycloadduct **3** formation catalyzes the transformation of **3** to **5** but does not substantially affect the vinyl sulfide. In contrast, the addition of acid-sensitive vinyl ethers to the salt **1** requires the acid scavenger $CaCO_3$ to obtain good yields of the products.[7] An attractive aspect of vinyl sulfide dienophiles is that the SR activating group can be easily removed from the tetralin products. This sequence is equivalent to the regio- and stereoselective cycloaddition of unactivated alkenes to isoquinoline salts. For example, tetralins **5b** and **5c** were treated with Amberlite-IRA-400-OH^- in aqueous acetone[8] to yield the corresponding aminotetralins **6b** and **6c**, which were then treated with Raney Nickel in cyclohexene or t-BuOH to give the products **7b** and **7c**, respectively.



In summary, we have demonstrated that the stereoselective cycloadditions of vinyl sulfides to isoquinolinium salts, which proceed in high yields and under mild conditions, constitute an attractive approach for the syntheses of tetralins and 1-naphthaldehydes. We believe that the numerous methods available for the syntheses of vinyl sulfides[9] and isoquinolines[10] enhance the scope of this reaction.

(1) (a) Trost, B. M.; Lavoie, A. C. *J. Am. Chem. Soc.* **1983**, *105*, 5075 and references therein. (b) Trost, B. M.; Tanigawa, Y. *J. Am. Chem. Soc.* **1979**, *101*, 4413. (c) Okamura, H.; Miura, M.; Takei, H. *Tetrahedron Lett.* **1979**, 43. (d) Brown, C. A. *J. Org. Chem.* **1978**, *43*, 3083. (e) Muthukrishnan, R.; Schlosser, M. *Helv. Chim. Acta* **1976**, *59*, 13.

(2) (a) Williams, D. R.; Gaston, R. D. *Tetrahedron Lett.* **1986**, *27*, 1485. (b) Caramella, P.; Bandiera, T.; Grunanger, P.; Albini, F. M. *Tetrahedron* **1984**, *40*, 441. (c) Caramella, P.; Albini, E.; Bandiera, T.; Corsico Coda, A.; Grunanger, P.; Albini, F. M. *Tetrahedron* **1983**, *39*, 689. (d) Hall, H. K.; Rasoul, H. A. A.; Gillard, M.; Abdelkader, M.; Nogues, P.; Sentman, R. C. *Tetrahedron Lett.* **1982**, *23*, 603. (e) Takaki, K.; Yamada, M.; Negoro, K. *J. Org. Chem.* **1982**, *47*, 5246.

(3) Denmark, S. E.; Sternberg, J. A. *J. Am. Chem. Soc.* **1986**, *108*, 8277.

(4) Posner, G. H.; Haces, A.; Harrison, W.; Kinter, C. M. *J. Org. Chem.* **1987**, *52*, 4836.

(5) Chen, T. K.; Bradsher, C. K. *J. Org. Chem.* **1979**, *44*, 4680 and references cited therein.

(6) (a) Boger, D. L.; Weinreb, S. M. *Hetero Diels-Alder Methodology in Organic Synthesis*; Academic Press: New York, 1987; p 278. (b) For a recent article with complete bibliography, see: Gupta, R. B.; Franck, R. W. *J. Am. Chem. Soc.* **1987**, *109*, 5393.

(7) (a) Manna, S.; Falck, J. R.; Mioskowski, C. *J. Org. Chem.* **1982**, *47*, 5021. (b) Falck, J. R.; Manna, S.; Mioskowski, C. *J. Am. Chem. Soc.* **1983**, *105*, 631.

(8) Lloyd, P. F.; Stacey, M. *Tetrahedron* **1960**, *9*, 116.

(9) For recent articles, see: (a) Bartels, B.; Hunter, R.; Simon, C. D.; Tomlinson, G. D. *Tetrahedron Lett.* **1987**, *28*, 2985. (b) Rodriguez, A. D.; Nickon, A. *Tetrahedron* **1985**, *41*, 4443. (c) Harpp, D. N.; Aida, T.; Chan, T. H. *Tetrahedron Lett.* **1985**, *26*, 1795. (d) Fujiwara, T.; Yanagihara, H.; Yamada, T.; Suzuki, K.; Takeda, T. *Chem. Lett.* **1985**, 1629. (e) Nakayama, J.; Takeue, S.; Hoshino, M. *Tetrahedron Lett.* **1984**, *25*, 2679. (f) Ruel, O.; Guittet, E.; Julia, S. *Tetrahedron Lett.* **1983**, *24*, 61. (g) Tiecco, M.; Testaferri, L.; Tingoli, M.; Chianelli, D.; Montanucci, M. *J. Org. Chem.* **1983**, *48*, 4795. (h) Trost, B. M.; Ornstein, P. L. *J. Org. Chem.* **1982**, *47*, 748. (i) Denis, J. N.; Krief, A. *Tetrahedron Lett.* **1982**, *23*, 3407. (j) Fiandanese, V.; Marchese, G.; Naso, F.; Ronzini, L. *J. Chem. Soc., Chem. Commun.* **1982**, 647.

(10) (a) Hendrickson, J. B.; Rodriguez, C. *J. Org. Chem.* **1983**, *48*, 3344. (b) Grethe, G. *The Chemistry of Heterocyclic Compounds*; John Wiley & Sons: New York, 1981; Vol. 38.

