Supporting Information

Intramolecular [4 + 2] Cycloadditions of Benzyne with Conjugated Enynes, Arenynes, and Dienes

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General Procedures. All reactions were performed in flame-dried glassware under a positive pressure of argon. Reaction mixtures were stirred magnetically unless otherwise indicated. Air- and moisture-sensitive liquids and solutions were transferred via syringe or cannula and were introduced into reaction vessels through rubber septa. Reaction product solutions and chromatography fractions were concentrated using a Büchi rotary evaporator at ca. 20 mmHg and then at 0.02 mmHg (vacuum pump) unless otherwise indicated. Thin layer chromatography was performed on Merck precoated glass-backed silica gel 60 F-254 0.25 mm plates. Column chromatography was performed on EM Science silica gel 60 or Silicycle silica gel 60 (230-400 mesh).

Materials. Commercial grade reagents and solvents were used without further purification except as indicated below. Dichloromethane, diethyl ether, and tetrahydrofuran were purified by pressure filtration through activated alumina. Diisopropylethylamine, *N,N*-dimethylformamide, chlorotrimethylsilane, piperidine, and pyridine were distilled under argon from calcium hydride. Trifluoromethanesulfonyl anhydride was distilled under argon from phosphorous pentoxide. Methyl vinyl ketone was distilled under argon from K₂CO₃. Copper(I) iodide was extracted with THF for 24 h in a Soxhlet extractor and then dried under vacuum (0.1 mmHg). Palladium(II) chloride (bis)triphenylphosphine was recrystallized from boiling chloroform. 2-Bromopropene and 1-bromopropene were passed through a pad of alumina in a disposable pipette prior to use. *n*-Butyllithium was titrated according to the Watson-Eastham method using menthol or BHT in THF at 0 °C with 1,10-phenanthroline as an indicator.¹

Instrumentation. Melting points were determined with a Fisher-Johns melting point apparatus and are uncorrected. Infrared spectra were obtained using a Perkin Elmer 2000 FT-IR spectrophotometer. ¹H NMR and ¹³C NMR spectra were measured with an Inova 500 spectrometer. ¹H NMR chemical shifts are expressed in parts per million (δ) downfield from tetramethylsilane (with the CHCl₃ peak at 7.27 ppm used as a standard). ¹³C NMR chemical shifts are expressed in parts per million (δ) downfield from tetramethylsilane (with the central peak of CHCl₃ at 77.23 ppm used as a standard). High resolution mass spectra (HRMS) were measured on a Bruker Daltonics APEXII 3 Tesla Fourier transform mass spectrometer. Elemental analyses were performed by E&R Microanalytical Laboratory, Inc. of Parsippany, NJ.

¹ (a) Watson, S. C.; Eastham, J. F. *J. Organomet. Chem.* **1967**, *9*, 165. (b) Ellison, R. A.; Griffin, R.; Kotsonis, F. N. *J. Organomet. Chem.* **1972**, *36*, 209.

Part I. Tables for the Preparation of Cycloaddition Substrates

Table S1. Preparation of Enyne Cycloaddition Substrates

entry	alkenyl-X	Sonogashira product (% yield) ^c	cycloaddition substrate	% yield ^c
1		7 (84-85)		82-85
2		S2 (80)		84
3		S3 (88)		85
4		S4 (77) ^d		83
5		S6 (82)		85
6		S7 (80)		82

^a 1-3 equiv alkenyl halide or triflate, 12 mol% CuI, 6 mol% Pd(PPh₃)₂Cl₂, 3.5 equiv piperidine, THF, rt to 60 °C, 25 min to 2 h. ^b 4 equiv Tf₂O, 6 equiv *i*-Pr₂NEt, CH₂Cl₂, -78 °C, 20 min to 1 h. ^c Yields for products purified by column chromatography. ^d Reaction conducted with *i*-Pr₂NEt in place of piperidine.

Table S2. Preparation of Arenyne Cycloaddition Substrates

entry	aryl-X	Sonogashira product (% yield) ^c	cycloaddition substrate	% yield ^c
1		S8 (90)		85
2		S9 (62)		86
3		S10 (83)		84
4		S11 (61) ^d		85

^a 1-3 equiv aryl halide, 12 mol% CuI, 6 mol% Pd(PPh₃)₂Cl₂, 3.5 equiv piperidine, THF, rt to 60 °C, 25 min to 2 h. ^b 4 equiv Tf₂O, 6 equiv *i*-Pr₂NEt, CH₂Cl₂, -78 °C, 20 min to 1 h. ^c Yields for products purified by column chromatography. ^d Reaction conducted in refluxing piperidine.

Part II. Experimental Procedures for Preparation of Cycloaddition Substrates

2-(Methoxymethoxy)-3-(trimethylsilyl)benzaldehyde (S1). A 100-mL, three-necked, round-bottomed flask equipped with an argon inlet adapter, rubber septum, and glass stopper was charged with methoxymethyl phenyl ether (**4**)² (1.75 g, 12.7 mmol) and 42 mL of THF and cooled at 0 °C while 6.9 mL of *n*-BuLi solution (2.21 M in hexane, 15 mmol) was added dropwise over 6 min. After 2 h, chlorotrimethylsilane (1.90 mL, 1.63 g, 15.2 mmol) was added dropwise over 4 min and the resulting solution was allowed to warm to room temperature over 20 min. The reaction mixture was then cooled at 0 °C while 6.9 mL of *n*-BuLi solution (2.21 M in hexane, 15 mmol) was added dropwise over 6 min. After 2 h, the solution was cooled to -78 °C and DMF (1.5 mL, 1.4 g, 19 mmol) was added dropwise over 1 min. The resulting mixture was allowed to warm to room temperature over 1 h and then treated with 30 mL of satd aq NH₄Cl solution. The organic phase was separated and washed with 30 mL of satd aq NH₄Cl solution, and the combined aqueous phases were extracted with two 50-mL portions of diethyl ether. The organic phases were combined and washed with two 50-mL portion of water, 50 mL of satd NaCl solution, dried over MgSO₄, filtered, and concentrated at reduced pressure (≥ 20 mmHg due to volatility) to afford 2.68 g of brown oil. Column chromatography on 54 g of silica gel (gradient elution with 2-5% methyl *tert*-butyl ether-hexanes) provided 2.62 g (87%) of acetal **S1**³ as a pale yellow oil: IR (film) 3054, 2954, 2830, 1687, and 1150 cm⁻¹; ¹H NMR (300 MHz, CDCl₃) δ 10.27 (s, 1H), 7.86 (dd, *J* = 7.5, 1.5 Hz, 1H), 7.68 (dd, *J* = 7.0, 2.0 Hz, 1H), 7.24 (app t, *J* = 7.5 Hz, 1H), 5.03 (s, 2H), 3.58 (s, 3H), and 0.33 (s, 9H); ¹³C NMR (75 MHz, CDCl₃) δ 191.4, 165.4, 141.8, 134.8, 130.3, 129.5, 124.7, 102.0, 57.9, and -0.2; HRMS-ESI (*m/z*): [M + Na]⁺ calcd for C₁₂H₁₈O₃Si, 261.0917; found, 261.0917; Anal. Calcd for C₁₂H₁₈O₃Si: C, 60.47; H, 7.61; found: C, 60.22; H, 7.66.

² Prepared by alkylation of the sodium salt of phenol with MOMCl in a mixture of DMF and ether as described in: Agharahimi, M. R.; LeBel, N. A. *J. Org. Chem.* **1995**, *60*, 1856.

³ For the previous preparation of this aldehyde, see O'Connor, K. J.; Wey, S.-J.; Burrows, C. J. *Tetrahedron Lett.* **1992**, *33*, 1001.

2-Hydroxy-3-(trimethylsilyl)benzaldehyde (5). A 500-mL, three-necked, round-bottomed flask equipped with a rubber septum, glass stopper, and reflux condenser fitted with an argon inlet adapter was charged with acetal **S1** (4.09 g, 17.2 mmol), NaI (3.08 g, 20.6 mmol), 200 mL of acetone, and 1.72 mL of aq HCl solution (2.0 M, 3.43 mmol). The resulting mixture was heated at 55 °C for 45 min, and then allowed to cool to room temperature and concentrated at reduced pressure (≥ 20 mmHg due to volatility). The resulting pale yellow solid was dissolved in 100 mL of diethyl ether and washed with 100 mL of water. The aqueous phase was extracted with three 100-mL portions of diethyl ether, and the combined organic phases were washed with 100 mL of satd Na₂S₂O₃ solution, 100 mL of satd NaCl solution, dried over MgSO₄, filtered, and concentrated at reduced pressure (≥ 20 mmHg due to volatility) to furnish 3.51 g of pale yellow oil. Column chromatography on 70 g of silica gel (elution with pentane) provided 3.23 g (97%) of aldehyde **5**³ as a colorless oil: IR (film) 3130, 3055, 2955, 2745, and 1658 cm⁻¹; ¹H NMR (300 MHz, CDCl₃) δ 11.33 (s, 1H), 9.87 (s, 1H), 7.62 (dd, $J = 7.2, 1.5$ Hz, 1H), 7.54 (dd, $J = 7.5, 1.8$ Hz, 2H), 7.00 (t, $J = 7.5$ Hz, 1H), and 0.35 (s, 9H); ¹³C NMR (75 MHz, CDCl₃) δ 196.9, 166.3, 142.7, 135.0, 128.7, 119.7, 119.6, and -1.0.

2-[(Prop-2-ynylamino)methyl]-6-(trimethylsilyl)phenol (6). A 100-mL, one-necked, round-bottomed flask equipped with a rubber septum and an argon inlet needle was charged with aldehyde **5** (1.15 g, 5.94 mmol), 3Å molecular sieves, propargylamine (0.49 mL, 0.61 g, 7.1 mmol), and 24 mL of methanol. The resulting suspension was stirred at room temperature for 30 min and then cooled at 0 °C while NaBH₄ (0.337 g, 8.91 mmol) was added in portions over 5 min. After 1 h, the reaction mixture was diluted with 50 mL of water and filtered through a plug of Celite in a sintered glass funnel with the aid of five 30-mL portions of diethyl ether. The aqueous phase was separated and extracted with three 150-mL portions of diethyl ether, and the combined organic phases were washed with 50 mL of satd NaCl solution, dried over MgSO₄, filtered, and concentrated to afford 1.30 g of ivory solid. Column

chromatography on 7 g of silica gel (elution with diethyl ether) provided 1.15 g (83%) of amine **6** as a white solid: mp 94-95 °C; IR (CH₂Cl₂) 3300, 3050, 2960, 2300, 1595, 1575, 1415, 1230, and 830 cm⁻¹; ¹H NMR (300 MHz, CDCl₃) δ 10.10-10.70 (br s, 1H), 7.31 (d, *J* = 7.2 Hz, 1H), 7.07 (d, *J* = 6.0 Hz, 1H), 6.82 (t, *J* = 7.2 Hz, 1H), 4.08 (s, 2H), 3.50 (d, *J* = 2.4 Hz, 2H), 2.33 (t, *J* = 2.4 Hz, 1H), 1.42-2.20 (br s, 1H), and 0.33 (s, 9H); ¹³C NMR (75 MHz, CDCl₃) δ 163.0, 134.5, 130.4, 126.4, 120.7, 119.1, 80.4, 72.9, 51.3, 36.9, and -0.6; HRMS-ESI (*m/z*): [M + H]⁺ calcd for C₁₃H₁₉NOSi, 234.1309; found, 234.1319; Anal. Calcd for C₁₃H₁₉NOSi: C, 66.90; H, 8.21; N, 6.00; found: C, 66.95; H, 8.19; N, 6.00.

