Brønsted-acid Catalyzed Intramolecular Hydroamination of Protected Alkenylamines. Synthesis of Pyrrolidines and Piperidines

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Supporting information

General Methods. All reactions were conducted under a nitrogen atmosphere. ^{1}H and ^{13}C NMR spectra were recorded on a Bruker DPX 500 MHz spectrometer on samples dissolved in deuterated chloroform. Residual protiated solvent was used as a reference, and coupling constants are reported in Hertz (Hz). All ^{13}C NMR spectra were proton decoupled. GCMS spectra were recorded on an HP5890 instrument equipped with a HP5971A Mass Spectral Analyzer and an HP-1 methyl silicone column. Elemental analyses were performed by Atlantic Microlabs Inc., Norcross, GA. High resolution mass spectra were recorded by Mass Spectra Labs, Urbana, IL. Chromatographic purifications were performed by flash chromatography on silica gel (200-400 mesh) from Natland International Corporation or aluminium oxide, neutral, activated grade 1 from Aldrich. Spectroscopic data and combustion or HRMS analyses are reported for all new compounds. Previously reported products were isolated in greater than 95% purity, as determined by ^{1}H NMR spectroscopy.

General procedure A: Synthesis of arenylphthalimides by Wittig olefination.
Following the general procedure of Braun,[1] 1 equiv of aromatic aldehyde and 1 equiv of the given triphenylphosphonium salt were dissolved in dry tetrahydrofuran. The mixture was cooled to 0 °C and stirred for 15 min. At this temperature 1 equiv of potassium *tert* butoxide was added in one portion. After stirring for 15 min, the reaction mixture was allowed to warm to room temperature over the course of 1 h. Then it was heated to reflux for the given time. After cooling to room temperature, the suspension was filtered through a paper filter. The solvent was evaporated under vacuum and the resulting material was subjected to flash chromatography.

General procedure B: Reaction of phthalimide derivatives with hydrazine to give primary amines.[2]

One equiv of the given phthalimide derivative and 3 equivs of hydrazine hydrate were dissolved in methanol. The mixture was heated to reflux until no further precipitation of colorless solid was observed. Then, 5 mL of concentrated hydrochloric acid were added, and the suspension was heated for 1 h. After cooling to room temperature, the reaction mixture was filtered through a paper filter, and the solid was washed with cold methanol. The solvent was evaporated under vacuum, and the residue was dissolved in ethanol. The resulting suspension was filtered through a paper filter, and the solvent was evaporated under vacuum. The resulting material was dissolved in concentrated aqueous sodium hydroxide. The aqueous phase was extracted with diethyl ether (3 x 50 mL). The combined organic phases were dried over sodium carbonate, and the solvent was evaporated under vacuum to give the primary amine.

General procedure C: Reaction of amines with acid chlorides.[3]

One equiv of the given amine was dissolved in dichloromethane. After cooling to 0 °C, 1.5 equivs of triethylamine and 1.0 equivs of the given acid chloride were added. The solution was allowed to warm to room temperature over the course of 12 h. After washing with 1 N hydrochloric acid, 1 N sodium hydroxide, water and brine, evaporation of the solvent under vacuum gave the amide.

(*Z*)-4-Phenylbut-3-enylamine[1] Following general procedure A, 6.70 g (63.1 mmol) of benzaldehyde, 33.5 g (63.1 mmol) of triphenyl(3-phthalimido-propyl)phosphonium bromide and 7.07 g (63.1 mmol) of potassium *tert* butoxide in 250 mL of tetrahydrofuran were allowed to react for 60 h. Purification by flash chromatography (ethyl acetate/hexanes: 40/60) led to isolation of 13.6 g (77%) of (*Z*)-4-phenylbut-3-enylphthalimide as a yellow oil. ^{1}H NMR: δ = 2.73 (ddt, J = 1.6, 7.3, 7.3 Hz, 2H), 3.81 (t, J = 7.2 Hz, 2H), 5.65 (dt, J = 7.3, 11.6 Hz, 1H), 6.51 (d, J = 11.6 Hz, 1H), 7.15-7.30 (m, 5H), 7.60-7.70 (m, 2H), 7.75-7.85 (m, 2H). ^{13}C NMR: δ = 27.8, 37.6, 123.2, 126.8, 127.7, 128.2, 128.4, 128.5, 131.7, 133.8, 136.9, 168.3. Following general procedure B, 5.55 g (20.0 mmol) of (*Z*)-4-phenylbut-3-enylphthalimide and 2.50 mL (40 mmol) of hydrazine hydrate in 50 mL of methanol were allowed to react for 2 h to give 2.39 g (81%) of (*Z*)-4-phenylbut-3-enylamine as a yellow liquid. ^{1}H NMR: δ = 1.40 (broad s, 2H), 2.45 (ddt, J = 1.7, 7.0, 7.0 Hz, 2H), 2.78 (t, J = 7.0 Hz, 2H), 5.63 (dt, J = 7.2, 11.7 Hz, 1H), 6.52 (d, J = 11.7 Hz, 1H), 7.10-7.40 (m, 5H). ^{13}C NMR: δ = 32.7, 42.1, 125.8, 128.1, 128.6, 129.8, 130.6, 137.4.

