Intramolecular Cyclizations of Imines Bearing the 2-(Thiomethyl)-3-trimethylsilyl-1-propenyl Terminator. An Efficient New Procedure for the Stereocontrolled Synthesis of Functionalized Pyrrolidine Derivatives

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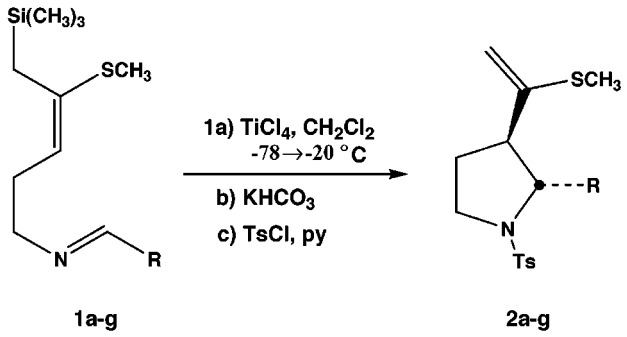
The nucleophilic addition of allylsilanes, vinylsilanes, and related species to carbon-based electrophiles has come to be regarded as a particularly versatile and efficient means for the construction of strategic bonds.[1] It is therefore surprising that there have been relatively few instances of highly diastereoselective cyclizations involving intramolecular additions of this variety to azomethine moieties.[2,3] We have previously shown that 2-propylidene-1,3-bis(silane) assemblages undergo stereodefined intramolecular aminoalkylations in the presence of $TiCl_4$ to provide functionalized pyrrolidine and isotropane derivatives.[4a] As part of a parallel study, it was discovered that corresponding cyclizations involving simple *(Z)*-allylsilanes proceed with diminished stereoselectivity and cyclization efficiency, thereby rendering this process synthetically unattractive.[4c] In principle, the installation of a thioalkyl substituent at the 2-position of an allylsilane should augment the nucleophilicity of the conjugated π-system with an attendant increase in coupling efficiency. We now describe an electronically modified allylsilane terminator of this type for intramolecular imine-alkylations that provides excellent levels of cyclization stereocontrol under comparatively mild reaction conditions. As an additional feature, cyclizations of the type described herein result in the formation of products possessing a synthetically versatile vinyl sulfide moiety (Scheme 1).[2g]

Scheme 1



1a-g **2a-g**

At the commencement of this investigation, no preparatively general methods for the synthesis of molecules containing the 2-(thiomethyl)-3-trimethylsilyl-1-propenyl subunit were available. After some experimentation, the following procedure was developed for the synthesis of amine **7** and was later shown to be extendable to the preparation of related intermediates. Sequential treatment of 3-butyn-1-ol (**3a**) with *n*-BuLi (2 equiv) followed by MeSSMe provided 4-methylthio-3-butyn-1-ol (79%), which was subsequently converted to phthalimide **4** under Mitsunobu conditions [PPh_3/phthalimide/DIAD, (86%)]. Exposure of **4** to gaseous HCl followed by treatment of the resulting vinyl chloride **5** with $(Me_3SiCH_2)_2$-Zn (1.5 equiv, prepared from $Me_3SiCH_2MgCl + ZnCl_2$ in situ) in the presence of 7 mol % $PdCl_2(PPh_3)_2$ (THF, rt) then gave phthalimide **6** (87% overall). Final PHT cleavage with $N_2H_4 \cdot H_2O$ (EtOH, reflux), afforded **7** as a 7:1 mixture of *E*- and *Z*-isomers (92% from **6**).[5] Condensation of amine **7** with a variety of aldehydes was readily achieved in the presence of 4 Å molecular sieves (THF, rt) to provide the corresponding imines **1a**−**g** as pure *E*-isomers about the C=N bond[6] in quantitative yield (Scheme 2).