General Procedure for Sonogashira Cross-Coupling. **2-[(4-Methylpent-4-en-2-ynyl)amino]methyl-6-(trimethylsilyl)phenol (7).** A 100-mL, three-necked, round-bottomed flask equipped with a glass stopper, rubber septum, and a reflux condenser fitted with an argon inlet adapter was charged with (Ph₃P)₂PdCl₂ (0.543 g, 0.774 mmol), CuI (0.295 g, 1.55 mmol), and alkyne **6** (3.00 g, 12.9 mmol). The reaction flask was evacuated for 5 min at 0.05 mmHg, filled with argon, and then charged 21 mL of THF, piperidine (4.5 mL, 3.9 g, 45 mmol), and 2-bromopropene (3.4 mL, 4.6 g, 39 mmol) (each in one portion) via syringe. The resulting suspension was heated at 60 °C for 30 min and then allowed to cool to room temperature and filtered through a plug of silica gel with the aid of diethyl ether. Concentration afforded 5.39 g of brown solid which was purified by column chromatography on 175 g of silica gel (elution with 2% ethyl acetate-hexanes) to provide 3.02 g (85%) of enyne **7** as a white solid: mp 52-53 °C; IR (CH₂Cl₂) 3040, 2970, 2280, 1415, and 1235 cm⁻¹; ¹H NMR (300 MHz, CDCl₃) δ 10.54 (br s, 1H), 7.31 (d, *J* = 7.4 Hz, 1H), 7.08 (d, *J* = 7.4 Hz, 1H), 6.82 (t, *J* = 7.4 Hz, 1H), 5.32 (br s, 1H), 5.27 (app d, *J* = 1.4 Hz, 1H), 4.08 (s, 2H), 3.61 (s, 2H), 1.94 (t, *J* = 1.4 Hz, 3H), and 0.34 (s, 9H); ¹³C NMR (75 MHz, CDCl₃) δ 163.1, 134.4, 130.3, 126.5, 126.3, 122.1, 120.9, 119.0, 86.1, 84.9, 51.4, 37.7, 23.8, and -0.6; HRMS-ESI (*m/z*): [M + H]⁺ calcd for C₁₆H₂₃NOSi, 274.1622; found, 274.1628.

(*E*)-2-Hex-4-en-2-ynylaminomethyl-6-(trimethylsilyl)phenol (S2). Cross-coupling of (*E*)-1-bromopropene (0.50 mL, 0.70 g, 5.8 mmol) and alkyne **6** (0.450 g, 1.93 mmol) with (Ph₃P)₂PdCl₂ (0.081 g, 0.12 mmol), CuI (0.044 g, 0.23 mmol), and piperidine (0.67 mL, 0.58 g, 6.8 mmol) in 3.2 mL of THF was performed according to the general procedure. Concentration afforded 0.770 g of brown solid which was purified by column chromatography on 39 g of silica gel (elution with 2% ethyl acetate-hexanes) to provide 0.392 g (74%) of enyne **S2** as an ivory solid: mp 41-42 °C; IR (CH₂Cl₂) 3304, 3029, 2953, 1600, 1580, 1427, and 1243 cm⁻¹; ¹H NMR (500 MHz, CDCl₃) δ 7.30 (dd, *J* = 7.3, 1.5 Hz, 1H), 7.07 (dd, *J* = 7.3, 1.5 Hz, 1H), 6.81 (t, *J* = 7.3 Hz, 1H), 6.17 (dq, *J* = 15.6, 6.6 Hz, 1H), 5.52 (dq, *J* = 15.6, 1.8 Hz, 1H), 4.06 (s, 2H), 3.58 (s, 2H), 1.81 (dd, *J* = 6.6, 1.8 Hz, 3H), and 0.3 (s, 9H); ¹³C NMR (125 MHz, CDCl₃) δ 163.2, 139.9, 134.6, 130.4, 126.4, 121.0, 119.1, 109.7, 81.56, 81.47, 51.4, 37.8, 18.8, and -0.7; HRMS-ESI (*m/z*): [M + H]⁺ calcd for C₁₆H₂₃NOSi, 274.1622; found, 274.1619.

2-[(3-Cyclohex-1-enylprop-2-ynylamino)methyl]-6-(trimethylsilyl)phenol (S3). Cross-coupling of trifluoromethanesulfonic acid 1-cyclohexenyl ester⁴ (0.169 g, 0.734 mmol) and alkyne **6** (0.114 g, 0.489 mmol) with (Ph₃P)₂PdCl₂ (0.021 g, 0.029 mmol), CuI (0.011 g, 0.059 mmol), and piperidine (0.17 mL, 0.15 g, 1.7 mmol) in 1.2 mL of THF was performed according to the general procedure except that the reaction was run at rt for 1 h. Concentration provided 0.428 g of brown oil which was purified by column chromatography on 21 g of silica gel (elution with 2% diethyl ether-pentane) to give 0.131 g (85%) of enyne **S3** as a white solid: mp 56 °C; IR (CH₂Cl₂) 3303, 3051, 2931, 2219, 1600, 1427, and 1243 cm⁻¹; ¹H NMR (500 MHz, CDCl₃) δ 7.32 (dd, *J* = 7.3, 1.7 Hz, 1H), 7.08 (dd, *J* = 7.3, 1.7 Hz, 1H), 6.82 (app t, *J* = 7.4 Hz, 1H), 6.14 (m, 1H), 4.08 (s, 2H), 3.60 (s, 2H), 2.10-2.20

⁴ Prepared by reaction of cyclohexenone with 2,6-di-*t*-butyl-4-methylpyridine and Tf₂O according to the general procedure described previously: Scott, W. J.; Crisp, G. T.; Stille, J. K., *Org. Synth.*, Coll. Vol. 8, 97. For spectral data and the previous preparation of this triflate, see (a) McMurry, J. E.; Scott, W. J. *Tetrahedron* **1983**, 24, 979. (b) Scheiper, B.; Bonnekeessel, M.; Krause, H.; Fürstner, A. *J. Org. Chem.* **2004**, 69, 3943.

(m, 4H), 1.60-1.75 (m, 4H), and 0.33 (s, 9H); ^{13}C NMR (125 MHz, CDCl_3) δ 163.3, 135.3, 134.5, 130.4, 126.3, 121.1, 120.5, 119.0, 86.7, 83.0, 51.3, 37.7, 29.5, 25.8, 22.5, 21.7, and -0.7; HRMS-ESI (m/z): $[\text{M} + \text{H}]^+$ calcd for $\text{C}_{19}\text{H}_{27}\text{NOSi}$, 314.1935; found, 314.1939.

(*E*)-6-[2-Hydroxy-3-(trimethylsilyl)benzylamino]hex-2-en-4-ynoic acid methyl ester (S4).

Cross-coupling of *E*-2-iodomethylacrylate⁵ (0.515 g, 2.43 mmol) and alkyne **6** (0.300 g, 1.29 mmol) with $(\text{Ph}_3\text{P})_2\text{PdCl}_2$ (0.068 g, 0.097 mmol), CuI (0.037 g, 0.19 mmol), and $(i\text{-Pr})_2\text{NEt}$ (0.99 mL, 0.73 g, 5.7 mmol) in 3.2 mL of THF was performed according to the general procedure except the reaction was run at rt for 4 h. Concentration afforded 0.647 g of brown solid which was purified by column chromatography on 32 g of silica gel (elution with 10% ethyl acetate-hexanes) to provide 0.309 g (75%) of enyne **S4** as an ivory solid: mp 92 °C; IR (CH_2Cl_2) 3309, 2955, 1718, 1428, 1307, and 1230 cm^{-1} ; ^1H NMR (500 MHz, CDCl_3) δ 10.27 (s, 1H), 7.30 (d, $J = 7.3$ Hz, 1H), 7.06 (d, $J = 7.3$ Hz, 1H), 6.82 (t, $J = 7.3$ Hz, 1H), 6.80 (dt, $J = 15.9, 2.2$ Hz, 1H), 6.25 (d, $J = 15.9$ Hz, 1H), 4.07 (s, 2H), 3.79 (s, 3H), 3.67 (d, $J = 2.2$ Hz, 2H), 1.90 (br s, 1H), and 0.3 (s, 9H); ^{13}C NMR (125 MHz, CDCl_3) δ 166.9, 163.1, 135.4, 134.7, 130.5, 127.9, 126.5, 120.6, 119.2, 95.5, 81.8, 52.1, 51.5, 37.8, and -0.8; HRMS-ESI (m/z): $[\text{M} + \text{H}]^+$ calcd for $\text{C}_{17}\text{H}_{23}\text{NO}_3\text{Si}$, 318.1520; found, 318.1510.

2,2-Dimethylpropionic acid 3-iodo-(*E*)-but-2-enyl ester (S5). A 25-mL, one-necked, round-bottomed flask equipped with a rubber septum and an argon inlet needle was protected from light with aluminum foil and charged with 3-tributylstannanyl-(*E*)-but-2-en-1-ol⁶ (0.300 g, 0.831 mmol), iodine (0.232 g, 0.914 mmol), and 17 mL of CH_2Cl_2 . After 45 min, the reaction mixture was treated with 10 mL of satd $\text{Na}_2\text{S}_2\text{O}_3$ solution and the aqueous phase was separated and extracted with three 15-mL portions of

⁵ Prepared by hydroiodination of propiolic acid followed by Fischer esterification with methanol according to the procedure described in: Carpita, A.; Neri, D.; Rossi, R. *Gazz. Chim. Ital.* **1987**, *117*, 481.

⁶ Prepared by stannylcupration of 2-butyne-1-ol in the presence of methanol according to the published procedure: Betzer, J-F.; Delalogue, F.; Muller, B.; Pancrazi, A.; Prunet, J. *J. Org. Chem.* **1997**, *62*, 7768.

CH₂Cl₂. The combined organic phases were washed with 10 mL of satd NaCl solution, dried over Na₂SO₄, filtered, and concentrated at reduced pressure (≥ 20 mmHg due to volatility) to give 0.544 g of colorless oil. Column chromatography on 14 g of silica gel (elution with 10% ethyl acetate-hexanes) afforded 0.142 g (86%) of 3-iodo-(*E*)-but-2-en-1-ol as a yellow oil with spectroscopic properties identical to those previously reported:⁷ ¹H NMR (500 MHz, CDCl₃) δ 6.37 (tq, *J* = 6.9, 1.5 Hz, 1H), 4.06 (app t, *J* = 5.9 Hz, 2H), 2.44 (s, 3H), and 2.39 (t, *J* = 5.2 Hz, 1H); ¹³C NMR (125 MHz, CDCl₃) δ 139.8, 98.6, 59.9, and 28.2.