Experimental Section

Nuclear magnetic resonance spectra were obtained on a JEOL GX 400 MHz and GE QE-300 MHz instruments. Infrared spectra were recorded on a Perkin-Elmer 1310 spectrophotometer. The high-resolution mass spectra were obtained by the Mass Spectrometric Biotechnology Resource, Rockfeller University, New York, NY. Elemental analyses were performed by the Spang Microanalytical Laboratory, Eagle Harbor, MI. Melting points were determined on a Fisher-Johns melting point apparatus and were uncorrected.

Thin-layer chromatograms were done on precoated TLC sheets of silica gel 60 F_{254} (E. Merck) with use of (2,4-dinitrophenyl)-hydrazine spray, potassium permanganate spray, and/or short- and longwave ultraviolet light to visualize the spots. Chromatotron (radial chromatography) plates were prepared by using Kieselgel 60 PF_{254} gipshaltig (E. Merck), and all separations using the chromatotron were done under nitrogen atmosphere.

Materials. Ethyl vinyl sulfide was purchased from Alfa, phenyl vinyl sulfide was obtained from Aldrich, and phenyl propenyl sulfide was prepared according to a literature method.[11] 5-Hydroxyisoquinoline, 5-nitroisoquinoline, 1-chloro-2,4-dinitrobenzene, Dowex-50X8-400, Amberlyst-15, and Amberlite-IRA-400-OH^- were purchased from Aldrich, and Celite 545 was obtained from Fisher Scientific. All solvents used were dry and distilled. The preparation of 5-methoxyisoquinoline and its 2,4-dinitrophenyl salt are described in the supplementary material.

General Procedures: (a) For the Cycloaddition Reaction. To a stirred mixture of isoquinolinium salt **1** (1 mmol), $CaCO_3$ (6 mmol), and methanol (3 mL) was added vinyl sulfide **2** (1.1 mmol), and the reaction mixture was stirred at 25–40 °C for a period of 1–3 days under N_2. An additional amount of vinyl sulfide **2** (1.1 mmol) was added after 10 h. The reaction mixture was diluted with anhydrous dichloromethane, and filtered through Celite. The residue on the Celite was washed with dichloromethane, and the combined filtrates were concentrated in vacuo to give the crude tricyclic adduct **3**.

(b) For the Conversion of Tricyclic Adducts 3 to 1-Naphthaldehydes 4. The crude tricyclic adduct **3** from 1 mmol of the salt was dissolved in 22 mL of THF/H_2O (20:2) and treated with Amberlyst-15 (300 mg) at 40 °C for 24 h. The resin was filtered off, and the filtrate was diluted with water (100 mL) and extracted with ethyl acetate (3 × 50 mL). The organic layer was dried ($MgSO_4$) and evaporated to dryness in vacuo. The residue was dissolved in tetrahydrofuran (6 mL) and treated with a solution of K_2CO_3 (500 mg) in methanol (8 mL) and water (2 mL) at 50–60 °C for 2–3 min. The reaction mixture was cooled, poured into ice-cold water (100 mL), and extracted with ethyl acetate (3 × 50 mL). The organic layer was dried ($MgSO_4$) and concentrated in vacuo. The residue was purified by using a chromatotron (petroleum ether/CH_2Cl_2, 1:1) to get 1-naphthaldehyde **4**.

The aromatic aldehydes **4** can also be obtained in one pot without using any base and in almost the same yields as the two-step method by the following procedure: Tricyclic adduct **3** (0.5 mmol) was dissolved in 6 mL of THF, and 3 N HCl (2 mL) was added to it. The mixture was stirred at 45 °C for 24 h, diluted with H_2O (100 mL), and extracted with ethyl acetate (3 × 50 mL). The organic layer was washed with H_2O (20 mL) and brine (20 mL), dried ($MgSO_4$), and concentrated. The residue was purified as described above to obtain pure 1-naphthaldehyde **4**.

(c) For the Conversion of Tricyclic Adducts 3 to Tetralins 5. The crude tricyclic adduct **3** from 1 mmol of the salt was dissolved in 6–8 mL of methanol (dichloromethane was used as cosolvent in some cases) and stirred with Dowex-50X8-400 (400 mg) at room temperature for 24 h under N_2. The resin was filtered off, and the filtrate was diluted with dichloromethane (150 mL), washed successively with saturated $NaHCO_3$ (40 mL) and water (50 mL), dried ($MgSO_4$), and concentrated in vacuo. The residue was purified by using a chromatotron (CH_2Cl_2) to obtain the tetralins **5**.

(d) For the Removal of 2,4-Dinitrophenyl Group from Tetralin 5. To a solution of the tetralin **5** (0.5 mmol) in acetone (20 mL) and water (2 mL) was added Amberlite-IRA-400-OH^- (2.5 g), and the mixture was stirred at room temperature for 2 days under N_2. The resin was filtered off and washed with acetone (20 mL), the combined filtrate was concentrated in vacuo, and the residue was purified with a chromatotron (15–20% MeOH in EtOAc) to obtain aminotetralin **6**.

(e) For the Desulfurization. A mixture of aminotetralin **6** (0.25 mmol), *tert*-butyl alcohol (2 mL), and Raney Ni (~500 mg) was refluxed for nearly 40 h under N_2. An additional amount of Raney Ni (~500 mg) was added in two lots after 12 and 24 h of refluxing. The reaction mixture was filtered through a small bed of Celite, and the residue on the Celite was washed with hot *tert*-butyl alcohol (10 mL) and acetone (10 mL). The combined filtrate was concentrated in vacuo, and the residue was purified by preparative TLC (CH_2Cl_2/MeOH, 80:20).

The spectral data of the compounds obtained by using the general procedures described above are as follows.