Cyclization Studies. The $TiCl_4$-mediated cyclization of imines **1a**−**g** could be readily accomplished by the procedure described previously by us for imines bearing the 2-propylidene-1,3-bis(silane) terminator.[4a] Accordingly, simple exposure of these substrates to $TiCl_4$ (1.0 equiv) in CH_2Cl_2 at −78 °C followed by stirring at −20 °C for 10 h and final inverse addition to saturated aqueous $KHCO_3$ provided optimal conversion to the 1,2-disubstituted pyrrolidines **2a**−**g**, typically with excellent *trans*-selectivity and in good isolated yield. In the case of **2f**, a 1.3:7.0 ratio of isomeric pyrrolidines was obtained. This mixture was converted to the corresponding *N*-TFA derivatives (TFAA-pyridine) to facilitate chromatographic separation of the *cis* and *trans* isomers. Sequential amide hydrolysis of the pure isomers (K_2CO_3, MeOH) followed by N-tosylation (TsCl, Py, CH_2Cl_2, 0 °C → rt) provided the pure isomeric tosamides $\mathbf{2f}_{(Ts)cis}$ and $\mathbf{2f}_{(Ts)trans}$. NOE spectroscopic analyses of the individual isomers provided compelling evidence for the relative stereochemical orientation of the substituents at positions 2 and 3. Specifically, irradiation of the C-3 methine ($H^{(3)}$) of the major isomer ($\mathbf{2f}_{(Ts)cis}$) gave rise to a 13.4% NOE enhancement

(1) (a) Langkopf, E.; Schinzer, D. *Chem. Rev.* **1995**, *95*, 1375. (b) The Electrophilic Substitution of Allylsilanes and Vinylsilanes. Fleming, I.; Dunoguès, J.; Smithers, R. In *Organic Reactions*; Kende, A. S., Ed.; John Wiley and Sons: New York, 1989; Vol. 37, Chapter 2, p 57.

(2) (a) Heerding, D. A.; Hong, C. Y.; Kado, N.; Look, G. C.; Overman, L. E. *J. Org. Chem.* **1993**, *58*, 6947. (b) Hong, C. Y.; Kado, N.; Overman, L. E. *J. Am. Chem. Soc.* **1993**, *115*, 11028. (c) Hiemstra, H.; Fortgens, H. P.; Speckamp, W. N. *Tetrahedron Lett.* **1985**, *26*, 3155. (d) Hiemstra, H.; Sno, M. H. A. M.; Vijn, R. J.; Speckamp, W. N. *J. Org. Chem.* **1985**, *50*, 4014. (e) An account addressing stereoselective cyclizations of allylsilanes with iminium ions generated by a Beckmann rearrangement has appeared: Schinzer, D.; Bo, Y. *Angew. Chem., Int. Ed. Engl.* **1991**, *30*, 687. (f) A related intramolecular cyclization initiated by a $TiCl_4$-activated imine has recently appeared: Frank, K. E.; Aube, J. *J. Org. Chem.* **2000**, *65*, 655. (g) The *intermolecular* addition of 2-methylthio-3-trimethylsilyl-1-propene to simple imines has been described: Narasaka, K.; Shibata, T.; Hayashi, Y. *Bull Soc. Chem. Jpn.* **1992**, *65*, 1392.

(3) (a) Jin, J.; Smith, D. T.; Weinreb, S. M. *J. Org. Chem.* **1995**, *60*, 5366. (b) Borzilleri, R. M.; Parvez M.; Weinreb, S. M. *J. Am. Chem. Soc.* **1994**, *116*, 9789.

(4) (a) Kercher, T.; Livinghouse, T. *J. Am. Chem. Soc.* **1996**, *118*, 4200. (b) For cyclizations involving the intramolecular coupling of *C*-acylnitrilium ions with 2-propylidene-1,3-bis(silane)s, see: Kercher, T.; Livinghouse, T. *J. Org. Chem.* **1997**, *62*, 805. (c) Li, J. M.S. Thesis, Montana State University, 2001.

(5) All new compounds have been fully characterized by ^1H and ^{13}C NMR and IR and possess satisfactory exact mass.

(6) Aldimine geometrical constitution was determined by 300 MHz ^1H NMR.