A 25-mL, one-necked, round-bottomed flask equipped with a rubber septum and an argon inlet needle was charged with 3-iodo-(*E*)-but-2-en-1-ol (0.142 g, 0.717 mmol), DMAP (0.009 g, 0.07 mmol), pyridine (0.170 g, 0.174 mL, 2.15 mmol), and 3.6 mL of CH₂Cl₂, and pivaloyl chloride (0.104 g, 0.106 mmol, 0.860 mmol) was added dropwise via syringe. After 4 h, the reaction mixture was treated with 10 mL of satd NaHCO₃ solution and the resulting aqueous phase was separated and extracted with 20 mL of CH₂Cl₂. The combined organic phases were washed with two 20-mL portions of 1M HCl solution, two 20-mL portions of 10% NaOH solution, 20 mL of satd NaCl solution, dried over MgSO₄, filtered, and concentrated at reduced pressure (≥ 20 mmHg due to volatility) to give 0.194 g (96%) of **S5** as a colorless oil: IR (film) 2974, 1810, 1732, 1480, 1280, and 1148 cm⁻¹; ¹H NMR (500 MHz, CDCl₃) δ 6.28 (app t, *J* = 7.0 Hz, 1H), 4.45 (d, *J* = 7.0 Hz, 2H), 2.46 (app s, 3H), and 1.17 (s, 9H); ¹³C NMR (125 MHz, CDCl₃) δ 178.3, 135.1, 100.5, 61.0, 38.9, 28.4, and 27.3; HRMS-ESI (*m/z*): [M + Na]⁺ calcd for C₉H₁₅IO₂, 305.0009; found, 305.0011.

2,2-Dimethylpropionic acid 6-[2-hydroxy-3-(trimethylsilyl)benzylamino]-3-methylhex-2-en-4-ynyl ester (S6). Cross-coupling of vinyl iodide **S5** (0.484 g, 1.72 mmol) and alkyne **6** (0.401 g, 1.72 mmol) with (Ph₃P)₂PdCl₂ (0.072 g, 0.10 mmol), CuI (0.039 g, 0.21 mmol), and piperidine (0.52 mL, 0.45 g, 5.3 mmol) in 2.5 mL of THF was performed according to the general procedure except that the reaction was run at rt for 2 h. Concentration afforded 0.896 g of brown oil which was purified by column chromatography on 18 g of silica gel (gradient elution with 3-5% ethyl acetate-hexanes) to furnish 0.499 g (75%) of enyne **S6** as a pale yellow oil: IR (film) 3307, 2957, 1729, 1427, and 1150 cm⁻¹; ¹H NMR (500

⁷ Queneau, Y.; Krol, W. J.; Bornmann, W. G.; Danishefsky, S. J. *Bull. Soc. Chim. Fr.* **1993**, 130, 358.

MHz, CDCl₃) δ 10.20-10.60 (br s, 1H), 7.30 (d, J = 7.3 Hz, 1H), 7.07 (d, J = 7.3 Hz, 1H), 6.81 (t, J = 7.3 Hz, 1H), 5.91 (app t, J = 6.9 Hz, 1H), 4.64 (d, J = 6.9 Hz, 2H), 4.06 (s, 2H), 3.60 (s, 2H), 1.89 (app s, 3H), 1.22 (s, 9H), and 0.31 (s, 9H); ¹³C NMR (125 MHz, CDCl₃) δ 178.6, 163.2, 134.6, 131.1, 130.4, 126.4, 122.5, 120.9, 119.1, 86.7, 84.7, 60.7, 51.4, 39.0, 37.6, 27.4, 18.1, and -0.7; HRMS-ESI (m/z): [M + H]⁺ calcd for C₂₂H₃₃NO₃Si, 388.2302; found, 388.2304.

2-[[4-(*tert*-Butyldimethylsilyloxymethyl)pent-4-en-2-ynylamino]methyl]-6-(trimethylsilyl)phenol (S7). Cross-coupling of 2-iodo-3-(*tert*-butyldimethylsilyloxy)-1-propene⁸ (0.220 g, 0.738 mmol) and alkyne **6** (0.150 g, 0.643 mmol) with (Ph₃P)₂PdCl₂ (0.027 g, 0.039 mmol), CuI (0.015 g, 0.077 mmol), and piperidine (0.22 mL, 0.19 g, 2.3 mmol) in 1.3 mL of THF was performed according to the general procedure except that the reaction was run at rt for 1 h. Concentration afforded 0.349 g of orange solid which was purified by column chromatography on 14 g of silica gel (elution with 3% ethyl acetate-hexanes) to provide 0.208 g (80%) of enyne **S7** as a pale yellow oil: IR (CH₂Cl₂) 3305, 2955, 1428, 1244, and 1121 cm⁻¹; ¹H NMR (500 MHz, CDCl₃) δ 10.49 (s, 1H), 7.30 (d, J = 7.3 Hz, 1H), 7.06 (d, J = 7.3 Hz, 1H), 6.81, (t, J = 7.3 Hz, 1H), 5.61 (app s, 1H), 5.47 (app s, 1H), 4.15 (app s, 2H), 4.06 (s, 2H), 3.60 (s, 2H), 1.85 (br s, 1H), 0.94 (s, 9H), 0.30 (s, 9H), and 0.11 (s, 6H); ¹³C NMR (125 MHz, CDCl₃) δ 163.2, 134.6, 130.7, 130.4, 126.4, 120.9, 120.0, 199.1, 86.9, 83.0, 65.3, 51.5, 37.6, 26.1, 18.6, -0.7, and -5.1; HRMS-ESI (m/z): [M + H]⁺ calcd for C₂₂H₃₇NO₂Si₂, 404.2436; found, 404.2422.

2-[(3-Phenylprop-2-ynylamino)methyl]-6-(trimethylsilyl)phenol (S8). Cross-coupling of iodobenzene (0.86 mL, 1.6 g, 7.7 mmol) and alkyne **6** (0.600 g, 2.57 mmol) with (Ph₃P)₂PdCl₂ (0.108 g, 0.154 mmol), CuI (0.059 g, 0.31 mmol), and piperidine (0.89 mL, 0.77 g, 9.0 mmol) in 2.5 mL of THF

⁸ Prepared by silylation of the corresponding alcohol as described by Lai, M.; Li, D.; Oh, E.; Liu, H. *J. Am. Chem. Soc.* **1993**, *115*, 1619. The alcohol was prepared by hydroiodination of propargyl alcohol with NaI, H₂O, and TMSCl as reported in Irifune, S.; Kibayashi, T.; Ishii, Y.; Ogawa, M. *Synthesis* **1988**, 366.

was performed according to the general procedure except that the reaction was run at rt for 1.5 h. Concentration gave 1.90 g of black oil which was purified by column chromatography on 95 g of silica gel (elution with 5% ethyl acetate-hexanes) to provide 0.688 g (86%) of enyne **S8** as a white solid: mp 90-92 °C; IR (CH₂Cl₂) 3310, 2960, 1595, and 1426 cm⁻¹; ¹H NMR (500 MHz, CDCl₃) δ 7.47-7.50 (m, 2H), 7.34-7.39 (m, 4H), 7.12 (d, *J* = 7.3 Hz, 1H), 6.85 (t, *J* = 7.3 Hz, 1H), 4.16 (s, 2H), 3.72 (s, 2H), and 0.36 (s, 9H); ¹³C NMR (125 MHz, CDCl₃) δ 163.7, 135.2, 132.8, 130.5, 127.8, 127.7, 126.9, 123.4, 121.4, 119.7, 90.5, 78.7, 52.0, 38.4, and -0.2; HRMS-ESI (*m/z*): [M + H]⁺ calcd for C₁₉H₂₃NOSi, 310.1622; found, 310.1624; Anal. Calcd for C₁₉H₂₃NOSi: C, 73.74; H, 7.49; N, 4.53; found: C, 73.77; H, 7.45; N, 4.40.

2-{3-[2-Hydroxy-3-(trimethylsilyl)benzylamino]prop-1-ynyl}pyrrole-1-carboxylic acid *tert*-butyl ester (S9**).** Cross-coupling of 2-iodopyrrole-1-carboxylic acid *t*-butyl ester⁹ (1.13 g, 3.86 mmol) and alkyne **6** (0.600 g, 2.57 mmol) with (Ph₃P)₂PdCl₂ (0.108 g, 0.154 mmol), CuI (0.059 g, 0.31 mmol), and piperidine (0.89 mL, 0.77 g, 9.0 mmol) in 4.3 mL of THF was performed according to the general procedure except that the reaction was run at rt for 4 h. Concentration furnished 1.56 g of black oil which was purified by column chromatography on 30 g of silica gel (elution with 3% ethyl acetate-hexanes) to give 0.635 g (62%) of enyne **S9** as a pale yellow oil: IR (film) 3308, 3154, 3052, 2229, and 1746 cm⁻¹; ¹H NMR (500 MHz, CDCl₃) δ 7.31 (dd, *J* = 7.2, 1.7 Hz, 1H), 7.28 (dd, *J* = 3.3, 1.7 Hz, 1H), 7.11 (dd, *J* = 7.4, 1.6 Hz, 1H), 6.82 (t, *J* = 7.3 Hz, 1H), 6.55 (dd, *J* = 1.7, 3.5 Hz, 1H), 6.18 (t, *J* = 3.4 Hz, 1H), 4.16 (s, 2H), 3.74 (s, 2H), 1.63 (s, 9H), and 0.32 (s, 9H); ¹³C NMR (125 MHz, CDCl₃) δ 163.3, 148.4, 134.5, 130.5, 126.3, 125.4, 122.6, 121.1, 119.1, 115.0, 111.1, 89.7, 84.4, 51.4, 38.1, 28.2, and -0.7; HRMS-ESI (*m/z*): [M + H]⁺ calcd for C₂₂H₃₀N₂O₃Si, 399.2098; found, 399.2073.

⁹ Prepared by radical bromination of pyrrole and conversion to the *N*-Boc derivative using Boc₂O followed by metal-halogen exchange with *n*-BuLi and trapping with I₂ as described previously: (a) Chen, W.; Cava, M. P. *Tetrahedron Lett.* **1987**, 28, 6025. (b) Chen, W.; Stephenson, E. K.; Cava, M. P.; Jackson, Y. A. *Org. Synth. Coll. Vol.* 9, 121.