(*Z*)-4-(2-Methylphenyl)but-3-enylamine Following general procedure A, 4.20 g (35.0 mmol) of *o*-tolualdehyde, 18.6 g (35.0 mmol) of triphenyl(3-phthalimidopropyl)phosphonium bromide and 3.92 g (35.0 mmol) of potassium *tert* butoxide in 150 mL of tetrahydrofuran were allowed to react for 70 h. Purification by flash chromatography (ethyl acetate/hexanes: 40/60) led to isolation of 7.55 g (74%) of (*Z*)-4-(2-methylphenyl)but-3-enylphthalimide as a yellow oil. ^{1}H NMR: δ = 2.05 (s, 3H), 3.73 (t, *J* = 7.0 Hz, 2H), 4.10 (dt, *J* = 7.1, 7.1 Hz, 2H), 5.72 (dt, *J* = 7.5, 11.4 Hz, 1H), 6.52 (d, *J* = 11.5 Hz, 1H), 7.00-7.15 (m, 4H), 7.65-7.70 (m, 2H), 7.75-7.85 (m, 2H). ^{13}C NMR: δ = 19.7, 27.4, 37.6, 123.1, 125.4, 127.0, 127.7, 128.7, 129.7, 130.9, 132.0, 133.8, 135.8, 136.0, 168.2. Following general procedure B, 7.24 g (24.9 mmol) of (*Z*)-(2-methylphenyl)but-3-enylphthalimide and 2.50 mL (40.0 mmol) of hydrazine hydrate in 50 mL of methanol were allowed to react for 2 h to give 2.94 g (73%) of (*Z*)-4-(2-methylphenyl)but-3-enylamine as a yellow liquid. ^{1}H NMR: δ = 1.85 (broad s, 2H), 2.20-2.30 (m, 5H), 2.64 (t, *J* = 7.0 Hz, 2H), 5.65 (dt, *J* = 7.3, 11.5 Hz, 1H), 6.50 (d, *J* = 11.4 Hz, 1H), 7.05-7.20 (m, 4H). ^{13}C NMR: δ = 19.5, 32.3, 41.3, 125.0, 126.3, 128.5, 129.3, 129.4, 129.6, 135.7, 136.1. MS (EI): m/z = 160, 144, 132, 115, 105, 91, 77, 70. HRMS: Calc´d for $C_{11}H_{15}N$: 161.1204. Found: 161.1209.

(*Z*)-4-(3-Methylphenyl)but-3-enylamine[1] Following general procedure A, 4.20 g (35.0 mmol) of *m*-tolualdehyde, 18.6 g (35.0 mmol) of triphenyl(3-phthalimidopropyl)phosphonium bromide and 3.92 g (35.0 mmol) of potassium *tert* butoxide in 150 mL of tetrahydrofuran were allowed to react for 70 h. Purification by flash chromatography (ethyl acetate/hexanes: 40/60) led to isolation of 8.74 g (86%) of (*Z*)-4-(3-methylphenyl)but-3-enylphthalimide as a yellow oil. ^{1}H NMR: δ = 2.28 (s, 3H), 2.72 (ddt, *J* = 1.6, 7.2, 7.2 Hz, 2H), 3.80 (t, *J* = 7.2 Hz, 2H), 5.65 (dt, *J* = 7.4, 11.7 Hz, 1H), 6.45 (d, *J* = 11.7 Hz, 1H), 6.95-7.05 (m, 3H), 7.10-7.20 (m, 1H), 7.60-7.70 (m, 2H), 7.75-7.80 (m, 2H). ^{13}C NMR: δ = 21.4, 27.8, 37.6, 123.1, 125.8, 127.5, 127.6, 128.3, 129.2, 131.7, 132.0, 133.8, 136.8, 137.7, 168.2. Following general procedure B, 8.56 g (29.4 mmol) of (*Z*)-4-(3-methylphenyl)but-3-enylphthalimide and 2.50 mL (40.0 mmol) of hydrazine hydrate in 50 mL of methanol were allowed to react for 2 h to give 3.67 g (77%) of (*Z*)-4-(3-methylphenyl)but-3-enylamine as a yellow liquid. ^{1}H NMR: δ = 1.40 (broad s, 2H), 2.28 (s, 3H), 2.40 (dt, *J* = 7.0, 7.0 Hz, 2H), 2.70 (t, *J* = 7.0 Hz, 2H), 5.58 (dt, *J* = 7.2, 11.7 Hz, 1H), 6.45 (d, *J* = 11.7 Hz, 1H), 6.90-7.20 (m, 4H). ^{13}C NMR: δ = 20.9, 32.3, 41.6, 125.2, 126.8, 127.6, 128.6, 129.4, 130.2, 137.0, 137.1. MS (EI): m/z = 161, 144, 132, 115, 104, 91, 77, 70. HRMS: Calc´d for $C_{11}H_{15}N$: 161.1204. Found: 161.1207.