3-Methyl-1-naphthaldehyde (4b): IR ($CHCl_3$) 2930, 2870, 2750, 1685, 1630, 1610, 1580, 1500, 1460, 1400, 1350, 1290, 1070, 1005, 960, 880, 860 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) δ 10.31 (s, 1 H, C*H*O), 9.20 (d, 1 H, J = 8.49 Hz, Ar *H*), 7.81–7.53 (m, 5 H, Ar *H*), 2.53 (s, 3 H, ArCH_3); ^{13}C NMR (75 MHz, $CDCl_3$) δ 193.15, 138.25, 134.48, 134.16, 134.08, 131.40, 128.97, 127.96, 127.78, 126.87, 124.58, 21.05; high-resolution mass spectrum (CI) calcd for $C_{12}H_{10}O$ + H^+ 171.0910, found 171.0921.

3-Methyl-8-methoxy-1-naphthaldehyde (4d): mp 98–99 °C; IR ($CHCl_3$) 2920, 2840, 1675, 1625, 1580, 1500, 1465, 1410, 1375, 1360, 1270, 1220 (br), 1110, 1080, 1000, 980, 950, 880, 850 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) δ 11.08 (s, 1 H, C*H*O), 7.78–7.74 (m, 2 H, Ar *H*), 7.44–7.40 (m, 2 H, Ar *H*), 6.92–6.89 (m, 1 H, Ar *H*), 3.99 (s, 3 H, OCH_3), 2.53 (s, 3 H, ArCH_3); ^{13}C NMR (75 MHz, $CDCl_3$) δ 195.28, 156.40, 135.87, 135.47, 135.07, 132.03, 129.12, 126.40, 121.84, 120.99, 106.16, 55.59, 21.03; high-resolution mass spectrum (CI) calcd for $C_{13}H_{12}O$ + H^+ 201.0912, found 201.0935.

1(*R)-(Dimethoxymethyl)-2(*S**)-(ethylthio)-4(*S**)-[(2,4-dinitrophenyl)amino]-1,2,3,4-tetrahydronaphthalene (5a)**: mp 135–36 °C; IR ($CHCl_3$) 3340, 2940, 2840, 1620, 1590, 1500, 1430, 1370, 1335, 1295, 1210 (br), 1130, 1080, 980, 925 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 9.17 (d, 1 H, J = 2.44 Hz, Ar *H*), 8.92 (d, 1 H, J = 8.55 Hz, N*H*), 8.25 (dd, 1 H, J = 2.44, 9.77 Hz, Ar *H*), 7.37–7.22 (m, 4 H, Ar *H*), 7.13 (d, 1 H, J = 9.16 Hz, Ar *H*), 5.24 (ddd, 1 H, J = 4.88, 8.55, 9.77 Hz, C_4-*H*), 4.49 [d, 1 H, J = 4.28 Hz, C*H*$(OCH_3)_2$], 3.65 (ddd, 1 H, J = 2.44, 3.05, 5.50 Hz, C_2-H), 3.48, 3.36 [2 s, 3 H each, CH$(OCH_3)_2$], 3.23 (dd, 1 H, J = 2.44, 4.28 Hz, C_1-*H*), 2.65 (q, 2 H, J = 7.33 Hz, SCH_2CH_3), 2.53 (ddd, 1 H, J = 3.05, 9.77, 13.43 Hz, C_3-*H*a), 2.31 (ddd, 1 H, J = 4.89, 5.50, 13.43 Hz, C_3-*H*e), 1.31 (t, 3 H, J = 7.33 Hz, SCH_2CH_3); ^{13}C NMR (75 MHz, $CDCl_3$) δ 147.89, 136.12, 135.16, 134.30, 130.70, 130.27, 128.03, 127.45, 126.89, 124.42, 114.31, 109.15, 56.40, 56.01, 50.39, 47.41, 38.29, 32.34, 25.53, 14.82; high-resolution mass spectrum (CI) calcd for $C_{21}H_{25}N_3O_6S$ + H^+ 448.1542, found 448.1522. Anal. Calcd for $C_{21}H_{25}N_3O_6S$: C, 56.37; H, 5.63; N, 9.39; S, 7.15. Found: C, 56.28; H, 5.58; N, 9.41; S, 7.22.

1(*R)-(Dimethoxymethyl)-2(*S**)-(phenylthio)-4(*S**)-[(2,4-dinitrophenyl)amino]-1,2,3,4-tetrahydronaphthalene (5b)**: mp 165–66 °C; IR ($CHCl_3$) 3320, 2920, 2820, 1610, 1580, 1490, 1420, 1360, 1330, 1280, 1200 (br), 1070, 1010, 990, 970, 910 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 9.16 (d, 1 H, J = 2.20 Hz, Ar *H*), 8.89 (d, 1 H, J = 8.06 Hz, N*H*), 8.10 (dd, 1 H, J = 2.93, 9.53 Hz, Ar *H*), 7.49 (d, 1 H, J = 6.60 Hz, Ar *H*), 7.39–7.28 (m, 8 H, Ar *H*), 6.80 (d, 1 H, J = 9.52 Hz, Ar *H*), 5.23 (ddd, 1 H, J = 5.86, 8.06, 10.26 Hz, C_4-*H*), 4.49 [d, 1 H, J = 3.66 Hz, C*H*$(OCH_3)_2$], 4.23 (br ddd, 1 H, C_2-*H*), 3.41, 3.31 [2 s, 3 H each, CH$(OCH_3)_2$], 3.22 (br dd, 1 H, C_1-*H*), 2.47 (ddd, 1 H, J = 3.66, 10.26, 13.92 Hz, C_3-*H*a), 2.32 (ddd, 1 H, J = 4.40, 5.86, 13.92 Hz, C_3-*H*e); ^{13}C NMR (75 MHz, $CDCl_3$) δ 147.82, 136.28, 135.08, 134.22, 134.05, 132.03, 130.85, 130.66, 130.11, 129.17, 128.05, 127.63, 127.50, 126.76, 124.32, 114.10, 109.11, 56.20, 55.80, 49.94, 46.11, 41.66, 31.01; high-resolution mass spectrum (CI) calcd for $C_{25}H_{25}N_3O_6S$ + H^+ 496.1542, found 496.1557. Anal. Calcd for $C_{25}H_{25}N_3O_6S$: C, 60.60; H, 5.09; N, 8.48; S, 6.46. Found: C, 60.57; H, 5.04; N, 8.30; S, 6.53.