2-[(3-Thiophen-2-ylprop-2-ynylamino)methyl]-6-(trimethylsilyl)phenol (S10). Cross-coupling of 2-iodothiophene (0.85 mL, 1.6 g, 7.7 mmol) and alkyne **6** (0.600 g, 2.57 mmol) with $(\text{Ph}_3\text{P})_2\text{PdCl}_2$ (0.108 g, 0.154 mmol), CuI (0.059 g, 0.31 mmol), and piperidine (0.89 mL, 0.77 g, 9.0 mmol) in 4.2 mL of THF was performed according to the general procedure. Concentration afforded 2.24 g of brown oil which was purified by column chromatography on 112 g of silica gel (gradient elution with 3-5% ethyl acetate-hexanes) to provide 0.727 g (89%) of enyne **S10** as a tan solid: mp 83-85 °C; IR (CH_2Cl_2) 3306, 2952, 1598, and 1426 cm^{-1} ; ^1H NMR (500 MHz, CDCl_3) δ 7.35 (dd, $J = 7.2, 1.7$ Hz, 1H), 7.28 (dd, $J = 5.2, 1.2$ Hz, 1H), 7.25 (dd, $J = 3.5, 1.2$ Hz, 1H), 7.12 (dd, $J = 7.3, 1.5$ Hz, 1H), 7.02 (dd, $J = 5.2, 3.7$ Hz, 1H), 6.85 (t, $J = 7.3$ Hz, 1H), 4.13 (s, 2H), 3.73 (s, 2H), and 0.36 (s, 9H); ^{13}C NMR (125 MHz, CDCl_3) δ 163.8, 135.1, 132.4, 131.0, 127.8, 127.7, 126.9, 123.5, 121.5, 119.6, 86.4, 85.4, 52.0, 38.3, and -0.2; HRMS-ESI (m/z): $[\text{M} + \text{H}]^+$ calcd for $\text{C}_{17}\text{H}_{21}\text{NOSSi}$, 316.1186; found, 316.1193; Anal. Calcd for $\text{C}_{17}\text{H}_{21}\text{NOSSi}$: C, 64.72; H, 6.71; N, 4.44; found: C, 64.79; H, 6.56; N, 4.32.

2-[(3-Thiophen-3-ylprop-2-ynylamino)methyl]-6-(trimethylsilyl)phenol (S11). Cross-coupling of 3-bromothiophene (1.09 mL, 1.90 g, 11.6 mmol) and alkyne **6** (0.900 g, 3.86 mmol) with $(\text{Ph}_3\text{P})_2\text{PdCl}_2$ (0.163 g, 0.232 mmol) and CuI (0.088 g, 0.46 mmol) in 7.7 mL of piperidine was performed according to the general procedure except that the reaction mixture was heated at 80 °C for 1.5 h. Concentration afforded 2.24 g of brown oil which was purified by column chromatography on 90 g of silica gel (elution with 5% ethyl acetate-hexanes) to provide 0.746 g (61%) of **S11** as a tan solid: mp 77-78 °C; IR (CH_2Cl_2) 3304, 3108, 3052, 2953, and 1427 cm^{-1} ; ^1H NMR (500 MHz, CDCl_3) δ 10.45 (br s, 1H), 7.45 (s, 1H), 7.27-7.32 (m, 2H), 7.12 (d, $J = 4.0$, 1H), 7.09 (d, $J = 8.0$ Hz, 1H), 6.82 (t, $J = 7.3$ Hz, 1H), 4.12 (s, 2H), 3.68 (s, 2H), and 0.31 (s, 9H); ^{13}C NMR (75 MHz, CDCl_3) δ 163.2, 134.6, 130.4, 130.1, 129.0, 126.4, 125.6, 121.9, 121.0, 119.1, 85.5, 80.0, 51.5, 37.8, and -0.7; HRMS-ESI (m/z): $[\text{M} + \text{H}]^+$ calcd for $\text{C}_{17}\text{H}_{21}\text{NOSSi}$, 316.1186; found, 316.1179.

General Procedure for Bis-Sulfonation. Trifluoromethanesulfonic acid 2-[(4-methylpent-4-en-2-ynyl)trifluoromethanesulfonylamino]methyl-6-(trimethylsilyl)phenyl ester (**8**). A 100-mL, one-necked, round-bottomed flask equipped with a rubber septum and argon inlet needle was charged with amine **7** (3.02 g, 11.0 mmol), (*i*-Pr)₂NEt (11.5 mL, 8.53 g, 66.0 mmol), and 65 mL of CH₂Cl₂ and cooled at -78 °C while Tf₂O (7.40 mL, 12.4 g, 44.0 mmol) was added rapidly via syringe. After 1 h, the reaction mixture was treated with 50 mL of satd NaCl solution and allowed to warm to rt. The aqueous phase was separated and extracted with two 100-mL portions of CH₂Cl₂, and the combined organic phases were washed with 50 mL of satd NaCl solution, dried over MgSO₄, filtered, and concentrated to give 24.1 g of brown solid. Column chromatography on 241 g of silica gel (gradient elution with 2-5% ethyl acetate-hexanes) provided 4.84 g (82%) of sulfonamide **8** as an ivory solid: mp 63 °C; IR (CH₂Cl₂) 3183, 2960, 2403, 1401, 1379 and 1220 cm⁻¹; ¹H NMR (300 MHz, CDCl₃) δ 7.52-7.62 (m, 2H), 7.47 (app t, *J* = 7.4 Hz, 1H), 5.29 (app s, 2H), 4.83 (br s, 2H), 4.00-4.30 (br s, 2H), 1.84 (t, *J* = 1.4 Hz, 3H), 0.40 (s, 9H); ¹³C NMR (125 MHz, CDCl₃) δ 149.2, 137.2, 136.2, 130.7, 129.0, 128.2, 125.5, 123.6, 120.1 (q, *J*_{CF} = 321 Hz), 118.7 (q, *J*_{CF} = 317 Hz) 88.3, 78.8, 45.7, 38.6, 23.1, and 0.4; HRMS-ESI (*m/z*): [M + Na]⁺ calcd for C₁₈H₂₁F₆NO₅S₂Si, 560.0427; found, 560.0431; Anal. Calcd for C₁₈H₂₁F₆NO₅S₂Si: C, 40.22; H, 3.94; N, 2.61; found: C, 40.31; H, 3.91; N, 2.60.

(E)-Trifluoromethanesulfonic acid 2-[(hex-4-en-2-ynyl-trifluoromethanesulfonylamino) methyl]-6-(trimethylsilyl)phenyl ester (10**).** Bis-sulfonation of amine **S2** (0.175 g, 0.640 mmol) with (*i*-Pr)₂NEt (0.67 mL, 0.50 g, 3.8 mmol) and Tf₂O (0.43 mL, 0.72 g, 2.6 mmol) in 3.8 mL of CH₂Cl₂ was performed according to the general procedure. Concentration gave 1.22 g of brown solid which was purified by column chromatography on 60 g of silica gel (gradient elution with 2-3% ethyl acetate-hexanes) to furnish 0.256 g (74%) of sulfonamide **10** as an ivory solid: mp 50-51 °C; IR (CH₂Cl₂) 3036, 2958, 2224, 1397, 1226, and 1140 cm⁻¹; ¹H NMR (500 MHz, CDCl₃) δ 7.56-7.61 (m, 2H), 7.47 (t, *J* = 7.4

Hz, 1H), 6.16 (dq, $J = 15.7, 6.9$ Hz, 1H), 5.44 (dq, $J = 15.7, 1.8$ Hz, 1H), 4.82 (s, 2H), 3.90-4.30 (br s, 2H), 1.80 (dd, $J = 6.9, 1.7$ Hz, 3H), 0.40 (s, 9H); ^{13}C NMR (125 MHz, CDCl_3) δ 149.3, 142.1, 137.4, 136.3, 130.9, 129.0, 128.3, 109.4, 120.1 (q, $J_{\text{CF}} = 321$ Hz), 118.7 (q, $J_{\text{CF}} = 317$ Hz), 84.2, 83.9, 45.5, 38.6, 18.9, and 0.3; HRMS-ESI (m/z): $[\text{M} + \text{H}]^+$ calcd for $\text{C}_{18}\text{H}_{21}\text{F}_6\text{NO}_5\text{S}_2\text{Si}$, 560.0427; found, 560.0429.

Trifluoromethanesulfonic acid 2-[[3-(cyclohex-1-enylprop-2-ynyl)trifluoromethane sulfonyl amino]methyl]-6-(trimethylsilyl)phenyl ester (11). Bis-sulfonation of amine **S3** (0.106 g, 0.338 mmol) with $(i\text{-Pr})_2\text{NEt}$ (0.35 mL, 0.26 g, 2.0 mmol) and Tf_2O (0.23 mL, 0.39 g, 1.4 mmol) in 2.3 mL of CH_2Cl_2 was performed according to the general procedure. Concentration afforded 0.680 g of brown solid which was purified by column chromatography on 20 g of silica gel (elution with 2% ethyl acetate-hexanes) to provide 0.166 g (85%) of sulfonamide **11** as a tan solid: mp 70-72 °C; IR (CH_2Cl_2) 2918, 2230, 1397, 1225, and 1140 cm^{-1} ; ^1H NMR (500 MHz, CDCl_3) δ 7.59 (d, $J = 6.5$ Hz, 1H), 7.57 (d, $J = 6.5$ Hz, 1H), 7.47 (t, $J = 7.5$ Hz, 1H), 6.09 (m, 1H), 4.83 (br s, 2H), 3.80-4.60 (br s, 2H), 2.10 (m, 2H), 2.04 (m, 2H), 1.56-1.65 (m, 4H), and 0.40 (s, 9H); ^{13}C NMR (125 MHz, CDCl_3)^{10,11} δ 149.3, 137.2, 136.8, 136.2, 130.8, 129.0, 128.3, 120.1 (q, $J = 321$ Hz), 119.6, 89.2, 45.5, 38.7, 28.8, 25.8, 22.3, 21.5, and 0.3; HRMS-ESI (m/z): $[\text{M} + \text{Na}]^+$ calcd for $\text{C}_{21}\text{H}_{25}\text{F}_6\text{NO}_5\text{S}_2\text{Si}$, 600.0740; found, 600.0734.

(E)-6-{Trifluoromethanesulfonyl-[2-trifluoromethanesulfonyloxy-3-(trimethylsilyl)benzyl] amino} hex-2-en-4-ynoic acid methyl ester (12). Bis-sulfonation of amine **S4** (0.250 g, 0.788 mmol) with $(i\text{-Pr})_2\text{NEt}$ (0.82 mL, 0.61 g, 4.7 mmol) and Tf_2O (0.53 mL, 0.89 g, 3.2 mmol) in 4.6 mL of CH_2Cl_2 was performed according to the general procedure. Concentration provided 1.60 g of brown solid which was purified by column chromatography on 80 g of silica gel (gradient elution with 10% ethyl acetate-

¹⁰ In some compounds, one or both of the weak CF_3 carbon resonances could not be distinguished from background.