(*Z*)-4-(4-Methylphenyl)but-3-enylamine[1] Following general procedure A, 4.20 g (35.0 mmol) of *p*-tolualdehyde, 18.6 g (35.0 mmol) of triphenyl(3-phthalimidopropyl)phosphonium bromide and 3.92 g (35.0 mmol) of potassium *tert* butoxide in 150 mL of tetrahydrofuran were allowed to

react for 40 h. Purification by flash chromatography (ethyl acetate/hexanes: 40/60) led to isolation of 5.57 g (55%) of (*Z*)-4-(4-methylphenyl)but-3-enylphthalimide as a yellow oil. ^{1}H NMR: δ = 2.30 (s, 3H), 2.72 (ddt, *J* = 1.7, 7.2, 7.2 Hz, 2H), 3.80 (t, *J* = 7.2 Hz, 2H), 5.62 (dt, *J* = 7.2, 11.6 Hz, 1H), 6.48 (d, *J* = 11.6 Hz, 1H), 7.00-7.15 (m, 4H), 7.60-7.70 (m, 2H), 7.75-7.80 (m, 2H). ^{13}C NMR: δ = 21.1, 27.8, 37.6, 123.1, 126.9, 128.5, 128.9, 131.5, 132.1, 133.8, 134.0, 136.5, 168.3. Following general procedure B, 5.24 g (18.0 mmol) of (*Z*)-(4-methylphenyl)but-3-enylphthalimide and 2.50 mL (40.0 mmol) of hydrazine hydrate in 50 mL of methanol were allowed to react for 2 h to give 1.01 g (35%) of (*Z*)-4-(4-methylphenyl)but-3-enylamine as a yellow liquid. ^{1}H NMR: δ = 1.85 (broad s, 2H), 2.35 (s, 3H), 2.47 (ddt, *J* = 1.7, 7.0, 7.0 Hz, 2H), 2.78 (t, *J* = 7.0 Hz, 2H), 5.55 (dt, *J* = 7.2, 11.6 Hz, 1H), 6.48 (broad d, *J* = 11.6 Hz, 1H), 7.00-7.20 (m, 4H). ^{13}C NMR: δ = 21.0, 32.6, 42.1, 128.5, 128.7, 128.9, 130.6, 134.4, 136.2.

(*Z*)-4-(4-Chlorophenyl)but-3-enylamine[1] Following general procedure A, 4.22 g (30.0 mmol) of *p*-chlorobenzaldehyde, 15.9 g (30.0 mmol) of triphenyl(3-phthalimidopropyl)phosphonium bromide and 3.36 g (30.0 mmol) of potassium *tert* butoxide in 150 mL of tetrahydrofuran were allowed to react for 60 h. Purification by flash chromatography (ethyl acetate/hexanes: 40/60) led to isolation of 5.90 g (63%) of (*Z*)-4-(4-chlorophenyl)but-3-enylphthalimide as a yellow oil. ^{1}H NMR: δ = 2.70 (ddt, *J* = 1.5, 7.2, 7.2 Hz, 2H), 3.78 (t, *J* = 7.1 Hz, 2H), 5.70 (dt, *J* = 7.5, 11.7 Hz, 1H), 6.45 (d, *J* = 11.6 Hz, 1H), 7.10-7.15 (m, 2H), 7.20-7.25 (m, 2H), 7.65-7.75 (m, 2H), 7.75-7.85 (m, 2H). ^{13}C NMR: δ = 27.7, 37.4, 123.2, 128.3, 128.4, 129.8, 130.5, 132.0, 132.6, 133.9, 135.3, 168.2. Following general procedure B, 5.61 g (18.0 mmol) of (*Z*)-4-(4-chlorophenyl)but-3-enylphthalimide and 2.50 mL (40.0 mmol) of hydrazine hydrate in 50 mL of methanol were allowed to react for 2 h to give 2.06 g (63%) of (*Z*)-4-(4-chlorophenyl)but-3-enylamine as a yellow liquid. ^{1}H NMR: δ = 1.55 (broad s, 2H), 2.45 (ddt, *J* = 1.6, 7.0, 7.0 Hz, 2H), 2.78 (t, *J* = 6.8 Hz, 2H), 5.65 (dt, *J* = 7.3, 11.3 Hz, 1H), 6.45 (d, *J* = 11.6 Hz, 1H), 7.10-7.30 (m, 4H). ^{13}C NMR: δ = 32.4, 41.8, 128.0, 129.3, 129.7, 130.4, 132.1, 135.6.

(*Z*)-4-(4-Methoxyphenyl)but-3-enylamine[1] Following general procedure A, 4.76 g (35.0 mmol) of *p*-methoxybenzaldehyde, 18.6 g (35.0 mmol) of triphenyl(3-phthalimidopropyl)phosphonium bromide and 3.92 g (35.0 mmol) of potassium *tert* butoxide in 150 mL of tetrahydrofuran were allowed to react for 40 h. Purification by flash chromatography (ethyl acetate/hexanes/triethylamine: 90/10/1) led to isolation of 4.80 g (45%) of (*Z*)-4-(4-methoxyphenyl)but-3-enylphthalimide as a yellow oil. ^{1}H NMR: δ = 2.72 (ddt, *J* = 1.7, 7.3, 7.3 Hz, 2H), 3.75 (s, 3 H), 3.80 (t, *J* = 7.1 Hz, 2H), 5.58 (dt, *J* = 7.3, 11.6 Hz, 1H), 6.43 (d, *J* = 11.6 Hz, 1H), 6.80-6.85 (m, 2H), 7.15-7.20 (m, 2H), 7.65-7.70 (m, 2H), 7.80-7.85 (m, 2H). ^{13}C NMR: δ = 27.8, 37.7, 55.2, 113.6, 123.2, 126.0, 129.8, 129.9, 131.0, 132.1, 133.9, 158.4, 168.3.