1(*R)-(Dimethoxymethyl)-2(*S**)-(phenylthio)-3(*S**)-methyl-4(*S**)-[(2,4-dinitrophenyl)amino]-1,2,3,4-tetrahydronaphthalene (5c)**: IR ($CHCl_3$) 3340, 2940, 2840, 1620, 1590, 1500, 1430, 1370, 1340, 1290 (br), 1210 (br), 1150, 1135, 1120, 1070, 1030, 990, 920 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 9.17 (d,

(11) Tarbell, D. S.; Lovett, W. E. *J. Am. Chem. Soc.* **1955**, *78*, 2259.

1 H, J = 3.05 Hz, Ar H), 8.93 (br d, 1 H, NH), 8.21 (br dd, 1 H, Ar H), 7.51–7.19 (m, 9 H, Ar H), 7.12 (d, 1 H, J = 8.54 Hz, Ar H), 4.89 (dd, 1 H, J = 7.94, 9.77 Hz, C_4-H), 4.49 [d, 1 H, J = 4.28 Hz, CH(OCH$_3$)$_2$], 4.01 (dd, 1 H, J = 3.05, 3.06 Hz, C_2-H), 3.33, 3.29 [2 s, 3 H each, CH(OCH_3)$_2$], 3.30 (dd, 1 H, J = 3.05, 4.28 Hz, 1 H, C_1-H), 2.90 (m, 1 H, C_3-H), 1.24 (d, 3 H, J = 6.72 Hz, CH_3); ^{13}C NMR (75 MHz, CDCl$_3$) δ 148.39, 136.24, 135.08, 134.09, 131.80, 130.67, 130.06, 129.06, 128.03, 127.46, 127.38, 127.14, 124.38, 114.78, 108.86, 57.11, 56.31, 55.73, 50.07, 47.41, 35.85, 16.56; high-resolution mass spectrum (CI) calcd for $C_{26}H_{27}N_3O_6S$ + H$^+$ 510.1699, found 510.1693.

1(R*)-(Dimethoxymethyl)-2(S*)-(ethylthio)-4(S*)-[(2,4-dinitrophenyl)amino]-8-methoxy-1,2,3,4-tetrahydronaphthalene (5d): mp 160–62 °C; IR (CHCl$_3$) 3350, 2940, 2840, 1620, 1590, 1500, 1460, 1430, 1370, 1330, 1290, 1250 (br), 1200 (br), 1130, 1110, 1080, 1020, 980, 930 cm^{-1}; ^{1}H NMR (400 MHz, CDCl$_3$) δ 9.17 (d, 1 H, J = 2.44 Hz, Ar H), 9.03 (d, 1 H, J = 7.32 Hz, NH), 8.20 (br dd, 1 H, Ar H), 7.21 (dd, 1 H, J = 7.93, 8.55 Hz, Ar H), 7.11 (d, 1 H, J = 9.16 Hz, Ar H), 6.91 (d, 1 H, J = 7.93 Hz, Ar H), 6.84 (d, 1 H, J = 8.55 Hz, Ar H), 5.19 (ddd, 1 H, J = 5.49, 7.32, 10.38 Hz, C_4-H), 4.70 [d, 1 H, J = 2.44 Hz, CH(OCH$_3$)$_2$], 3.89 (s, 3 H, ArOCH_3), 3.85–3.83 (m, 1 H, C_2-H), 3.60 (br dd, 1 H, C_1-H), 3.55, 3.25 [2 s, 3 H each, CH(OCH_3)$_2$], 2.83–2.80 (m, 1 H, C_3-Ha), 2.65 (q, 2 H, J = 7.33 Hz, SCH_2CH$_3$), 2.25–2.20 (m, 1 H, C_3-He), 1.31 (t, 3 H, J = 7.33 Hz, SCH$_2$CH_3); ^{13}C NMR (75 MHz, CDCl$_3$) δ 157.60, 147.95, 136.89, 136.06, 130.75, 129.96, 128.02, 124.37, 123.39, 119.20, 114.67, 109.82, 107.39, 57.46, 56.09, 55.52, 50.28, 42.23, 37.23, 32.04, 25.59, 14.76; high-resolution mass spectrum (CI) calcd for $C_{22}H_{27}N_3O_7S$ + H$^+$ 478.1698, found 478.1737. Anal. Calcd for $C_{22}H_{27}N_3O_7S$: C, 55.34; H, 5.70; N, 8.80; S, 6.70. Found: C, 55.36; H, 5.68; N, 8.65; S, 6.78.