¹¹ One of the alkyne carbon resonances overlaps with the CDCl_3 carbon.

hexanes) to give 0.402 g (88%) of sulfonamide **12** as pale yellow solid: mp 59-61 °C; IR (film) 2957, 1728, 1624, 1398, 1228, and 1139 cm⁻¹; ¹H NMR (500 MHz, CDCl₃) δ 7.60 (d, *J* = 7.3 Hz, 2H), 7.49 (t, *J* = 7.3 Hz, 1H), 6.69 (dt, *J* = 15.9, 2.0 Hz, 1H), 6.20 (d, *J* = 15.9 Hz, 1H), 4.78-4.84 (br s, 2H), 4.00-4.50 (br s, 2H), 3.79 (s, 3H), 0.40 (s, 9H); ¹³C NMR (125 MHz, CDCl₃)¹⁰ δ 165.9, 149.2, 137.6, 136.4, 132.0, 131.0, 129.2, 128.0, 123.5, 88.8, 83.5, 52.3, 46.0, 38.5, and 0.2; HRMS-ESI (*m/z*): [M + Na]⁺ calcd for C₁₉H₂₁F₆NO₇S₂Si, 604.0325; found, 604.0324.

2,2-Dimethylpropionic acid 3-methyl-6-{trifluoromethanesulfonyl-[2-trifluoromethanesulfonyloxy-3-(trimethylsilyl)benzyl]amino}-(*E*)-hex-2-en-4-ynyl ester (13). Bis-sulfonation of amine **S6** (0.468 g, 1.21 mmol) with (*i*-Pr)₂NEt (1.26 mL, 0.935 g, 7.26 mmol) and Tf₂O (0.81 mL, 1.4 g, 4.8 mmol) in 7 mL of CH₂Cl₂ was performed according to the general procedure. Concentration provided 2.51 g of brown solid which was purified by column chromatography on 100 g of silica gel (elution with 5% ethyl acetate-hexanes) to furnish 0.704 g (89%) of sulfonamide **13** as a pale yellow solid: mp 59-60 °C; IR (film) 2974, 2227, 1732, 1398, 1226, and 1141 cm⁻¹; ¹H NMR (500 MHz, CDCl₃) δ 7.58 (d, *J* = 7.8 Hz, 2H), 7.48 (t, *J* = 7.8 Hz, 1H), 5.89 (app t, *J* = 6.8 Hz, 1H), 4.82 (br s, 2H), 4.63 (d, *J* = 6.8 Hz, 2H), 4.00-4.40 (br s, 2H), 1.82 (app s, 3H), 1.21 (s, 9H), and 0.40 (s, 9H); ¹³C NMR (125 MHz, CDCl₃)¹⁰ δ 178.5, 149.3, 137.4, 136.3, 132.7, 130.8, 129.1, 128.2, 121.4, 88.8, 78.6, 60.5, 45.6, 39.0, 38.4, 27.3, 17.5, and 0.3; HRMS-ESI (*m/z*): [M + Na]⁺ calcd for C₂₄H₃₁F₆NO₇S₂Si, 674.1108; found, 674.1113.

Trifluoromethanesulfonic acid 2-({[4-(*tert*-butyldimethylsilyloxymethyl)pent-4-en-2-ynyl]-trifluoromethanesulfonylamino}methyl)-6-(trimethylsilyl)phenyl ester (14). Bis-sulfonation of amine **S7** (0.201 g, 0.498 mmol) with (*i*-Pr)₂NEt (0.52 mL, 0.39 g, 3.0 mmol) and Tf₂O (0.335 mL, 0.562 g, 1.99 mmol) in 2.5 mL of CH₂Cl₂ was performed according to the general procedure. Concentration provided 0.531 g of brown solid which was purified by column chromatography on 10 g of silica gel (gradient

elution with 1% ethyl acetate-hexanes) to give 0.272 g (82%) of sulfonamide **14** as an ivory solid: mp 71 °C; IR (CH₂Cl₂) 2957, 1398, 1226, and 1140 cm⁻¹; ¹H NMR (500 MHz, CDCl₃) δ 7.59 (d, *J* = 7.6 Hz, 2H), 7.48 (d, *J* = 7.5 Hz, 1H), 5.67 (app s, 1H), 5.46 (app s, 1H), 4.83 (br s, 2H), 4.07 (app s, 2H), 0.9 (s, 9H), 0.4 (s, 9H), and 0.1 (s, 6H); ¹³C NMR (125 MHz, CDCl₃)¹⁰ δ 149.3, 137.4, 136.3, 130.8, 129.7, 129.1, 128.2, 121.3, 85.2, 80.8, 64.5, 45.7, 38.5, 26.0, 18.6, 0.3, and -5.3; HRMS-ESI (*m/z*): [M + Na]⁺ calcd for C₂₄H₃₅F₆NO₆S₂Si₂, 690.1241; found, 690.1269.

Trifluoromethanesulfonic acid 2-[(3-phenylprop-2-ynyl)trifluoromethanesulfonylamino]methyl}-6-(trimethylsilyl)phenyl ester (20). Bis-sulfonation of amine **S8** (0.309 g, 1.00 mmol) with (*i*-Pr)₂NEt (1.05 mL, 0.779 g, 6.00 mmol) and Tf₂O (0.67 mL, 1.1 g, 4.0 mmol) in 5.9 mL of CH₂Cl₂ was performed according to the general procedure. Concentration gave 1.86 g of brown solid which was purified by column chromatography on 93 g of silica gel (elution with 5% ethyl acetate-hexanes) to provide 0.523 g (91%) of sulfonamide **20** as an ivory solid: mp 68-70 °C; IR (CH₂Cl₂) 2963, 2254, 2227, 1598, 1400, and 1222 cm⁻¹; ¹H NMR (500 MHz, CDCl₃) δ 7.65 (dd, *J* = 7.6, 1.2 Hz, 1H), 7.60 (dd, *J* = 7.5, 1.7 Hz, 1H), 7.50 (t, *J* = 7.5 Hz, 1H), 7.32-7.40 (m, 5H), 4.91 (s, 2H), 4.00-4.60 (br s, 2H), and 0.40 (s, 9H); ¹³C NMR (125 MHz, CDCl₃) δ 149.3, 137.4, 136.3, 131.9, 130.9, 129.3, 129.1, 128.6, 128.3, 121.5, 120.2 (q, *J*_{CF} = 322 Hz), 118.7 (q, *J*_{CF} = 318 Hz), 87.2, 78.8, 45.8, 38.7, and 0.2; HRMS-ESI (*m/z*): [M + Na]⁺ calcd for C₂₁H₂₁F₆NO₅S₂Si, 596.0427; found, 596.0435; Anal. Calcd for C₂₁H₂₁F₆NO₅S₂Si: C, 43.97; H, 3.69; found: C, 44.22; H, 3.78.

2-{3-[Trifluoromethanesulfonyl(2-trifluoromethanesulfonyloxy-3-trimethylsilylbenzyl)amino]prop-1-ynyl}pyrrole-1-carboxylic acid tert-butyl ester (21). Bis-sulfonation of amine **S9** (0.602 g, 1.51 mmol) with (*i*-Pr)₂NEt (0.79 mL, 0.59 g, 4.53 mmol) and Tf₂O (0.51 mL, 0.86 g, 3.0

mmol) in 9.0 mL of CH₂Cl₂ was performed according to the general procedure. Concentration afforded 1.65 g of brown solid which was purified by column chromatography on 80 g of silica gel (elution with 5% ethyl acetate-hexanes) to furnish 0.758 g (83%) of sulfonamide **21** as a tan solid: mp 112 °C; IR (CH₂Cl₂) 3159, 3062, 2983, 2239, 1751, 1397, 1319, 1226, and 1139 cm⁻¹; ¹H NMR (500 MHz, CDCl₃) δ 7.65 (dd, *J* = 7.6, 1.8 Hz, 1H), 7.57 (dd, *J* = 7.4, 1.8 Hz, 1H), 7.47 (t, *J* = 7.5 Hz, 1H), 7.26 (dd, *J* = 3.4, 1.7 Hz, 1H), 6.49 (dd, *J* = 3.4, 1.7 Hz, 1H), 6.16 (t, *J* = 3.4 Hz, 1H), 4.90 (s, 2H), 4.00-4.60 (br s, 2H), 1.57 (s, 9H), and 0.39 (s, 9H); ¹³C NMR (125 MHz, CDCl₃) δ 149.3, 148.1, 137.3, 136.3, 130.9, 129.0, 128.4, 123.2, 122.1, 120.2 (q, *J*_{CF} = 321 Hz), 118.7 (q, *J*_{CF} = 318 Hz), 113.8, 111.2, 84.6, 83.8, 79.6, 45.9, 39.2, 28.0, and 0.3; HRMS-ESI (*m/z*): [M + Na]⁺ calcd for C₂₄H₂₈F₆N₂O₇S₂Si, 685.0904; found, 685.0883.

Trifluoromethanesulfonic acid 2-[[3-(3-thiophen-2-ylprop-2-ynyl)trifluoromethanesulfonyl amino]methyl]-6-(trimethylsilyl)phenyl ester (22). Bis-sulfonation of amine **S10** (0.293 g, 0.983 mmol) with (*i*-Pr)₂NEt (1.03 mL, 0.764 g, 5.90 mmol) and Tf₂O (0.66 mL, 1.1 g, 3.9 mmol) in 5.8 mL of CH₂Cl₂ was performed according to the general procedure. Concentration afforded 1.51 g of brown solid which was purified by column chromatography on 76 g of silica gel (elution with 5% ethyl acetate-hexanes) to provide 0.475 g (83%) of sulfonamide **22** as an ivory solid: mp 75-77 °C; IR (CH₂Cl₂) 2965, 2232, 1598, and 1400 cm⁻¹; ¹H NMR (500 MHz, CDCl₃) δ 7.64 (dd, *J* = 7.5, 1.8 Hz, 1H), 7.60 (dd, *J* = 7.3, 1.8 Hz, 1H), 7.49 (t, *J* = 7.5 Hz, 1H), 7.31 (dd, *J* = 5.2, 1.2 Hz, 1H), 7.20 (dd, *J* = 3.7, 1.0 Hz, 1H), 7.00 (dd, *J* = 5.0, 3.5 Hz, 1H), 4.88 (s, 2H), 4.00-4.30 (br s, 2H), and 0.41 (s, 9H); ¹³C NMR (125 MHz, CDCl₃) δ 149.8, 138.0, 136.9, 133.8, 131.4, 129.6, 128.9, 128.7, 127.7, 121.6, 120.2 (q, *J*_{CF} = 322 Hz), 118.7 (q, *J*_{CF} = 318 Hz), 84.3, 81.1, 46.5, 39.3, and 0.8; HRMS-ESI (*m/z*): [M + Na]⁺ calcd for C₁₉H₁₉F₆NO₅S₃Si, 601.9991; found, 601.9975; Anal. Calcd for C₁₉H₁₉F₆NO₅S₃Si: C, 39.37; H, 3.30; N, 2.42; found: C, 39.49; H, 3.17; N, 2.50.