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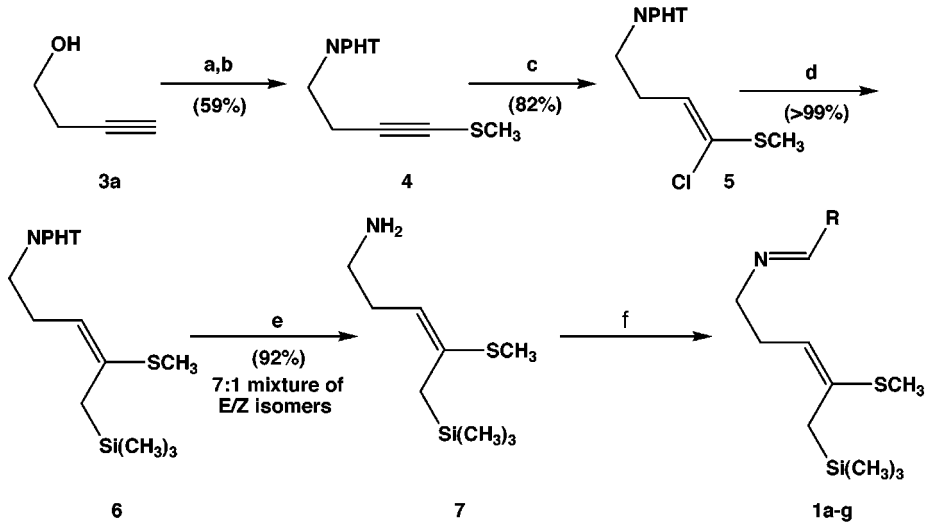
Scheme 2



(a) (1) *n*-BuLi, (2) MeSSMe; (b) PPh_3/phthalimide/DIAD; (c) HCl_g; (d) $(TMSCH_2)_2Zn$, $(Ph_3P)_2PdCl_2$ (7 mol %), THF, rt; (e) $N_2H_4 \cdot H_2O$, EtOH, reflux; (f) RCHO, 4 Å mol. sieves, THF, rt.

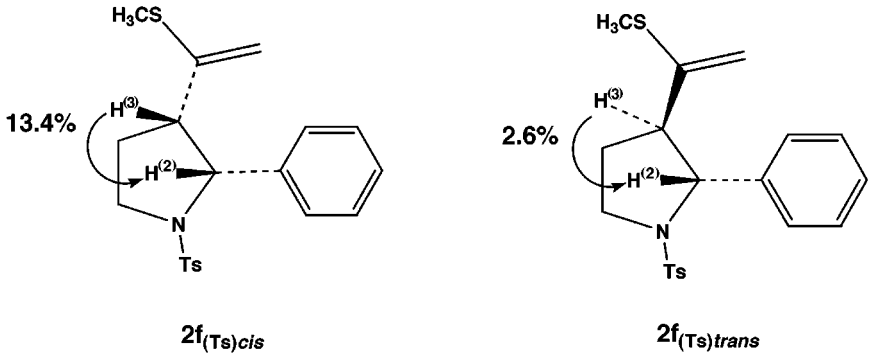


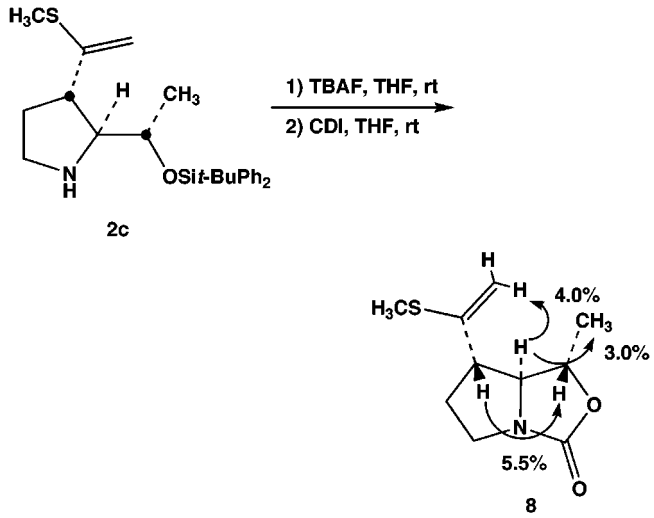
Figure 1.