1(R*)-(Dimethoxymethyl)-2(S*)-(phenylthio)-4(S*)-[(2,4-dinitrophenyl)amino]-8-methoxy-1,2,3,4-tetrahydronaphthalene (5e): mp 197–99 °C; IR (CHCl$_3$) 3360, 2940, 2840, 1620, 1590, 1500, 1460, 1430, 1370, 1340, 1290, 1250 (br), 1200 (br), 1130, 1080, 1020, 980, 960, 930 cm^{-1}; ^{1}H NMR (400 MHz, CDCl$_3$) δ 9.12 (d, 1 H, J = 2.44 Hz, Ar H), 8.96 (d, 1 H, J = 7.32 Hz, NH), 8.04 (dd, 1 H, J = 2.44, 9.15 Hz, Ar H), 7.48–7.22 (m, 6 H, Ar H), 6.96 (d, 1 H, J = 7.93 Hz, Ar H), 6.85 (d, 1 H, J = 7.94 Hz, Ar H), 6.85 (d, 1 H, J = 7.94 Hz, Ar H), 6.79 (d, 1 H, J = 9.77 Hz, Ar H), 5.18 (ddd, 1 H, J = 6.10, 7.32, 10.38 Hz, C_4-H), 4.70 [d, 1 H, J = 3.05 Hz, CH(OCH$_3$)$_2$], 4.40 (br ddd, 1 H, C_2-H), 3.87 (s, 3 H, ArOCH_3), 3.57 (br dd, 1 H, C_1-H), 3.46, 3.23 [2 s, 3 H each, CH (OCH_3)$_2$], 2.76–2.73 (m, 1 H, C_3-Ha), 2.26–2.21 (m, 1 H, C_3-He); ^{13}C NMR (75 MHz, CDCl$_3$) δ 157.69, 147.89, 136.78, 136.10, 134.71, 131.71, 130.76, 129.88, 129.03, 128.19, 127.15, 124.29, 123.16, 119.12, 114.51, 109.96, 107.31, 57.33, 55.98, 55.58, 49.88, 40.85, 40.51, 30.60; high-resolution mass spectrum (CI) calcd for $C_{26}H_{27}N_3O_7S$ + H$^+$ 526.1648, found 526.1616. Anal. Calcd for $C_{26}H_{27}N_3O_7S$: C, 59.42; H, 5.18; N, 8.00; S, 6.09. Found: C, 59.43; H, 5.16; N, 7.95; S, 6.14.

1(R*)-(Dimethoxymethyl)-2(S*)-(phenylthio)-3(S*)-methyl-4(S*)-[(2,4-dinitrophenyl)amino]-8-methoxy-1,2,3,4-tetrahydronaphthalene (5f): mp 200–202 °C; IR (CHCl$_3$) 3360, 3340, 2940, 2840, 1620, 1590, 1500, 1470, 1440, 1340 (br), 1270, 1210 (br), 1070, 980, 930 cm^{-1}; ^{1}H NMR (300 MHz, CDCl$_3$) δ 9.18 (d, 1 H, J = 2.02 Hz, Ar H), 8.94 (1 H, NH), 8.27 (1 H, Ar H), 7.55–7.11 (m, 7 H, Ar H), 6.95–6.76 (m, 2 H, Ar H), 4.83 (1 H, C_4-H), 4.69 [1 H, CH(OCH$_3$)$_2$], 4.20 (1 H, C_2-H), 3.85 (s, 3 H, ArOCH_3), 3.71 (1 H, C_1-H), 3.35 (s, 3 H, CHOCH_3), 3.27 (4 H, CHOCH_3 and C_3-H), 1.25 (d, 3 H, J = 6.55 Hz, CH_3); ^{13}C NMR (75 MHz, CDCl$_3$) δ 157.81, 137.40, 136.10, 135.59, 131.53, 130.63, 129.75, 128.90, 128.12, 126.73, 124.38, 123.05, 119.24, 118.90, 115.41, 109.77, 107.28, 57.42, 57.05, 56.00, 55.55, 49.35, 42.87 17.50; high-resolution mass spectrum (CI) calcd for $C_{27}H_{29}N_3O_7S$ + H$^+$ 590.1804, found 590.1838. Anal. Calcd for $C_{27}H_{29}N_3O_7S$: C, 60.11; H, 5.42; N, 7.79; S, 5.93. Found: C, 60.04; H, 5.39; N, 7.72; S, 5.80.

1(R*)-(Dimethoxymethyl)-2(S*)-(phenylthio)-4(S*)-amino-1,2,3,4-tetrahydronaphthalene (6b) was obtained in 85% yield from **5b**: IR (CHCl$_3$) 3360, 3300, 2940, 2840, 1590, 1480, 1440, 1370, 1330, 1285, 1120, 1075, 975, 910 (br), 890 (br), 870 cm^{-1}; ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.50–7.43 (m, 3 H, Ar H), 7.32–7.18 (m, 6 H, Ar H), 4.41 [d, 1 H, J = 4.88 Hz, CH (OCO$_3$)$_2$], 4.18–4.15 (m, 1 H, C_4-H), 4.05–4.02 (m, 1 H, C_2-H), 3.31–3.26 [2 s, 3 H each, CH(OCH_3)$_2$], 3.16 (dd, 1 H, J = 3.05, 4.88 Hz, C_1-H), 2.24–2.11 (m, 2 H, CH_2), 1.84 (br s, 2 H, NH_2); ^{13}C NMR (75 MHz, CDCl$_3$) δ 141.08, 135.29, 133.20, 131.90, 130.54, 128.87, 127.12, 127.02, 126.88, 126.43, 108.77, 55.97, 54.84, 47.38, 46.84, 42.61, 36.07; high-resolution mass spectrum (CI) calcd for $C_{19}H_{23}NO_2S$ + H$^+$ 330.1528, found 330.1462.