Trifluoromethanesulfonic acid 2-[[3-(thiophen-3-yl)prop-2-ynyl]trifluoromethanesulfonyl amino]methyl}-6-(trimethylsilyl)phenyl ester (23). Bis-sulfonation of amine **S11** (0.697 g, 2.21 mmol) with (*i*-Pr)₂NEt (1.15 mL, 0.853 g, 6.63 mmol) and Tf₂O (0.740 mL, 1.24 g, 4.42 mmol) in 13 mL of CH₂Cl₂ was performed according to the general procedure. Concentration gave 2.33 g of tan solid which was purified by column chromatography on 120 g of silica gel (elution with 5% ethyl acetate-hexanes) to furnish 1.09 g (85%) of sulfonamide **23** as an ivory solid: mp 110-111 °C; IR (CH₂Cl₂) 3116, 2958, 2229, 1396, 1226, and 1139 cm⁻¹; ¹H NMR (500 MHz, CDCl₃) δ 7.64 (d, *J* = 7.3 Hz, 1H), 7.60 (d, *J* = 7.2 Hz, 1H), 7.49 (t, *J* = 7.4 Hz, 1H), 7.43 (s, 1H), 7.27-7.30 (m, 1H), 7.04 (d, *J* = 4.7 Hz, 1H), 4.88 (s, 2H), 3.90-4.60 (br s, 2H), 0.40 (s, 9H); ¹³C NMR (125 MHz, CDCl₃) δ 149.3, 137.4, 136.3, 131.0, 130.1, 129.8, 129.1, 128.3, 125.8, 120.7, 120.2 (q, *J*_{CF} = 321 Hz), 118.7 (q, *J*_{CF} = 318 Hz), 82.4, 79.6, 45.8, 38.7, and 0.2; HRMS-ESI (*m/z*): [M + Na]⁺ calcd for C₁₉H₁₉F₆NO₅S₃Si, 601.9991; found, 601.9986; Anal. Calcd for C₁₉H₁₉F₆NO₅S₃Si: C, 39.37; H, 3.30; N, 2.42; found: C, 39.58; H, 3.30; N, 2.40.

Part III. Experimental Procedures for Enyne and Arenyne Cycloadditions

General Procedure for Aryne Cycloadditions. 5-Methyl-2-trifluoromethanesulfonyl-2,3-dihydro-1H-benzo[de]isoquinoline (9). A 250-mL, two-necked, round-bottomed flask equipped with a rubber septum and argon inlet adapter was charged with enyne **8** (0.300 g, 0.558 mmol) and 60 mL of THF. A solution of *n*-Bu₄NPh₃SiF₂ (0.605 g, 1.12 mmol) and BHT (0.184 g, 0.837 mmol) in 40 mL of THF was added rapidly via cannula over 1 min. After 6 h, the reaction mixture was concentrated to provide 1.01 g of pale yellow solid. Column chromatography on 40 g of silica gel (elution with 1% *t*-BuOMe-hexanes) afforded 0.131 g (74%) of **9** as a white solid: mp 123-124 °C; IR (CH₂Cl₂) 3056, 2986,

1604, and 1151 cm^{-1} ; ^1H NMR (500 MHz, CDCl_3) δ 7.72 (d, $J = 8.3$ Hz, 1H), 7.58 (s, 1H), 7.45 (dd, $J = 8.3$, 7.0 Hz, 1H), 7.22 (d, $J = 7.0$ Hz, 1H), 7.15 (s, 1H), 4.97 (app s, 4H), and 2.52 (s, 3H); ^{13}C NMR (125 MHz, CDCl_3) δ 136.0, 133.9, 128.74, 128.67, 127.2, 126.8, 126.2, 125.3, 124.7, 121.6, 120.1 (q, $J_{\text{CF}} = 322$ Hz), 49.55, 49.50, and 21.9; LRMS m/z (M^+) 315; Anal. Calcd for $\text{C}_{14}\text{H}_{12}\text{F}_3\text{NO}_2\text{S}$: C, 53.33; H, 3.84; N, 4.44; found: C, 53.36; H, 3.77; N, 4.41.

6-Methyl-2-trifluoromethanesulfonyl-2,3-dihydro-1H-benzo[de]isoquinoline (15).

Cycloaddition of enyne **10** (0.099 g, 0.184 mmol) in 17 mL of THF with a solution of $n\text{-Bu}_4\text{NPh}_3\text{SiF}_2$ (0.199 g, 0.368 mmol) and BHT (0.061 g, 0.276 mmol) in 20 mL of THF was performed according to the general procedure. Concentration afforded 0.352 g of tan solid which was purified by column chromatography on 35 g of silica gel (elution with 1% methyl *tert*-butyl ether-hexanes) to give 0.029 g of white solid. Further purification by preparative thin layer chromatography (elution with 20% ethyl acetate-hexanes) gave 0.012 g (21%) of **15** as an ivory solid: mp 83 $^\circ\text{C}$; IR (CH_2Cl_2) 2918, 1390, 1229, 1189, and 1147 cm^{-1} ; ^1H NMR (500 MHz, CDCl_3) δ 7.96 (d, $J = 8.5$ Hz, 1H), 7.52 (dd, $J = 8.5$, 7.0 Hz, 1H), 7.32 (m, 2H), 7.20 (d, $J = 7.0$ Hz, 1H), 4.98 (app d, 4H), and 2.70 (s, 3H); ^{13}C NMR (125 MHz, CDCl_3) δ 134.6, 132.8, 129.3, 127.0, 126.8, 126.6, 125.8, 124.3, 122.4, 122.3, 120.1 (q, $J_{\text{CF}} = 321$ Hz), 49.63, 49.56, and 19.7; HRMS-ESI (m/z): $[\text{M} + \text{Na}]^+$ calcd for $\text{C}_{14}\text{H}_{12}\text{F}_3\text{NO}_2\text{S}$, 338.0433; found, 338.0434.

5-Trifluoromethanesulfonyl-5,6,8,9,10,11-hexahydro-4H-5-aza-benzo[de]anthracene (16).

Cycloaddition of enyne **11** (0.152 g, 0.263 mmol) in 35 mL of THF with a solution of $n\text{-Bu}_4\text{NPh}_3\text{SiF}_2$ (0.605 g, 1.12 mmol) and BHT (0.087 g, 0.394 mmol) in 18 mL of THF was performed according to the general procedure. Concentration afforded 0.563 g of tan solid which was purified by column chromatography on 20 g of silica gel (elution with 1% methyl *tert*-butyl ether-hexanes) to give 0.062 g

(66%) of **16** as a white solid: mp 135-136 °C; IR (CH₂Cl₂) 2931, 1391, 1227, and 1150 cm⁻¹; ¹H NMR (500 MHz, CDCl₃) δ 7.92 (d, *J* = 8.6 Hz, 1H), 7.49 (t, *J* = 7.8 Hz, 1H), 7.24 (d, *J* = 7.0 Hz, 1H), 7.03 (s, 1H), 4.97 (app s, 2H), 4.92 (app s, 2H), 3.10 (t, *J* = 6.2 Hz, 2H), 2.90 (t, *J* = 6.2 Hz, 2H), and 1.86-2.01 (m, 4H); ¹³C NMR (125 MHz, CDCl₃) δ 134.7, 132.8, 131.9, 129.1, 126.0, 125.9, 125.5, 124.9, 122.9, 121.5, 120.1 (q, *J*_{CF} = 321.0 Hz), 49.6, 49.4, 30.5, 25.9, 23.2, and 22.9; HRMS-EI (*m/z*): [M]⁺ calcd for C₁₇H₁₆F₃NO₂S, 355.0848; found, 355.0860.

2-Trifluoromethanesulfonyl-2,3-dihydro-1H-benzo[de]isoquinoline-6-carboxylic acid methyl ester (17). Cycloaddition of enyne **12** (0.300 g, 0.516 mmol) in 53 mL of THF with a solution of *n*-Bu₄NPh₃SiF₂ (0.556 g, 1.03 mmol) and BHT (0.171 g, 0.774 mmol) in 50 mL of THF was performed according to the general procedure. Concentration afforded 0.970 g of tan solid which was purified by column chromatography on 35 g of silica gel (elution with 20% ethyl acetate-hexanes) to give 0.044 g (24%) of **17** as a pale yellow solid: mp 28 °C; IR (CH₂Cl₂) 2956, 1718, 1392, 1229, and 1150 cm⁻¹; ¹H NMR (500 MHz, CDCl₃) δ 8.93 (d, *J* = 8.7 Hz, 1H), 8.20 (app d, *J* = 7.5 Hz, 1H), 7.63 (app t, *J* = 7.5 Hz, 1H), 7.37 (d, *J* = 7.0 Hz, 1H), 7.35 (d, *J* = 7.5 Hz, 1H), 5.02 (s, 4H), and 4.02 (s, 3H); ¹³C NMR (125 MHz, CDCl₃)¹⁰ δ 167.6, 133.9, 131.8, 130.3, 129.0, 127.9, 127.4, 127.1, 126.1, 123.3, 121.6, 52.6, 49.6, and 49.5; HRMS-ESI (*m/z*): [M + Na]⁺ calcd for C₁₅H₁₂F₃NO₄S, 382.0331; found, 383.0340.

2,2-Dimethylpropionic acid 5-methyl-2-trifluoromethanesulfonyl-2,3-dihydro-1H-benzo[de]isoquinolin-6-yl methyl ester (18). Cycloaddition of enyne **13** (0.200 g, 0.307 mmol) in 30 mL of THF with a solution of *n*-Bu₄NPh₃SiF₂ (0.331 g, 0.614 mmol) and BHT (0.102 g, 0.461 mmol) in 31 mL of THF was performed according to the general procedure. Concentration afforded a pale yellow solid which was purified by column chromatography on 63 g of silica gel (elution with 10% ethyl acetate-

hexanes) to provide 0.061 g (46%) of **18** as a pale yellow wax: IR (CH₂Cl₂) 2975, 1726, 1394, 1229, and 1149 cm⁻¹; ¹H NMR (500 MHz, CDCl₃) δ 8.02 (d, J = 8.7 Hz, 1H), 7.53 (dd, J = 8.7, 7.4 Hz, 1H), 7.27 (d, J = 7.4 Hz, 1H), 7.18 (s, 1H), 5.58 (s, 2H), 4.97 (app d, 4H), 2.61 (s, 3H), and 1.17 (s, 9H); ¹³C NMR (125 MHz, CDCl₃) δ 178.8, 136.5, 133.1, 129.5, 129.2, 129.0, 126.7, 125.9, 125.8, 123.8, 121.8, 120.1 (q, J_{CF} = 321 Hz), 60.2, 49.5, 49.4, 39.2, 27.4, and 20.2; HRMS-ESI (m/z): [M + Na]⁺ calcd for C₂₀H₂₂F₃NO₄S, 452.1114; found, 452.1123.