Following general procedure B, 4.61 g (15.0 mmol) of (*Z*)-4-(4-methoxyphenyl)but-3-enylphthalimide and 2.50 mL (40.0 mmol) of hydrazine hydrate in 50 mL of methanol were allowed to react for 2 h to give 2.24 g (84%) of (*Z*)-4-(4-methoxyphenyl)but-3-enylamine as a yellow liquid. ^{1}H NMR: δ = 1.20 (broad s, 2H), 2.45 (ddt, *J* = 1.7, 7.0, 7.0 Hz, 2H), 2.78 (t, *J* = 7.0 Hz, 2H), 3.78 (s, 3 H), 5.53 (dt, *J* = 7.2, 11.6 Hz, 1H), 6.45 (d, *J* = 11.6 Hz, 1H), 6.80-6.90 (m, 2H), 7.15-7.25 (m, 2H). ^{13}C NMR: δ = 34.7, 42.0, 55.1, 113.9, 128.2, 129.5, 129.8, 131.1, 158.2.

(*Z*)-4-(4-Nitrophenyl)but-3-enylamine[1] Following general procedure A, 4.53 g (30.0 mmol) of *p*-nitrobenzaldehyde, 15.9 g (30.0 mmol) of triphenyl(3-phthalimidopropyl)phosphonium bromide and 3.36 g (30.0 mmol) of potassium *tert* butoxide in 150 mL of tetrahydrofuran were allowed to react for 60 h. Purification by flash chromatography (ethyl acetate/hexanes: 40/60) led to isolation of 3.83 g (45%) of (*Z*)-4-(4-nitrophenyl)but-3-enylphthalimide as a yellow oil. ^{1}H NMR: δ = 2.73 (ddt, *J* = 1.7, 7.2, 7.2 Hz, 2H), 3.83 (t, *J* = 11.7 Hz, 2H), 5.90 (dt, *J* = 7.6, 11.7 Hz, 1H), 6.55 (d, *J* = 11.7 Hz, 1H), 7.30-7.40 (m, 2H), 7.60-7.70 (m, 2H), 7.80-7.90 (m, 2H), 8.05-8.15 (m, 2H). ^{13}C NMR: δ = 27.8, 37.2, 123.3, 123.6, 129.3, 129.9, 131.5, 131.9, 134.0, 134.1, 143.5, 168.3. Following general procedure B, 3.55 g (11.0 mmol) of (*Z*)-(4-nitrophenyl)but-3-enylphthalimide and 2.50 mL (40.0 mmol) of hydrazine hydrate in 50 mL of methanol were allowed to react for 2 h to give 1.25 g (59%) of (*Z*)-4-(4-nitrophenyl)but-3-enylamine as a yellow liquid. ^{1}H NMR: δ = 1.10 (broad s, 2H), 2.48 (dt, *J* = 1.7, 6.9, 6.9 Hz, 2H), 2.80-2.90 (m, 2H), 5.85 (dt, *J* = 7.3, 11.7 Hz, 1H), 6.55 (d, *J* = 11.8 Hz, 1H), 7.40-7.50 (m, 2H), 8.10-8.20 (m, 2H). ^{13}C NMR: δ = 32.7, 41.8, 123.2, 128.7, 129.3, 133.9, 144.0, 146.1.

(*Z*)-5-Phenylpent-4-enylamine[4] Following general procedure A, 2.12 g (20.0 mmol) of benzaldehyde, 10.9 g (20.0 mmol) of triphenyl(4-phthalimidobutyl)phosphonium bromide and 2.24 g (20.0 mmol) of potassium *tert* butoxide in 100 mL of tetrahydrofuran were allowed to react for 60 h. Purification by flash chromatography (ethyl acetate/hexanes: 40/60) led to isolation of 4.96 g (85%) of (*Z*)-5-phenylpent-4-enylphthalimide as a yellow solid. ^{1}H NMR: δ = 1.85 (tt, *J* = 7.5, 7.5 Hz, 2H), 2.40 (ddt, *J* = 1.5, 7.5, 7.5 Hz, 2H), 3.68 (t, *J* = 7.5 Hz, 2H), 5.65 (dt, *J* = 7.3, 11.6 Hz, 1H), 6.43 (d, *J* = 11.6 Hz, 1H), 7.15-7.30 (m, 5H), 7.65-7.70 (m, 2H), 7.75-7.85 (m, 2H). ^{13}C NMR: δ = 25.9, 27.9, 37.6, 123.1, 126.6, 128.1, 128.6, 129.8, 131.1, 132.1, 133.8, 137.3, 168.3. Following general procedure B, 4.66 g (16.0 mmol) of (*Z*)-5-phenylpent-4-enylphthalimide and 2.50 mL (40.0 mmol) of hydrazine hydrate in 50 mL of methanol were allowed to react for 2 h to give 1.51 g (59%) of (*Z*)-5-phenylpent-4-enylamine as a yellow liquid. ^{1}H NMR: δ = 1.50-1.80 (m, 4H), 2.28-2.35 (m, 2H), 2.55-2.65 (m, 2H), 5.62 (dt, *J* = 7.2, 11.4

Hz, 1H), 6.42 (d, *J* = 11.6 Hz, 1H), 7.10-7.35 (m, 5H). ^{13}C NMR: δ = 25.4, 33.1, 41.2, 126.1, 127.8, 128.2, 128.9, 131.8, 137.1.