1(R*)-(Dimethoxymethyl)-2(S*)-(phenylthio)-3(S*)-methyl-4(S*)-amino-1,2,3,4-tetrahydronaphthalene (6c) was obtained in 78% yield from **5c**: IR (CHCl$_3$) 3380, 3300, 2960, 2940, 2840, 1590, 1480, 1450, 1380, 1330, 1300, 1270, 1190, 1110, 1060, 980, 910 cm^{-1}; ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.55 (d, 1 H, J = 7.93 Hz, Ar H), 7.43–7.40 (m, 2 H, Ar H), 7.32–7.16 (m, 6 H, Ar H), 4.46 [d, 1 H, J = 5.49 Hz, CH(OCH$_3$)$_2$], 3.87 (dd, 1 H, J = 3.05, 3.66 Hz, C_2-H), 3.80 (d, 1 H, J = 9.16 Hz, C_4-H), 3.25, 3.22 [2 s, 3 H each, CH(OCH_3)$_2$], 3.18 (dd, 1 H, J = 3.05, 5.49 Hz, C_1-H), 2.96 (br s, 2 H, NH_2), 2.39–2.34 (m, 1 H, C_3-H), 1.27 (d, 1 H, J = 6.72 Hz, CH_3); ^{13}C NMR (75 MHz, CDCl$_3$) δ 140.78, 136.14, 133.24, 131.53, 130.84, 128.93, 127.72, 127.05, 126.59, 126.39, 107.97, 56.10, 54.37, 54.15, 50.76, 47.58, 38.74, 17.26; high-resolution mass spectrum (CI) calcd for $C_{20}H_{25}NO_2S$ + H$^+$ 344.1684, found 344.1680.

1(R*)-(Dimethoxymethyl)-4(S*)-amino-1,2,3,4-tetrahydronaphthalene (7b) was obtained in 51% yield from **6b**: IR 3360, 3300, 2940, 2840, 1580 (br), 1490, 1450, 1375, 1320, 1280, 1110, 1070, 970, 920 cm^{-1}; ^{1}H NMR (300 MHz, CDCl$_3$) δ 7.40 (dd, 1 H, Ar H), 7.33 (d, 1 H, J = 7.33 Hz, Ar H), 7.24–7.17 (m, 2 H, Ar H), 4.48 [d, 1 H, J = 5.49 Hz, CH(OCH$_3$)$_2$], 3.95 (m, 1 H, CHNH$_2$), 3.40, 3.33 [2 s, 3 H each, CH(OCH_3)$_2$], 3.09–3.05 (m, 1 H, C_1-H), 2.14–1.76 (m, 6 H, CH_2CH_2 and NH_2); ^{13}C NMR (75 MHz, CDCl$_3$) δ 140.46, 135.71, 129.79, 128.06, 126.89, 126.67, 108.97, 55.82, 55.11, 49.93, 40.63, 29.69, 12.62; high-resolution mass spectrum (CI) calcd for $C_{13}H_{19}NO_2$ + H$^+$ 222.1417, found 222.1488.

1(R*)-(Dimethoxymethyl)-3(R*)-methyl-4(S*)-amino-1,2,3,4-tetrahydronaphthalene (7c) was obtained in 46% yield from **6c**: IR (CHCl$_3$) 3420, 3040 (br), 2840, 1610, 1490, 1450, 1390, 1320, 1260, 1110, 1050, 990 cm^{-1}; ^{1}H NMR (300 MHz, CDCl$_3$) δ 7.66–7.61 (m, 1 H, Ar H), 7.45–7.21 (m, 3 H, Ar H), 5.40 (br s, 2 H, NH_2), 4.52 [d, 1 H, J = 5.18 Hz, CH(OCH$_3$)$_2$], 4.03–3.93 [m, 1 H, C_4-H, CH(OCH_3)$_2$], 3.99, 3.36 [2 s, 3 H each, CH(OCH_3)$_2$], 3.20–3.14 (m, 1 H, C_1-H), 2.45–2.35 (m, 1 H, C_3-H), 2.24–2.16 (m, 1 H, $^1/_2$ C_2-H_2), 1.73–1.63 (m, 1 H, $^1/_2$ C_2-H_2), 1.05 (d, 3 H, J = 6.60 Hz, CH_3); ^{13}C NMR (75 MHz, CDCl$_3$) δ 135.88, 129.85, 129.64, 127.84, 127.09, 109.22, 56.03, 55.55, 39.75, 27.14, 19.41; high-resolution mass spectrum (CI) calcd for $C_{14}H_{21}NO_2$ + H$^+$ 236.1651, found 236.1649.