at $H^{(2)}$. Corresponding irradiation of $H^{(3)}$ of the minor isomer (**2f**$_{(Ts)trans}$) led to a much smaller (2.6%) NOE signal at $H^{(2)}$ (Figure 1). The stereochemical assignment for *N*-tosylpyrrolidines **2e**$_{(Ts)}$ were derived by an analogous NOE study. For *N*-tosylpyrrolidines **2a**−**d**$_{(Ts)}$, the observation of characteristically small NOEs in the range of 2−5% was considered diagnostic for the selective formation of the indicated *trans* isomers. In the case of **2c**, the sense of relative stereoinduction was established by NOE enhancement studies performed on the corresponding oxazolidinone **8** that was prepared by sequential desilylation (TBAF) followed by carbonyldiimidazole treatment (Scheme 3). A summary of the results obtained for the $TiCl_4$-mediated cyclizations of imines **1a**−**g** (Scheme 1) is provided in Table 1.

In consonance with our earlier findings in the 2-propylidine-1,3-bis(silane) series,[4a] $TiCl_4$-mediated cyclization of the ketimine **9** derived from **7** and ethyl levulinate furnished the pyrrolizidine derivative **10** directly with excellent and *reversed* stereoselectivity (*cis*/*trans* > 50:1) in 83% yield (Scheme 4).

In conclusion, this study has demonstrated that the 2-(thiomethyl)-3-trimethylsilyl-1-propenyl terminator serves as an effective nucleophile in efficient and stereoselective annulations leading to functionalized pyrrolidines. The utilization of this cyclization strategy for the stereodefined synthesis of bioactive substances is under current investigation.

Scheme 3

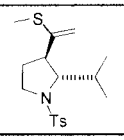
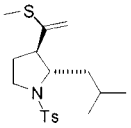
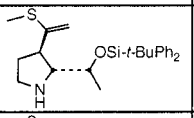
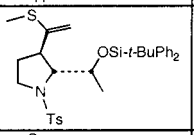
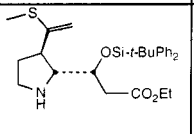
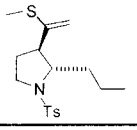
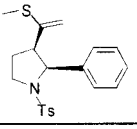
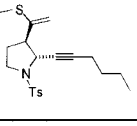
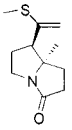


Experimental Section

General. All experiments were carried out under an argon atmosphere in oven-dried glassware. Tetrahydrofuran (THF) and diethyl ether (Et_2O) were distilled from sodium−benzophenone ketyl. All other reagents were either prepared according to published procedures or were available from commercial sources. Column flash chromatography was performed on Merck silica gel 60 (230−400 mesh) or Aldrich neutral alumina (~150 mesh).

***N*-(4-Methylthio)but-3-ynylphthalimide (4).** A 100-mL flame-dried round-bottomed flask equipped with a Teflon-coated

Table 1. $TiCl_4$-Mediated Cyclizations

Entry	Compound	Yield (%)	*Trans/Cis*[a] Ratio
2a$_{(Ts)}$		76	>20:1
2b$_{(Ts)}$		61	29:1
2c		77	>50:1
2c$_{(Ts)}$		67	>50:1
2d		60	>5:1
2e$_{(Ts)}$		49	1.8:1
2f$_{(Ts)cis}$		88	1.3:7
2g$_{(Ts)}$		67	7.0:1
10		83	3:97

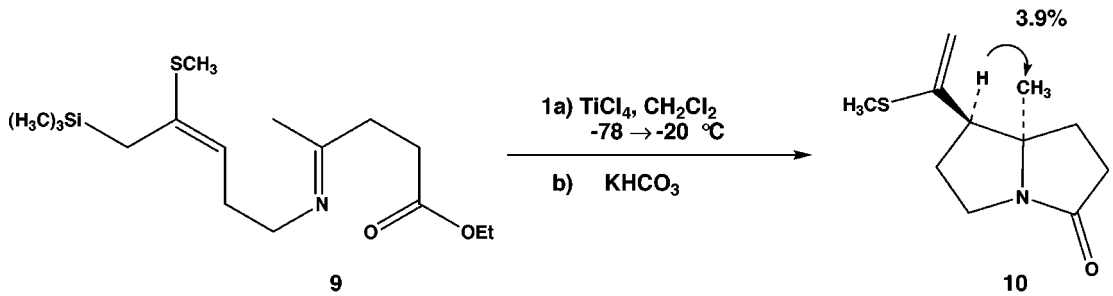
[a] As determined by ^{1}H NMR.