5-(*tert*-Butyldimethylsilyloxymethyl)-2-trifluoromethanesulfonyl-2,3-dihydro-1H-benzo[de]isoquinoline (19). Cycloaddition of enyne **14** (0.262 g, 0.392 mmol) in 30 mL of THF with a solution of *n*-Bu₄NPh₃SiF₂ (0.432 g, 0.784 mmol) and BHT (0.130 g, 0.558 mmol) in 48 mL of THF was performed according to the general procedure. Concentration afforded 0.861 g of brown oil which was purified by column chromatography on 34 g of silica gel (gradient elution with 1-10% *t*-BuOMe-hexanes) to give 0.107 g (61%) of **19** as a white solid: mp 133 °C; IR (CH₂Cl₂) 3059, 2955, 1392, 1229, 1191, and 1151 cm⁻¹; ¹H NMR (500 MHz, CDCl₃) δ 7.79 (d, J = 8.2 Hz, 1H), 7.75 (s, 1H), 7.47 (t, J = 7.6 Hz, 1H), 7.27 (s, 1H), 7.26 (d, J = 7.6 Hz, 1H), 4.99 (s, 4H), 4.90 (s, 2H), 1.00 (s, 9H), and 0.2 (s, 6H); ¹³C NMR (125 MHz, CDCl₃)¹⁰ δ 139.5, 133.6, 128.9, 128.8, 127.8, 126.2, 124.2, 122.1, 121.4, 121.2, 65.0, 49.5, 49.4, 26.2, 18.7, and -5.1; HRMS-ESI (m/z): [M + Na]⁺ calcd for C₂₀H₂₆F₃NO₃SSi, 468.1247; found, 468.1239.

5-Trifluoromethanesulfonyl-5,6-dihydro-4H-5-azabenzodeanthracene (24). Cycloaddition of enyne **20** (0.352 g, 0.614 mmol) in 73 mL of THF with a solution of *n*-Bu₄NPh₃SiF₂ (0.605 g, 1.12 mmol) and BHT (0.203 g, 0.921 mmol) in 50 mL of THF was performed according to the general procedure. Concentration afforded 1.30 g of tan solid which was purified by column chromatography on

35 g of silica gel (elution with 1% methyl *tert*-butyl ether-hexanes) to give 0.132 g (61%) of **24** as a white solid: mp 115-116 °C; IR (CH₂Cl₂) 3056, 2917, 1388, 1228, 1190, and 1150 cm⁻¹; ¹H NMR (500 MHz, CDCl₃) δ 8.66 (app t, *J* = 7.0 Hz, 2H), 7.87 (d, *J* = 7.6 Hz, 1H), 7.63-7.70 (m, 3H), 7.56 (s, 1H), 7.42 (d, *J* = 7.0 Hz, 1H), and 5.03 (app d, 4H); ¹³C NMR (125 MHz, CDCl₃) δ 131.3, 130.9, 130.0, 129.6, 128.7, 127.6, 127.2, 126.8, 126.5, 125.7, 123.7, 123.3, 123.0, 122.7, 120.1 (q, *J*_{CF} = 321 Hz), 49.8, and 49.7; HRMS-EI (*m/z*): [M]⁺ calcd for C₁₇H₁₂F₃NO₂S, 351.0535; found, 351.0540.

5-Trifluoromethanesulfonyl-5,6-dihydro-4*H*-5,8-diazacyclopenta[*a*]phenalene-8-carboxylic acid *tert*-butyl ester (25**).** Cycloaddition of enyne **21** (0.300 g, 0.453 mmol) in 41 mL of THF with a solution of *n*-Bu₄NPh₃SiF₂ (0.489 g, 0.906 mmol) and BHT (0.150 g, 0.680 mmol) in 50 mL of THF was performed according to the general procedure. Concentration afforded 0.982 g of orange-yellow oil which was purified by column chromatography on 50 g of silica gel (elution with 5% ethyl acetate-hexanes) to give 0.179 g (90%) of **25** as an ivory solid: mp 159 °C; IR (CH₂Cl₂) 3158, 3064, 2982, 1738, 1396, 1333, 1307, 1228, 1190, 1152, and 1133 cm⁻¹; ¹H NMR (500 MHz, CDCl₃) δ 8.26 (s, 1H), 8.15 (d, *J* = 8.4 Hz, 1H), 7.70 (d, *J* = 3.4 Hz, 1H), 7.57 (t, *J* = 7.7 Hz, 1H), 7.28 (d, *J* = 7.0 Hz, 1H), 7.09 (d, *J* = 3.7 Hz, 1H), 5.07 (s, 2H), 5.03 (s, 2H), and 1.74 (s, 9H); ¹³C NMR (125 MHz, CDCl₃) δ 149.8, 135.2, 130.3, 129.6, 128.1, 127.8, 126.3, 125.7, 125.2, 123.3, 121.4, 120.1 (q, *J*_{CF} = 321 Hz), 112.5, 105.8, 84.7, 50.3, 49.8, and 28.4; HRMS-ESI (*m/z*): [M + Na]⁺ calcd for C₂₀H₁₉F₃N₂O₄S, 463.0910; found, 463.0895; Anal. Calcd for C₂₀H₁₉F₃N₂O₄S: C, 54.54; H, 4.35; N, 6.36; found: C, 54.56; H, 4.19; N, 6.28.

5-Trifluoromethanesulfonyl-5,6-dihydro-4*H*-8-thia-5-azacyclopenta[*a*]phenalene (26**).** Cycloaddition of hetarenyne **22** (0.500 g, 0.863 mmol) in 100 mL of THF with a solution of *n*-Bu₄NPh₃SiF₂ (0.934 g, 1.73 mmol) and BHT (0.284 g, 1.29 mmol) in 73 mL of THF was performed

according to the general procedure. Concentration afforded 1.75 g of brown solid which was purified by column chromatography on 88 g of silica gel (elution with 1% *t*-BuOMe-hexanes) to give 0.160 g (52%) of **26** as a tan solid: mp 149-150 °C; IR (CH₂Cl₂) 3110, 3060, 2915, 1389, 1227, 1191, and 1152 cm⁻¹; ¹H NMR (500 MHz, CDCl₃) δ 8.30 (d, *J* = 8.2 Hz, 1H), 7.98 (d, *J* = 5.5 Hz, 1H), 7.74 (s, 1H), 7.60-7.64 (m, 2H), 7.36 (d, *J* = 7.2 Hz, 1H), and 5.06 (app s, 4H); ¹³C NMR (125 MHz, CDCl₃) δ 137.2, 135.8, 129.7, 129.6, 126.7, 126.6, 125.4, 124.7, 123.7, 122.3, 122.2, 120.0 (q, *J*_{CF} = 321 Hz), 117.4, 49.9, and 49.8; HRMS-EI (*m/z*): [M]⁺ calcd for C₁₅H₁₀F₃NO₂S₂, 357.0100; found, 357.0115; Anal. Calcd for C₁₅H₁₀F₃NO₂S₂: C, 50.41; H, 2.82; found: C, 50.45; H, 2.76.

5-Trifluoromethanesulfonyl-5,6-dihydro-4*H*-10-thia-5-azacyclopenta[*a*]phenalene (27).

Cycloaddition of hetarenyne **23** (0.300 g, 0.518 mmol) in 54 mL of THF with a solution of *n*-Bu₄NPh₃SiF₂ (0.561 g, 1.04 mmol) in 50 mL of THF was performed according to the general procedure. Concentration afforded 0.917 g of brown oily-solid which was purified by column chromatography on 50 g of silica gel (elution with 5% ethyl acetate-hexanes) to give 0.094 g (51%) of **27** as an ivory solid: mp 163-165 °C; IR (CH₂Cl₂) 3110, 2914, 1388, 1227, 1190, and 1150 cm⁻¹; ¹H NMR (500 MHz, CDCl₃) δ 8.10 (d, *J* = 8.2 Hz, 1H), 7.66 (s, 1H), 7.56-7.59 (m, 2H), 7.45 (dd, *J* = 5.3, 0.5 Hz, 1H), 7.33 (d, *J* = 7.2 Hz, 1H), and 5.03 (app d, 4H); ¹³C NMR (125 MHz, CDCl₃) δ 137.2, 136.9, 130.2, 129.3, 126.9, 126.4, 125.8, 125.2, 124.4, 123.6, 122.4, 120.1 (q, *J*_{CF} = 321 Hz), 118.7, 49.8, and 49.7; HRMS-ESI (*m/z*): [M + Na]⁺ calcd for C₁₅H₁₀F₃NO₂S₂, 379.9997; found, 380.0001.

5-Trifluoromethanesulfonyl-5,6-dihydro-4*H*-10-thia-5-azacyclopenta[*a*]phenalene (27) and 2,6-Di-*tert*-butyl-4-methyl-4-[2-(2-trifluoromethanesulfonyl-2,3-dihydro-1*H*-benzo[*de*] isoquinolin-5-yl)vinylsulfanyl]-cyclohexa-2,5-dienone (28). Cycloaddition of hetarenyne **23** (0.300 g, 0.518 mmol)

in 50 mL of THF with a solution of *n*-Bu₄NPh₃SiF₂ (0.561 g, 1.04 mmol) and BHT (0.171 g, 0.777 mmol) in 54 mL of THF was performed according to the general procedure. Concentration afforded 0.995 g of brown oily-solid which was purified by column chromatography on 50 g of silica gel (elution with 5% ethyl acetate-hexanes) to give 0.100 g (45% combined yield) of a yellow oil identified as a 2:1 mixture of azacyclopenta[*a*]phenalene **27** and thioether **28** by ¹H NMR analysis. An analytical sample of each compound was obtained by preparative thin-layer-chromatographic purification. Data for **28**: mp 135-137 °C; IR (CH₂Cl₂) 2960, 1655, 1451, 1393, 1228, and 1191 cm⁻¹; ¹H NMR (500 MHz, CDCl₃) δ 7.80 (d, *J* = 9.5 Hz, 1H), 7.79 (s, 1H), 7.46 (t, *J* = 8.0 Hz, 1H), 7.37 (s, 1H), 7.25 (d, *J* = 6.5 Hz, 1H), 6.53 (d, *J* = 11.0 Hz, 1H), 6.52 (s, 2H), 5.66 (d, *J* = 11.0 Hz, 1H), 4.97 (m, 4H), 1.64 (s, 3H), and 1.26 (s, 18H); ¹³C NMR (125 MHz, CDCl₃)¹⁰ δ 186.4, 157.8, 148.2, 143.2, 135.1, 134.0, 129.3, 128.6, 128.1, 127.0, 126.3, 124.1, 123.8, 123.1, 112.1, 50.3, 50.0, 49.9, 35.7, 30.4, and 25.8; HRMS-ESI (*m/z*): [M + Na]⁺ calcd for C₃₀H₃₄F₃NO₃S₂, 600.1824; found, 600.1802.