2-(2,4-Dinitrophenyl)-3(R*)-methoxy-9(S*)-(phenylthio)-1(S*),4(R*)-ethano-1,2,3,4-tetrahydroisoquinoline (3b). The cycloaddition of phenyl vinyl sulfide **2** (R_1 = Ph, R_2 = H) to 2-(2,4-dinitrophenyl)isoquinolinium chloride **1** (R = H) was done via the general procedure (a) described above. The crude product on trituration with methanol gave a yellow crystalline product in 95% yield, which was characterized to be the tricyclic adduct **3a** as a single isomer: IR (CHCl$_3$) 3080, 3000, 2940, 2840, 1610, 1590, 1510, 1490, 1440, 1370, 1340, 1320, 1270, 1080, 1040, 1020, 1000, 960, 920 cm^{-1}; ^{1}H NMR (400 MHz, CDCl$_3$) δ 8.61 (d, 1 H, J = 2.93 Hz, Ar H), 8.23 (dd, 1 H, J = 2.93, 9.53 Hz, Ar H), 7.49–7.13 (m, 10 H, Ar H), 5.06 (dd, 1 H, J = 1.83, 3.05 Hz, C_1-H), 4.76 (d, 1 H, J = 2.20 Hz, C_3-H), 3.81 (ddd, 1 H, J = 1.83, 4.27, 9.16 Hz, C_9-H), 3.58 (dd, 1 H, J = 1.84, 2.20 Hz, C_4-H), 2.95 (s, 3 H, OCH_3), 2.80 (ddd, 1 H, J = 3.05, 9.76, 14.04 Hz, $^1/_2$ C_{10}-H_2), 1.58 (ddd, 1 H, J = 1.83, 4.27, 14.04 Hz, $^1/_2$ C_{10}-H_2); ^{13}C NMR (75 MHz, CDCl$_3$) δ 144.12, 139.84, 138.86, 137.92, 134.55, 134.00, 131.81, 129.19, 128.84, 128.50, 128.20, 127.82, 127.58, 127.49, 127.16, 122.26, 122.05, 119.41, 87.61, 55.71, 53.56, 43.20, 40.61, 35.90; high-resolution mass spectrum (CI) calcd for $C_{24}H_{21}N_3O_5S$ + H$^+$ 464.1433, found 464.1275.

2-Methyl-3(R*)-ethoxy-5-nitro-9(S*)-(phenylthio)-1-(S*),4(R*)-ethano-1,2,3,4-tetrahydroisoquinoline (3g, X-ray Sample). To a stirred mixture of 2-methyl-5-nitroisoquinolinium iodide (300 mg, 0.95 mmol), $CaCO_3$ (574 mg, 5.7 mmol), and methanol (15 mL) was added phenyl vinyl sulfide **2** (128 μL, 0.98 mmol), and the reaction mixture was stirred at room temperature for 3 days in an atmosphere of argon. The reaction mixture was filtered through Celite, the residue was washed with methanol, and the combined filtrate was concentrated in vacuo. Radial chromatography (EtOAc/petroleum ether, 9:1) afforded 227 mg (61%) of **3g**, but with MeO in place of EtO at C3, as a light yellow

solid. On recrystallization of the tricyclic adduct from ethanol, the methoxy group on C_3 was replaced by ethoxy. The X-ray structure and spectral data were obtained from this adduct **3g**: mp 102–106 °C; IR ($CHCl_3$) 2940, 2860, 2810, 1585, 1525, 1450, 1350, 1120 (br), 1085 (br), 1020, 990, 970, 900 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) δ 8.00 (dd, 1 H, Ar *H*), 7.50–7.45 (m, 2 H, Ar *H*), 7.40–7.25 (m, 5 H, Ar *H*), 4.43 (m, 1 H, J = 2.5, 2.9 Hz, C_4-H), 4.27–4.21 (m, 1 H, J = 2.5, 4.9, 9.9 Hz, C_9-H), 3.85 (m, 1 H, C_6-H), 3.65 (d, 1 H, J = 2.9 Hz, C_3-H), 3.65–3.54 (m, 1 H, $^1/_2$ OCH_2CH_3), 3.52–3.40 (m, 1 H, $^1/_2$ OCH_2CH_3), 2.93 (ddd, 1 H, J = 3.4, 9.9, 13.9 Hz, $^1/_2$ C_{10}-H_2), 2.31 (s, 3 H, N-CH_3), 1.32 (m, 1 H, $^1/_2$ C_{10}-H_2), 1.26 (t, 3 H, OCH_2CH_3). NMR analysis indicates that the material contains 10% of the epimer at C_3: ^{13}C NMR (75 MHz, $CDCl_3$) δ 148.4, 142.8, 135.1, 131.7, 130.7, 129.1, 129.0, 128.8, 127.2, 126.9, 122.9, 94.9, 62.9, 59.0, 43.4, 39.3, 35.5, 15.5; high-resolution mass spectrum (CI) calcd for $C_{20}H_{22}N_2O_3S$ + H^+ 371.1429, found 371.1491. Anal. Calcd for $C_{20}H_{22}N_2O_3S$: C, 64.85; H, 5.99; N, 7.56; S, 8.64. Found: C, 64.75; H, 5.93; N, 7.52; S, 8.45.

Crystal data: $C_{20}H_{22}N_2O_3S$, M = 370.47, monoclinic, a = 7.920 (5) Å, b = 16.151 (14) Å, c = 20.688 (15) Å, β = 134.62 (3)°, U = 1883 (2) Å^3, Z = 4, D_c = 1.307 g/cm^3, $F(000)$ = 784. Mo Kα radiation (λ = 0.71069 Å), μ = 0.2 cm^{-1}. Space group $P2_1/c$ (C_2^5h) from systematic absences: $0k0$ when $k \neq 2n$ and $h0l$ when $l \neq 2n$. The structure was solved by direct methods and refined by full-matrix least-squares iterations using 1333 data with $I \geq 2\sigma(I)$ to R = 0.072, R_w = 0.082.

Acknowledgment. We are indebted to the National Cancer Institute for Grant CA 39351, to the American Cancer Society for Grant CH 272 and to CUNY for PSC research awards, which supported this work. NMR instruments used were obtained through Grants NSF-PCM 111745 and NIH RR 03214. Crystallographic computations were aided by NSF Instrument Grant CHE-8700787.