magnetic stirring bar and a rubber septum was charged with THF (50 mL), 4-(methylthio)but-3-yn-1-ol (3.00 g, 0.024 mol), phthalimide (3.83 g, 0.026 mol), and triphenylphosphine (6.82 g, 0.026 mol). The homogeneous solution was cooled to 0 °C and treated dropwise with diisopropyldiazocarboxylate (5.26 g, 0.026 mol) over a 10-min period. The solution was allowed to warm to ambient temperature and stirred for 12 h. Evaporation of solvent at reduced pressure afforded a viscous oil, which was triturated with 20% ethyl acetate/hexane and filtered through a pad of silica gel. The filtrate was concentrated, and the resulting residue was subjected to flash chromatography (20% ethyl acetate/hexane for elution) to afford the title compound as a white solid (5.06 g, 86%). Mp: 70−72 °C. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.81 (m, 2H, Ar*H*), 7.68 (m, 2H, Ar*H*), 3.82 (t, 2H, J = 7.0 Hz, NCH_2CH_2-), 2.65 (t, 2H, J = 7.0 Hz, $-CH_2CH_2C-$), 2.24 (s, 3H, $-SCH_3$). ^{13}C NMR (75 MHz, $CDCl_3$): δ 168.4, 134.4, 132.4, 89.2, 73.1, 37.1, 20.4, 19.3. IR (film): 3251, 1767, 1706, 1430, 1400, 1369, 1335, 1114, 996, 867, 724 cm^{-1}. HRMS (EI) m/z 245.0516 (calcd for $C_{13}H_{11}NO_2S$, 245.0511), ppm error = −2.1.

***N*-[4-Chloro-4-(methylthio)but-3-enyl]phthalimide (5).** A 250-mL flame-dried round-bottomed flask equipped with a Teflon-coated magnetic stirring bar and a rubber septum was charged with *N*-[(4-methylthio)but-3-ynyl]phthalimide (**4**) (5.00 g, 20.4 mmol) and chloroform (100 mL). The solution was cooled to 0 °C, and $HCl_{(g)}$ was bubbled through the reaction mixture until the starting material had been consumed (the consumption of starting material was monitored by GC analysis). The reaction mixture was concentrated, dissolved in a minimal amount of 20% ethyl acetate/hexane, and filtered through a plug of silica gel (20% ethyl acetate/hexane as eluent). The solvent was then removed under reduced pressure to afford the title compound as a viscous oil (5.60 g, 98%) that was used without further purification. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.83 (m, 2H, Ar*H*), 7.69 (m, 2H, Ar*H*), 5.88 (t, 1H, J = 7.0 Hz, $-CH_2CH=$), 3.76 (t, 2H, J = 6.8 Hz, NCH_2CH_2-), 2.62 (dt, 2H, J = 7.0, 6.8 Hz, $-CH_2CH_2CH=$), 2.26 (s, 3H, $-SCH_3$). ^{13}C NMR (75 MHz, $CDCl_3$): δ 168.6, 134.4, 131.2, 127.2, 123.7, 36.7, 29.5, 16.9. IR (KBr): 3467, 3279, 2926, 1773, 1712, 1611, 1466, 1436, 1360, 1187, 1046, 970, 862, 793, 719 cm^{-1}. HRMS (EI) m/z 281.0280 (calcd for $C_{13}H_{11}ClNO_2Si$, 281.0277), ppm error = −1.1.