6-Phenyl-hex-5-enylamine[5] 2.60 g (14.7 mmol) of 6-phenyl-hex-5-enol[6] (*E*/*Z*-ratio: 44/56), 4.24 g (16.1 mmol) of triphenylphosphine and 2.26 g (15.4 mmol) of phthalimide were dissolved in 50 mL of dry tetrahydrofuran and cooled to 0°C. A solution of 2.80 g (16.1 mmol) of diethyl-*azo*-dicarboxylate in 30 mL of dry tetrahydrofuran was added dropwise, and the solution was stirred at room temperature for 24 h. The solvent was evaporated under vacuum. Purification by flash chromatography (ethyl acetate/hexanes: 10/90) led to isolation of 1.86 g (41%) of 6-phenyl-hex-5-enylphthalimide as a colorless oil. *Z*-Isomer: ^{1}H NMR: δ = 1.50-1.80 (m, 4H), 2.40 (ddt, *J* = 1.6, 7.5, 7.5 Hz, 2H), 3.70 (t, *J* = 7.2 Hz, 2H), 5.62 (dt, *J* = 7.2, 11.6 Hz, 1H), 6.42 (d, *J* = 11.6 Hz, 1H), 7.15-7.35 (m, 5H), 7.65-7.75 (m, 2H), 7.80-7.90 (m, 2H). ^{13}C NMR: δ = 27.2, 28.1, 28.3, 37.8, 123.1, 125.9, 126.5, 128.5, 129.3, 130.3, 132.2, 133.9, 137.7, 168.4. *E*-Isomer: ^{1}H NMR: δ = 1.50-1.80 (m, 4H), 2.25 (ddt, *J* = 0.5, 7.3, 7.3 Hz, 2H), 3.65 (t, *J* = 7.3 Hz, 2H), 6.19 (dt, *J* = 7.0, 15.7 Hz, 1H), 6.35 (d, *J* = 15.7 Hz, 1H), 7.15-7.35 (m, 5H), 7.65-7.75 (m, 2H), 7.80-7.90 (m, 2H). ^{13}C NMR: δ = 26.5, 27.9, 28.1, 37.8, 123.5, 125.9, 126.9, 128.1, 129.3, 130.1, 132.1, 134.2, 137.5, 167.4. Following general procedure B, 1.86 g (6.10 mmol) of 6-phenyl-hex-5-enylphthalimide and 2.50 mL (40.0 mmol) of hydrazine hydrate in 40 mL of methanol were allowed to react for 13 h to give 554 mg (52%) of 6-phenyl-hex-5-enylamine (*E*/*Z*-ratio: 44/56) as a yellow liquid. *Z*-Isomer: ^{1}H NMR: δ = 1.40-1.60 (m, 4H), 1.85 (s, 2H), 2.10-2.20 (m, 2H), 2.60-2.70 (m, 2H), 5.63 (dt, *J* = 7.3, 11.7 Hz, 1H), 6.40 (d, *J* = 12.0 Hz, 1H), 7.10-7.30 (m, 5H). ^{13}C NMR: δ = 27.1, 28.3, 33.2, 41.9, 125.8, 128.0, 128.4, 128.9, 130.6, 137.7. *E*-Isomer: ^{1}H NMR: δ = 1.40-1.60 (m, 4H), 1.85 (s, 2H), 2.20-2.30 (m, 2H), 2.60-2.70 (m, 2H), 6.20 (dt, *J* = 6.9, 15.8 Hz, 1H), 6.30 (d, *J* = 16.1 Hz, 1H), 7.10-7.30 (m, 5H). ^{13}C NMR: δ = 28.3, 29.0, 33.2, 42.0, 125.8, 128.0, 128.3, 128.6, 130.0, 137.6.

***N*-(4-Toluenesulfonyl)-(*Z*)-4-phenylbut-3-enylamine (1a)**[7] Following general procedure C, 380 mg (2.58 mmol) of (*Z*)-4-phenylbut-3-enylamine, 392 mg (3.87 mmol) of triethylamine and 492 mg (2.58 mmol) of *p*-toluenesulfonylchloride were allowed to react in 20 mL of dichloromethane to give 776 mg (100%) of *N*-(4-toluenesulfonyl)-(*Z*)-4-phenylbut-3-enylamine (**1a**) as a yellow oil. ^{1}H NMR: δ = 2.35 (s, 3H), 2.45 (broad dd, *J* = 7.2, 7.2 Hz, 2H), 3.00 (dd, *J* = 6.6, 6.6 Hz, 2H), 5.28 (t, *J* = 6.1 Hz, 1H), 5.50 (dt, *J* = 7.2, 11.8 Hz, 1H), 6.45 (d, *J* = 11.7 Hz, 1H), 7.10-7.30 (m, 7H), 7.60-7.81 (m, 2H). ^{13}C NMR: δ = 21.4, 28.7, 42.9, 126.8, 126.9, 127.7, 128.2, 128.6, 129.6, 131.4, 136.7, 136.8, 143.2.

***N*-(4-Toluenesulfonyl)-5-amino-pentene (1b)**[8] Following general procedure C, 1.28 g (15.0 mmol) of 5-amino-pentene, 2.28 g (22.5 mmol) of triethylamine and 2.86 g (15.0 mmol) of *p*-toluenesulfonylchloride were allowed to react in 50 mL of dichloromethane to give 2.60 g (72%) of *N*-(4-toluenesulfonyl)-5-amino-pentene (**1b**) as a colorless liquid. ^{1}H NMR: δ = 1.55 (quint, *J* = 7.2 Hz, 2H), 2.02 (q, *J* = 7.2 Hz, 2H), 2.42 (s, 3H), 2.92 (q, *J* = 6.9 Hz, 2H), 4.90-5.00 (m, 3H), 5.70 (ddt, *J* = 6.7, 10.2, 17.0 Hz, 1H), 7.28-7.32 (m, 2H), 7.73-7.78 (m, 2H). ^{13}C NMR: δ = 22.1, 28.7, 30.6, 42.6, 115.5, 127.5, 129.6, 129.7, 137.3, 143.3.