Registry No. **1a**, 33107-14-1; **1b**, 1723-72-4; **2a**, 627-50-9; **2b**, 1822-73-7; **2c**, 22103-05-5; **3b**, 118629-88-2; **3a** (C3 = OEt), 118629-89-3; **3a** (C3 = OMe), 118629-90-6; **4a**, 66-77-3; **4b**, 63409-02-9; **4c**, 35689-27-1; **4d**, 118629-77-9; **5a**, 118629-78-0; **5b**, 118629-79-1; **5c**, 118629-80-4; **5d**, 118629-81-5; **5e**, 118629-82-6; **5f**, 118629-83-7; **6b**, 118629-84-8; **6c**, 118629-85-9; **7b**, 118629-86-0; **7c**, 118629-87-1; 5-methoxyisoquinoline, 90806-58-9; 5-hydroxyisoquinoline, 2439-04-5; 1-chloro-2,4-dinitrobenzene, 97-00-7; 2-methyl-5-nitroisoquinolinium iodide, 42792-95-0; Amberlite-IRA-400-OH^-, 9002-24-8.

Supplementary Material Available: Crystallographic details for the adduct **3g** including atomic coordinates, anisotropic thermal parameters for the non-hydrogen atoms, bond lengths, bond angles, and torsion angles and experimental data for 5-methoxyisoquinoline and compound **1b** (12 pages). Ordering information is given on any current masthead page.

Reaction of [Hydroxy(tosyloxy)iodo]benzene and [Hydroxy(mesyloxy)iodo]benzene with Trimethylsilyl Enol Ethers. A New General Method for α-Sulfonyloxylation of Carbonyl Compounds

Robert M. Moriarty,* Raju Penmasta, Alok K. Awasthi, W. Ruwan Epa, and Indra Prakash

Department of Chemistry, University of Illinois at Chicago, Chicago, Illinois 60680

Received June 20, 1988

Reaction of [hydroxy(tosyloxy)iodo]benzene (**1**) with trimethylsilyl enol ethers of aromatic ketones **4a–d**, alicyclic ketone **7**, aliphatic ketone **10**, and esters **13a–c** in dichloromethane at room temperature gives good yields of α-(tosyloxy)carbonyl compounds **5a–d**, **8**, **11**, and **14a–c**, respectively. The trimethylsilyl enol ether of ε-caprolactone **16** yields α-(tosyloxy)-ε-caprolactone **17** upon treatment with **1** in hexane at room temperature. Similarly, the trimethylsilyl derivatives **4a–c** and **13a–c** yield α-(mesyloxy)carbonyl compounds **18a–c** and **19a–c** upon treatment with [hydroxy(mesyloxy)iodo]benzene (**2**) in dichloromethane at room temperature. A possible pathway for these processes is discussed.

The preparation and reactions of α-(haloalkyl)carbonyl compounds have been widely studied,[1-3] and the scope and limitations of their reactions have been defined.[2] The chemistry of the related [1-(sulfonyloxy)alkyl]carbonyl compounds has received relatively little attention.[4-13] The superior nucleofugacity of sulfonyloxy group relative to halogen has been noted,[12] and α-sulfonyloxy ketones have been used in generation and study of α-keto carbocations[4-7,14] and in the functionalization of ketones.

The most common method for the synthesis of α-sulfonyloxy ketones obviously involves condensation of α-hydroxyalkyl ketones with a sulfonyl chloride, but the synthesis of α-hydroxyalkyl ketones often involves multiple steps.[6,7] There are other methods also for the synthesis of α-sulfonyloxy ketones, but they involve indirect ap-

(1) Rappe, C. *The Chemistry of Carbon–Halogen Bond*; Patai, S., Ed.; Interscience: London, 1973; Part 2, pp 1071–1105.
(2) March, J. A. *Advanced Organic Chemistry*, 2nd ed.; McGraw-Hill: New York, 1977; pp 991–995.
(3) House, H. O. *Modern Synthetic Reactions*, 2nd ed.; W. A. Benjamin: New York, 1972.
(4) Creary, X. *J. Am. Chem. Soc.* **1984**, *106*, 5568.
(5) Creary, X.; Geiger, C. C. *J. Am. Chem. Soc.* **1983**, *105*, 7123.
(6) Creary, X.; Geiger, C. C. *J. Am. Chem. Soc.* **1982**, *104*, 4151.
(7) Creary, X.; Rollin, A. J. *J. Org. Chem.* **1977**, *42*, 4226, 4231.
(8) Simons, S. S., Jr.; Pons, M.; Johnson, D. F. *J. Org. Chem.* **1980**, *45*, 3084 and references therein.
(9) Conia, J. M.; Salaun, J. R. *Acc. Chem. Res.* **1972**, *5*, 33.
(10) Koser, G. F.; Relenyi, A. G.; Kalos, A. N.; Rebrovic, L.; Wettach, R. H. *J. Org. Chem.* **1982**, *47*, 2487 and references therein.
(11) Hoffman, R. V. *Synthesis* **1985**, 760.
(12) Hoffman, R. V.; Jankowski, B. C.; Carr, C. S. *J. Org. Chem.* **1986**, *51*, 130.
(13) Newman, M. S.; Beal, P. F. *J. Am. Chem. Soc.* **1950**, *72*, 5161.
(14) Creary, X. *Acc. Chem. Res.* **1985**, *18*, 3.

0022-3263/89/1954-1101$01.50/0