***N*-[4-(Methylthio)-5-(trimethylsilyl)pent-3-enyl]phthalimide (6).** A 50-mL flame-dried round-bottomed flask equipped with a Teflon-coated magnetic stirring bar and a rubber septum was charged with a solution of anhydrous $ZnCl_2$ (3.69 mL of 1.06 M in THF, 3.91 mmol). The solution was cooled to 0 °C, and a solution of $TMSCH_2MgCl$ (4.76 mL of 1.64 M in THF, 7.81 mmol) was added dropwise over a 15-min period. The gray reaction mixture was stirred for 15 min at 0 °C, and $PdCl_2(PPh_3)_2$ (350 mg, 0.50 mmol, 7 mol %) was added in one portion. After 15 min of stirring at 25 °C, *N*-[4-chloro-4-(methylthio)but-3-enyl]-pthalimide (**5**) (2 g, 7.10 mmol) in THF (20 mL) was added dropwise to the black/brown reaction mixture over a 40 min period, which was stirred at 25 °C for 7 h and poured into a solution of cold, saturated ammonium chloride (50 mL). Both phases were decanted into a separatory funnel, and the organic phase was removed. The aqueous phase was extracted with ether (3 × 25 mL), and the combined organic extracts were washed with brine, dried over magnesium sulfate, and concentrated. The residue was triturated with pentane and filtered through a pad of Celite. The pentane was removed, and the residue was purified by flash chromatography (20% ethyl acetate/hexane for elution) to afford the title compound as a yellowish, viscous oil (2.06 g, 87%). ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.80 (m, 2H, Ar*H*), 7.67 (m, 2H, Ar*H*), 4.85 (app t, 1H, J = 7.1 Hz, $-CH_2CH=$), 3.69 (t, 2H, J = 6.5 Hz, NCH_2CH_2-), 2.40 (dt, 2H, J = 7.1, 6.5 Hz, NCH_2CH_2-), 2.17 (s, 3H, $-SCH_3$), 1.70 (s, 2H, $=CCH_2Si(CH_3)_3$)), 0.01 (s, 9H, $-Si(CH_3)_3$). ^{13}C NMR (75 MHz, $CDCl_3$): δ 168.77, 137.47, 134.27, 132.55, 123.55, 117.58, 38.15, 35.10, 29.73, 23.62, −0.54. IR (KBr): 3251, 1771, 1710, 1465, 1396, 1364, 1337, 1114, 867, 744 cm^{-1}. HRMS (EI) m/z 333.1225 (calcd for $C_{17}H_{23}NO_2SSi$, 333.1219), ppm error = −1.8.

Scheme 4



9 **10**

4-(Methylthio)-5-(trimethylsilyl)pent-3-enylamine (7). A 100-mL flame-dried round-bottomed flask equipped with a Teflon-coated magnetic stirring bar, reflux condenser, and a rubber septum was charged with *N*-[(4-methylthio)-5-(trimethylsilyl)pent-3-enyl]pthalimide (**6**) (1.5 g, 4.5 mmol) and ethanol (50 mL). The reaction mixture was treated with hydrazine monohydrate (0.48 g, 9.50 mmol) and heated to reflux temperatures with stirring for 8 h. The heterogeneous mixture was cooled to ambient temperature and filtered through a pad of Celite. The filtrate was concentrated, and the residue was triturated with pentane, filtered through a pad of Celite, and concentrated. The residue was purified by bulb-to-bulb distillation (120 °C at 0.25 Torr) to afford the title compound as a colorless liquid (0.84 g, 92%), which consisted of 2 inseparable isomers (7:1 *E*/*Z* isomeric ratio) (*major isomer only*). ^{1}H NMR (300 MHz, $CDCl_3$): δ 4.86 (app t, 1H, J = 7.2 Hz, $-CH_2CH=$), 2.68 (t, 2H, J = 7.0 Hz, $H_2NCH_2CH_2-$), 2.17 (s, 3H, $-SCH_3$), 2.16 (m, 2H, $H_2NCH_2CH_2CH=$), 1.75 (s, 2H, $-CH_2Si(CH_3)_3$), 1.28 (bs, 2H, $-NH_2$), 0.05 (s, 9H, $-CH_2Si(CH_3)_3$). ^{13}C NMR (75 MHz, $CDCl_3$): δ 135.9, 115.2, 42.7 34.31, 23.6, 15.5, 0.48. IR (film): 3370, 3299, 2952, 2919, 1618, 1438, 1424, 1247, 1156, 958, 856, 724 cm^{-1}. HRMS (EI$^+$) (M + 1) 204.1232 *m*/*z* (calcd for $C_9H_{22}NSSi$, 204.1242), ppm error = 5.1.