***N*-(4-Toluenesulfonyl)-(*Z*)-4-(4-methylphenyl)but-3-enylamine (1c)**[7] Following general procedure C, 895 mg (5.60 mmol) of (*Z*)-4-(4-methylphenyl)but-3-enylamine, 849 mg (8.40 mmol) of triethylamine and 1.07 g (5.6 mmol) of *p*-toluenesulfonylchloride were allowed to react in 50 mL of dichloromethane to give 1.61 g (91%) of *N*-(4-toluenesulfonyl)-(*Z*)-4-(4-methylphenyl)but-3-enylamine (**1c**) as a yellow oil. ^{1}H NMR: δ = 2.33 (s, 3H), 2.39 (s, 3H), 2.45 (ddt, *J* = 1.5, 6.6, 6.6 Hz, 2H), 3.04 (dt, *J* = 6.7, 6.7 Hz, 2H), 4.75 (broad s, 1H), 5.43 (dt, *J* = 7.1, 11.6 Hz, 1H), 6.48 (d, *J* = 11.6 Hz, 1H), 7.05-7.15 (m, 4H), 7.20-7.25 (m, 2H), 7.65-7.75 (m, 2H). ^{13}C NMR: δ = 21.1, 21.4, 28.6, 42.9, 126.8, 127.0, 128.5, 128.9, 129.6, 131.7, 133.9, 136.6, 136.9, 143.3.

***N*-(4-Toluenesulfonyl)-(*Z*)-4-(3-methylphenyl)but-3-enylamine (1d)** Following general procedure C, 1.93 g (12.0 mmol) of (*Z*)-4-(3-methylphenyl)but-3-enylamine, 1.82 g (18.0 mmol) of triethylamine and 2.29 g (12.0 mmol) of *p*-toluenesulfonylchloride were allowed to react in 50 mL of dichloromethane to give 3.43 g (91%) of *N*-(4-toluenesulfonyl)-(*Z*)-4-(3-methylphenyl)but-3-enylamine (**1d**) as a yellow oil. ^{1}H NMR: δ = 2.33 (s, 3H), 2.40 (s, 3H), 2.48 (ddt, *J* = 1.7, 7.0, 7.0 Hz, 2H), 3.03 (dt, *J* = 6.5, 6.5 Hz, 2H), 4.62 (broad s, 1H), 5.45 (dt, *J* = 7.2, 11.6 Hz, 1H), 6.48 (d, *J* = 11.6 Hz, 1H), 6.90-7.10 (m, 3H), 7.15-7.30 (m, 3H), 7.65-7.70 (m, 2H). ^{13}C NMR: δ = 21.4, 21.5, 28.6, 42.9, 125.6, 127.0, 127.3, 127.7, 128.1, 129.3, 129.6, 132.0, 136.7, 136.9, 137.8, 143.3. MS (EI): m/z = 315, 184, 155, 144, 129, 115, 91, 77, 65, 51. Anal. Calc´d for $C_{18}H_{21}NSO_2$: C 68.54; H 6.71; N 4.44. Found: C 68.17; H 6.69; N 4.38.

***N*-(4-Toluenesulfonyl)-(*Z*)-4-(2-methylphenyl)but-3-enylamine (1e)** Following general procedure C, 1.93 g (12.0 mmol) of (*Z*)-4-(2-methylphenyl)but-3-enylamine, 1.82 g (18.0 mmol) of triethylamine and 2.29 g (12.0 mmol) of *p*-toluenesulfonylchloride were allowed to react in 50 mL of dichloromethane to give 3.33 g (88%) of *N*-(4-toluenesulfonyl)-(*Z*)-4-(2-methylphenyl)but-3-enylamine (**1e**) as a yellow oil. ^{1}H NMR: δ = 2.20 (s, 3H), 2.25-2.35 (m, 2H), 2.40 (s, 3H), 2.98 (dt, *J* = 6.7, 6.7 Hz, 2H), 4.50 (broad s, 1H), 5.55 (dt, *J* = 7.2, 11.4 Hz, 1H), 6.53 (d, *J* = 11.4 Hz, 1H), 7.00-7.30 (m, 6H), 7.60-7.70 (m, 2H). ^{13}C NMR: δ = 19.8, 21.5,

28.4, 42.8, 125.4, 127.0, 127.2, 127.5, 128.7, 129.7, 130.2, 131.3, 135.8, 136.2, 136.8, 143.3. MS (EI): m/z = 315, 184, 155, 129, 115, 91, 65, 51. Anal. Calc´d for $C_{18}H_{21}NSO_2$: C 68.54; H 6.71; N 4.44. Found: C 68.34; H 6.82; N 4.45.