Part IV. Experimental Procedures for Preparation and Cycloaddition of Diene **30**

2-(Allyl)aminomethyl-6-(trimethylsilyl)phenol (S12). A 100-mL, one-necked, round-bottomed flask equipped with a rubber septum and an argon inlet needle was charged with aldehyde **5** (1.37 g, 7.05 mmol), 3Å molecular sieves, propargylamine (0.635 mL, 0.438 g, 8.46 mmol), and 28 mL of methanol. The resulting suspension was stirred at room temperature for 30 min and then cooled at 0 °C while NaBH₄ (0.401 g, 10.6 mmol) was added in portions over 5 min. After 1 h, the reaction mixture was diluted with 50 mL of water and filtered through a plug of Celite in a sintered glass funnel with the aid of five 30-mL portions of diethyl ether. The aqueous phase was separated and extracted with three 150-mL portions of diethyl ether, and the combined organic phases were washed with 50 mL of satd NaCl solution, dried over MgSO₄, filtered, and concentrated to afford 1.24 g of ivory solid. Column chromatography on 6 g of silica gel (elution with diethyl ether) provided 1.03 g (62%) of amine **S12** as an ivory solid: mp 38-39 °C; IR (CH₂Cl₂) 3297, 3076, 2956, 1599, 1578, 1426, and 1240 cm⁻¹; ¹H NMR (500 MHz, CDCl₃) δ 11.12 (br s, 1H), 7.29 (d, *J* = 7.3 Hz, 1H), 7.02 (d, *J* = 7.3 Hz, 1H), 6.80 (t, *J* = 7.3 Hz, 1H), 5.92 (m, 1H), 5.17-5.25 (m, 2H), 3.98 (s, 2H), 3.32 (d, *J* = 6.0 Hz, 2H), 1.70 (br s, 1H), and 0.3

(s, 9H); ^{13}C NMR (125 MHz, CDCl_3) δ 163.5, 135.3, 134.3, 130.0, 126.3, 121.6, 118.9, 117.5, 52.3, 51.2, and -0.7; HRMS-ESI (m/z): $[\text{M} + \text{H}]^+$ calcd for $\text{C}_{13}\text{H}_{21}\text{NOSi}$, 236.1465; found, 236.1464.

Trifluoromethanesulfonic acid 2-[(allyltrifluoromethanesulfonylamino)methyl]-6-(trimethylsilyl)phenyl ester (29). Bis-sulfonation of amine **S12** (0.681 g, 2.81 mmol) with $(i\text{-Pr})_2\text{NEt}$ (3.0 mL, 2.2 g, 17 mmol) and Tf_2O (1.95 mL, 3.27 g, 11.6 mmol) in 14.5 mL of CH_2Cl_2 was performed according to the general procedure. Concentration gave 6.62 g of brown solid which was purified by column chromatography on 120 g of silica gel (gradient elution with 2-3% ethyl acetate-hexanes) to furnish 1.14 g (79%) of sulfonamide **29** as an ivory solid: mp 65-66 $^\circ\text{C}$; IR (CH_2Cl_2) 3088, 2959, 1646, 1597, 1579, 1394, 1226, 1139, and 1070 cm^{-1} ; ^1H NMR (500 MHz, CDCl_3) δ 7.63 (d, $J = 7.6$ Hz, 1H), 7.59 (d, $J = 7.3$ Hz, 1H), 7.48 (t, $J = 7.5$ Hz, 1H), 5.65-5.74 (m, 1H), 5.27 (d, $J = 10.1$ Hz, 1H), 5.10 (d, $J = 17.0$ Hz, 1H), 4.67 (br s, 2H), 3.85 (br s, 2H), and 0.4 (s, 9H); ^{13}C NMR (125 MHz, CDCl_3) δ 149.1, 137.3, 135.9, 131.3, 130.3, 129.1, 128.8, 122.0, 120.2 (q, $J_{\text{CF}} = 321$ Hz), 118.7 (q, $J_{\text{CF}} = 318$ Hz), 51.3, 45.4, and 0.2; HRMS-ESI (m/z): $[\text{M} + \text{Na}]^+$ calcd for $\text{C}_{15}\text{H}_{19}\text{F}_6\text{NO}_5\text{S}_2\text{Si}$, 522.0270; found, 522.0254.

Trifluoromethanesulfonic acid 2-[(4-oxo-pent-2-enyl)trifluoromethanesulfonylamino]methyl-6-(trimethylsilyl)phenyl ester (S13). A 10-mL, one-necked, round-bottomed flask equipped with a rubber septum and argon inlet needle was charged with alkene **29** (0.200 g, 0.400 mmol), methyl vinyl ketone (0.049 mL, 0.042 g, 0.60 mmol), and 1 mL of CH_2Cl_2 . A 10 mL, one-necked, round-bottomed flask equipped with a rubber septum and argon inlet needle was charged with the ruthenium catalyst **32** (0.0125 g, 0.0200 mmol) and 1 mL of CH_2Cl_2 . The resulting solution was transferred to the reaction flask via cannula and after 1 h, methyl vinyl ketone (0.049 mL, 0.042 g, 0.60 mmol) was added in one portion via syringe. After 1 h, the green reaction mixture was filtered through a plug of silica gel with the aid of 5 mL of CH_2Cl_2 . Concentration afforded 0.237 g of dark green oil which was purified by

column chromatography on 12 g of silica gel (gradient elution with 5-10% ethyl acetate-hexanes) to furnish 0.038 g (19%) of recovered alkene **29** and 0.157 g (73%, 90% yield corrected for recovered starting material) of enone **S13** as an ivory solid: mp 72 °C, IR (CH₂Cl₂) 2956, 1707, 1686, 1395, 1228, and 1141 cm⁻¹; ¹H NMR (500 MHz, CDCl₃) δ 7.63 (d, *J* = 7.5 Hz, 1H), 7.59 (d, *J* = 7.3 Hz, 1H), 7.49 (t, *J* = 7.5 Hz, 1H), 6.38 (dt, *J* = 16.0, 6.6 Hz, 1H), 5.94 (d, *J* = 16.0 Hz, 1H), 4.67 (br s, 2H), 4.03 (d, *J* = 6.7 Hz, 2H), 2.12 (s, 3H), and 0.4 (s, 9H); ¹³C NMR (125 MHz, CDCl₃)¹⁰ δ 206.1, 196.7, 149.0, 137.8, 136.5, 134.2, 131.6, 129.2, 128.5, 50.1, 46.9, 27.3, and 0.2; HRMS-ESI (*m/z*): [M + Na]⁺ calcd for C₁₇H₂₁F₆NO₆S₂Si, 564.0376; found, 564.0388.

Trifluoromethanesulfonic acid 2-[(4-methylpenta-2,4-dienyl)trifluoromethanesulfonyl amino]methyl}-6-(trimethylsilyl)phenyl ester (30). A 50-mL, three-necked, round-bottomed flask equipped with an argon inlet adapter, rubber septum, and glass stopper was charged with Ph₃PMeBr (0.372 g, 1.04 mmol) and 3 mL of THF and cooled at 0 °C while 0.407 mL of *n*-BuLi solution (2.35 M in hexane, 0.957 mmol) was added dropwise over 1 min. After 10 min, a 10-mL, one-necked, round-bottomed flask equipped with a rubber septum and argon inlet needle was charged with enone **S13** (0.471 g, 0.870 mmol) and 3 mL of THF and the resulting solution was transferred to the reaction mixture via cannula with the aid of 2.7 mL of THF. After 45 min, the reaction mixture was treated with 10 mL of satd NH₄Cl solution. The aqueous phase was separated and extracted with two 30-mL portions of CH₂Cl₂, and the organic phases were combined and washed with 30 mL of satd Na₂S₂O₃, 30 mL of satd NaCl solution, dried over MgSO₄, filtered, and concentrated to afford 0.694 g of brown oil. Column chromatography on 3.5 g of silica gel (elution with 1% ethyl acetate-hexanes) provided 0.311 g (66%) of diene **30** as a colorless oil: IR (film) 3086, 2957, 1653, 1613, 1598, 1394, 1227, and 1140 cm⁻¹; ¹H NMR (500 MHz, CDCl₃) δ 7.64 (d, *J* = 7.6 Hz, 1H), 7.56 (d, *J* = 7.3 Hz, 1H), 7.48 (t, *J* = 7.5 Hz, 1H), 6.03 (d, *J* = 15.6, Hz, 1H), 5.28-5.35 (m, 1H), 5.03 (s, 1H), 4.93 (s, 1H), 4.62 (br s, 2H), 3.91 (br s, 2H), 1.68 (s, 3H), and 0.4 (s, 9H); ¹³C NMR (125 MHz, CDCl₃)¹⁰ δ 148.8, 140.4, 139.5, 137.2, 135.9, 131.5, 129.1, 129.0, 121.0, 119.1, 51.2, 45.6, 18.3, and 0.2; HRMS-ESI (*m/z*): [M + Na]⁺ calcd for C₁₈H₂₃F₆NO₅S₂Si, 562.0583; found, 562.0579.

5-Methyl-2-trifluoromethanesulfonyl-2,3,3a,6-tetrahydro-1H-benzo[de]isoquinoline (31).

Cycloaddition of diene **30** (0.285 g, 0.528 mmol) in 45 mL of THF with a solution of *n*-Bu₄NPh₃SiF₂ (0.572 g, 1.06 mmol) in 61 mL of THF was performed according to the general procedure. Concentration afforded 0.912 g of pale yellow solid which was purified by column chromatography on 90 g of silica gel (gradient elution with 10-20% benzene-hexanes) to give 0.144 g (86%) of **31** as a white solid: mp 83-84 °C; IR (CH₂Cl₂) 3026, 2970, 1684, 1593, 1472, 1391, 1229, 1188, 1152, and 1066 cm⁻¹; ¹H NMR (500 MHz, CDCl₃) δ 7.23 (t, *J* = 7.6 Hz, 1H), 7.14 (d, *J* = 7.3 Hz, 1H), 7.01 (d, *J* = 7.6 Hz, 1H), 5.41 (br s, 1H), 4.81 (app d, *J* = 14.7, 1H), 4.60 (app d, *J* = 15.3, Hz, 1H), 4.17 (app dd, *J* = 11.9, 4.9 Hz, 1H), 3.51 (app s, 1H), 3.41 (app dd, *J* = 20.3, 7.5 Hz, 1H), 3.23 (app dd, *J* = 20.3, 3.5 Hz, 1H), 3.02 (app t, *J* = 11.9 Hz, 1H), and 1.88 (s, 3H); ¹³C NMR (125 MHz, CDCl₃) δ 136.2, 132.1, 130.2, 127.9, 127.1, 127.0, 123.8, 120.4 (q, *J*_{CF} = 321 Hz), 118.5, 49.3, 47.8, 35.4, 35.3, and 23.2; HRMS-ESI (*m/z*): [M + Na]⁺ calcd for C₁₄H₁₄F₃NO₂S, 340.0590; found, 340.0580.

S2

S5

S7

11

21

18

19

7 1.20 1.36
1.12 2.27

2

3

4

5

6

7

1

4.00
2.25

9.61

6.06

24

25

26

S12

29

S13

30

31

STANDARD PROTON PARAMETERS

Pulse Sequence: gCOSY

Solvent: CDCl3
 Ambient temperature
 File: meh-5-232a-cosy-cdcl3
 INOVA-500 "zippy"
 PULSE SEQUENCE: gCOSY
 Relax. delay 1.000 sec
 Acq. time 0.190 sec
 Width 5375.6 Hz
 2D Width 5375.6 Hz
 2 repetitions
 512 increments
 OBSERVE H1, 499.7537722 MHz
 DATA PROCESSING
 Sq. sine bell 0.095 sec
 F1 DATA PROCESSING
 Sq. sine bell 0.024 sec
 FT size 2048 x 2048
 Total time 0 min, -1 sec

31