***N*-(2-Methylpropylidene)-4-methylthio-5-trimethylsilyl-3-penten-1-amine (1a).** The following serves as a general experimental procedure used for the preparation of aldimines. A 10-mL single-necked, round-bottomed flask equipped with a Teflon-coated magnetic stirring bar and a rubber septum was charged with activated 4 Å molecular sieves (700 mg), 4-(methylthio)-5-(trimethylsilyl)pent-3-enylamine (**7**) (0.203 g, 1.00 mmol), and CH_2Cl_2 (2 mL). Freshly distilled isobutyraldehyde (0.087 g, 1.20 mmol) was added to the reaction mixture and stirred for 12 h at ambient temperature. The reaction mixture was diluted with hexane (~5 mL) and filtered through a Celite pad. Evaporation of the solvent and excess aldehyde in vacuo afforded the title aldimine (0.252 g, 98%) as a colorless oil, which was used immediately in the next step (**2a**$_{(Ts)}$). Crude aldimines (**1a**−**g**, and the ketimine precursor for **10**) were prepared using this procedure.

***Trans*-*N*-tosyl-2-isopropyl-3-[(2-methylthio)ethenyl]pyrrolidine (2a$_{(Ts)}$).** The following represents the general experimental procedure used for the preparation of pyrrolidines from the corresponding aldimines. A 5-mL flame-dried round-bottomed flask containing a Teflon-coated magnetic stirring bar and a rubber septum was charged with a solution of freshly prepared aldimine **1a** (52 mg, 0.20 mmol) in CH_2Cl_2 (2 mL). The solution was cooled to −78 °C and treated dropwise over a 2 min period with $TiCl_4$ (0.32 M in toluene, 0.63 mL, 0.20 mmol). The resulting deep orange solution was stirred for 3 h at −78 °C followed by an additional 12 h at −20 °C. The reaction mixture was transferred *dropwise* via cannula into a vigorously stirred, saturated aqueous solution of $KHCO_3$ cooled to 0 °C. The biphasic mixture was stirred for 30 min at ambient temperature and decanted into a separatory funnel. The organic phase was removed, and the aqueous phase was extracted with CH_2Cl_2 (2 × 5 mL). The combined organic phases were then dried with $MgSO_4$, filtered, and concentrated to give a thick yellow oil. For the purposes of complete and accurate characterization as well as NOE analysis, the pyrrolidine was immediately converted to the corresponding *N*-tosylate via the following procedure. A 25-mL flame-dried round-bottomed flask containing a Teflon-coated magnetic stirring bar and a rubber septum was charged with the crude pyrrolidine (0.20 mmol calc), pyridine (0.65 μL, 0.80 mmol), and CH_2Cl_2 (2 mL). The reaction mixture was cooled to 0 °C, and TsCl (38 mg, 0.20 mmol) was added in one portion. The mixture was stirred at 0 °C for 2 h followed by an additional 2 h at room temperature. A solution of aqueous $KHCO_3$ (saturated, 2 mL) was added, and the biphasic mixture was stirred vigorously for 1 h. The organic phase was removed and the aqueous phase was extracted with CH_2Cl_2 (3 × 2 mL). The combined organic phases were dried ($MgSO_4$) and concentrated in vacuo to give a deep yellow oil. The residue was subjected to flash chromatography on silica gel (10% ethyl acetate/hexanes for elution) to afford the title compound as a colorless, viscous oil (52 mg, 76%). ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.86 (d, 2H, J = 8.3 Hz, Ar*H*), 6.83 (d, 2H, J = 8.3 Hz, Ar*H*), 4.54 (app s, 1H, $-C(CH_3S)=CHH$), 4.12 (app s, 1H, $-C(CH_3S)=CHH$), 3.99 (dd, 1H, J = 4.9, 4.8 Hz, $-CH_2NCHCH-$), 3.44 (m, 1H, $-NCHHCH_2-$), 3.15 (m, 1H, $-NCHHCH_2$), 2.57 (m, 1H, $-CHC=CH_2$), 2.55 (m, 1H, $-CH(CH_3)_3$), 1.92 (s, 3H, ArCH_3), 1.63 (s, 3H, SCH_3), 1.52 (m, 1H, $-NCHCHH$), 1.41 (m, 1H, $-NCHCHH$), 1.04 (d, 3H, J = 7.0 Hz, $-CH(CH_3)_2$), 0.95 (d, 3H, J = 6.9 Hz, $-CH(CH_3)_2$). ^{13}C NMR (75 MHz, $CDCl_3$): δ 149.8, 143.4, 137.8, 129.6, 103.2, 69.9, 49.5, 47.8, 33.7, 32.5, 21.2, 19.7, 17.03, 14.3. IR (film): 2972, 2915, 2867, 1593, 1464, 1339, 1152, 1089, 1046, 998, 840 cm^{-1}. HRMS (EI): 339.1329 *m*/*z* (calcd for $C_{17}H_{25}NO_2S_2$, 339.1327), ppm error = −0.7.