***N*-(4-Toluenesulfonyl)-(*Z*)-4-(4-chlorophenyl)but-3-enylamine (1f)** Following general procedure C, 1.88 g (10.3 mmol) of (*Z*)-4-(4-chlorophenyl)but-3-enylamine, 1.56 g (15.5 mmol) of triethylamine and 1.96 g (10.3 mmol) of *p*-toluenesulfonylchloride were allowed to react in 50 mL of dichloromethane to give 3.42 g (99%) of *N*-(4-toluenesulfonyl)-(*Z*)-4-(4-chlorophenyl)but-3-enylamine (**1f**) as a yellow oil. ^{1}H NMR: δ = 2.35-2.45 (m, 5H), 3.06 (dt, *J* = 6.7, 6.7 Hz, 2H), 4.55 (broad s, 1H), 5.52 (dt, *J* = 7.1, 11.6 Hz, 1H), 6.45 (d, *J* = 11.6 Hz, 1H), 7.05-7.15 (m, 2H), 7.20-7.35 (m, 4H), 7.65-7.75 (m, 2H). ^{13}C NMR: δ = 21.5, 28.6, 42.8, 127.0, 128.2, 128.4, 129.7, 129.8, 129.9, 130.9, 135.1, 136.8, 143.4. MS (EI): m/z = 335, 184, 155, 129, 115, 91, 77, 65, 51. Anal. Calc´d for $C_{17}H_{18}NSO_2Cl$: C 60.80; H 5.40; N 4.17. Found: C 60.56; H 5.45; N 4.03.

***N*-(4-Toluenesulfonyl)-(*Z*)-4-(4-methoxyphenyl)but-3-enylamine (1g)** Following general procedure C, 1.77 g (10.0 mmol) of (*Z*)-4-(4-methoxyphenyl)but-3-enylamine, 1.52 g (15.0 mmol) of triethylamine and 1.90 g (10.0 mmol) of *p*-toluenesulfonylchloride were allowed to react in 80 mL of dichloromethane to give 3.32 g (100%) of *N*-(4-toluenesulfonyl)-(*Z*)-4-(4-methoxyphenyl)but-3-enylamine (**1g**) as a yellow oil. ^{1}H NMR: δ = 2.40 (s, 3H), 2.47 (ddt, *J* = 1.6, 6.8, 6.8 Hz, 2H), 3.05 (dt, *J* = 6.7, 6.7 Hz, 2H), 3.80 (s, 3H), 4.70 (s, 1H), 5.38 (dt, *J* = 7.1, 11.5 Hz, 1H), 6.43 (d, *J* = 11.5 Hz, 1H), 6.80-6.90 (m, 2H), 7.10-7.15 (m, 2H), 7.20-7.30 (m, 2H), 7.65-7.75 (m, 2H). ^{13}C NMR: δ = 21.4, 28.0, 42.9, 55.2, 113.6, 125.9, 127.0, 129.4, 129.6, 129.8, 131.4, 136.9, 143.3, 158.5. MS (EI): m/z = 331, 184, 160, 155, 147, 131, 115, 103, 91, 78, 65, 51. Anal. Calc´d for $C_{17}H_{18}NSO_2Cl$: C 65.23; H 6.39; N 4.23. Found: C 65.19; H 6.38; N 4.25.

***N*-(4-Toluenesulfonyl)-(*Z*)-4-(4-nitrophenyl)but-3-enylamine (1h)** Following general procedure C, 1.12 g (5.80 mmol) of (*Z*)-4-(4-nitrophenyl)but-3-enylamine, 880 mg (8.70 mmol) of triethylamine and 1.11 g (5.80 mmol) of *p*-toluenesulfonylchloride were allowed to react in 50 mL of dichloromethane to give 1.83 g (91%) of *N*-(4-toluenesulfonyl)-(*Z*)-4-(4-nitrophenyl)but-3-enylamine (**1h**) as a brown oil. ^{1}H NMR: δ = 2.38-2.55 (m, 5H), 3.00-3.15 (m, 2H), 5.10 (s, 1H), 5.75 (dt, *J* = 7.5, 11.9 Hz, 1H), 6.55 (d, *J* = 11.5 Hz, 1H), 7.20-7.40 (m, 4H), 7.60-7.80 (m, 2H), 8.00-8.20 (m, 2H). ^{13}C NMR: δ = 21.4, 28.9, 42.6, 123.5, 126.6, 127.0, 129.3, 129.7, 129.8, 131.5, 131.6, 136.8, 143.5. MS (EI): m/z = 283, 256, 205, 180, 165, 139, 115, 77, 51. Anal. Calc´d for $C_{17}H_{18}N_2SO_4$: C 58.94; H 5.24; N 8.09. Found: C 59.37; H 5.32; N 7.92.

***N*-(4-Toluenesulfonyl)-(*Z*)-5-phenylpent-4-enylamine (1i)** Following general procedure C, 1.27 g (7.87 mmol) of (*Z*)-5-phenylpent-4-enylamine, 1.19 g (11.8 mmol) of triethylamine and 1.50 g (7.87 mmol) of *p*-toluenesulfonylchloride were allowed to react in 50 mL of dichloromethane to give 2.15 g (87%) of *N*-(4-toluenesulfonyl)-(*Z*)-5-phenylpent-4-enylamine as a colorless liquid. ^{1}H NMR: δ = 1.58 (quint, *J* = 7.2 Hz, 2H), 2.30 (dt, *J* = 7.5, 7.5 Hz, 2H), 2.40 (s, 3H), 2.90 (dt, *J* = 6.8, 6.8 Hz, 2H), 4.80 (broad s, 1H), 5.53 (dt, *J* = 7.2, 11.6 Hz, 1H), 6.40 (d, *J* = 11.6 Hz, 1H), 7.15-7.35 (m, 7H), 7.65-7.75 (m, 2H). ^{13}C NMR: δ = 21.4, 25.5, 29.7, 42.7, 126.7, 127.0, 128.2, 128.6, 129.6, 129.9, 131.0, 136.9, 137.2, 143.2. MS (EI): m/z = 315, 184, 160, 129, 115, 91, 77, 65, 51. HRMS: Calc´d for $C_{18}H_{21}NSO_2$: 315.1294 Found: 315.1293.