Pyrrolizidinone (10). A 25-mL flame-dried round-bottomed flask containing a Teflon-coated magnetic stirring bar and a rubber septum was charged with 4-(methylthio)-5-(trimethylsilyl)pent-3-enylamine (**7**) (203 mg, 1.00 mmol), 4 Å molecular sieves, and CH_2Cl_2 (2 mL). Ethyl levulinate (144 mg, 1.00 mmol) was added to the reaction mixture and stirred for 12 h at ambient temperature. The reaction mixture was diluted with hexane and filtered through a plug of Celite. The filtrate was concentrated, and the residue was dissolved in CH_2Cl_2 (10 mL). This solution was cooled to −78 °C and treated dropwise over a 2-min period with $TiCl_4$ (1.50 mL of mL 0.70 M in toluene, 1.00 mmol) via syringe. The resulting deep orange solution was stirred for 3 h at −78 °C followed by an additional 12 h at −20 °C. The reaction mixture was transferred *dropwise* via cannula into a vigorously stirred, saturated aqueous solution of $KHCO_3$ cooled to 0 °C. The biphasic mixture was stirred for 30 min at ambient temperature. The organic phase was removed, and the aqueous phase was extracted with CH_2Cl_2 (2 × 5 mL). The combined organic phases were then dried with Na_2SO_4, filtered, and concentrated to give a thick oil, which was subjected to flash chromatography (20% ethyl acetate/hexane followed by 90% ethyl acetate/hexane for elution) to give the title compound as a colorless oil (175 mg, 83%). ^{1}H NMR (300 MHz, C_6D_6): δ 4.76 (app s, 1H, $-C(CH_3S)=CHH$), 4.44 (app s, 1H, $-C(CH_3S)=CHH$), 3.88 (app dt, 1H, J = 6.8, 7.4 Hz, $-NCHHCH_2$), 2.76 (ddd, 1H, J = 1.0, 7.4, 11.3 Hz, $-NCHHCH_2-$), 2.46 (m, 1H, $O=CCHH-$), 2.32 (app t, 1H, J = 6.6 Hz, $=CCH-$), 2.30 (m, 1H, $O=CCH_2-CHH-$), 2.05 (app dt, 1H, J = 9.9, 12.8 Hz, $O=CCHH-$), 1.85 (m, 1H, $O=CCH_2CHH$), 1.81 (m, 1H $-NCH_2CHH-$), 1.79 (s, 3H, $-SCH_3$), 1.44 (ddd, 1H, J = 2.5, 9.3, 15.3 Hz, $O=CH_2CHH$), 1.04 (s, 3H, $-CCH_3$). ^{13}C NMR (75 MHz, C_6D_6): δ 173.9, 148.19, 103.7, 69.2, 53.8, 40.3, 33.3, 31.9, 28.9, 27.8, 14.1. IR (film): 2967, 2918, 1692, 1392, 1244, 842 cm^{-1}. HRMS (EI$^+$): 211.1027 (calcd for $C_{11}H_{17}NOS$, 211.1031), ppm error = 1.7.

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Supporting Information Available: Experimental procedures and listings of ^{1}H and ^{13}C NMR, IR, and HRMS composition data for all new compounds. This material is available free of charge via the Internet at http://pubs.acs.org.

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