***N*-(4-Toluenesulfonyl)-6-phenyl-hex-5-enylamine (1j)** Following general procedure C, 550 mg (3.14 mmol) of 6-phenyl-hex-5-enylamine (*E*/*Z*-ratio: 44/56), 477 mg (4.71 mmol) of triethylamine and 598 mg (3.14 mmol) of *p*-toluenesulfonylchloride were allowed to react in 25 mL of dichloromethane to give 486 mg (47%) of *N*-(4-toluenesulfonyl)-6-phenyl-hex-5-enylamine (**1j**) (*E*/*Z*-ratio: 43/57) as a yellow oil. *Z*-Isomer: ^{1}H NMR: δ = 1.35-1.50 (m, 4H), 2.22 (dt, *J* = 7.2, 7.2 Hz, 2H), 2.36 (s, 3H), 2.87 (dt, *J* = 6.4, 6.4 Hz, 2H), 5.12 (t, *J* = 6.3 Hz, 1H), 5.53 (dt, *J* = 7.2, 11.7 Hz, 1H), 6.37 (d, *J* = 11.7 Hz, 1H), 7.15-7.30 (m, 7H), 7.70-7.80 (m, 2H). ^{13}C NMR: δ = 21.4, 26.7, 29.0, 32.2, 42.9, 125.5, 127.0, 128.1, 128.6, 129.6, 130.0, 132.1, 137.0, 137.4, 143.1. *E*-isomer: ^{1}H NMR: δ = 1.35-1.50 (m, 4H), 2.11 (dt, *J* = 7.0, 7.0 Hz, 2H), 2.35 (s, 3H), 2.93 (dt, *J* = 6.6, 6.6 Hz, 2H), 5.18 (t, *J* = 5.9 Hz, 1H), 6.10 (dt, *J* = 7.0, 15.8 Hz, 1H), 6.30 (d, *J* = 15.7 Hz, 1H), 7.15-7.30 (m, 7H), 7.70-7.80 (m, 2H). ^{13}C NMR: δ = 21.4, 26.1, 27.8, 31.1, 42.9, 126.5, 127.0, 128.1, 128.4, 129.6, 130.2, 132.1, 137.0, 137.6, 143.1. MS (EI): m/z = 331, 329, 286, 252, 212, 174, 158, 129, 115, 91, 65. HRMS: Calc´d for $C_{19}H_{25}NSO_2$ [M^++2H]: 331.1607 Found: 331.1606.

General procedure D: In a screw capped vial equipped with a stirbar was placed 1.00 mmol of the given substrate. Dry toluene (1.00 mL) was added and the vial was sealed with a cap fitted with a PTFE septum. The given amount of acid catalyst was added by syringe and the vial was placed in an oil bath that was preheated to 100 °C. At the end of the reaction the mixture was allowed to cool to room temperature. Triethylamine (0.5 mL) was added, and the product was isolated by flash chromatography.

***N*-(4-Toluenesulfonyl)-2-phenylpyrrolidine (2a)**[9] Following general procedure D, 301 mg (1.00 mmol) of *N*-(4-toluenesulfonyl)-(*Z*)-4-phenylbut-3-enylamine (**1a**) were allowed to react with 17.6 μL (0.20 mmol) of trifluoromethanesulfonic acid for 2 h. Purification by flash

chromatography (ethyl acetate/hexanes: 40/60) led to isolation of 250 mg (83%) of *N*-(4-toluenesulfonyl)-2-phenylpyrrolidine (**2a**) as a colorless solid. Reaction with 10.6 μL (0.20 mmol) of sulfuric acid for 4 h yielded 240 mg (80%) of **2a**. ^{1}H NMR: δ = 1.60-1.70 (m, 1H), 1.72-1.85 (m, 2H), 1.90-2.00 (m, 1 H), 2.40 (s, 3H), 3.35-3.45 (m, 1H), 3.55-3.65 (m, 1H), 4.78 (dd, *J* = 3.5, 8.0 Hz, 1H), 7.15-7.35 (m, 7H), 7.60-7.70 (m, 2H). ^{13}C NMR: δ = 21.5, 23.9, 35.8, 49.4, 63.3, 126.1, 127.0, 127.5, 128.3, 129.6, 135.1, 143.0, 143.2.

***N*-(4-Toluenesulfonyl)-2-methylpyrrolidine (2b)**[10] Following general procedure D, 120 mg (0.50 mmol) *of N*-(4-toluenesulfonyl)-5-amino-pentene (**1b**) were allowed to react with 8.8 μL (0.10 mmol) of trifluoromethanesulfonic acid for 2 h. Purification by flash chromatography (ethyl acetate/hexanes: 40/60) led to isolation of 114 mg (95%) of *N*-(4-toluenesulfonyl)-2-methylpyrrolidine (**2b**) as a colorless solid. Reaction with 5.3 μL (0.10 mmol) of sulfuric acid for 4 h yielded 83 mg (77%) of **2b**. ^{1}H NMR: δ = 1.30 (d, *J* = 6.4 Hz, 3H), 1.40-1.54 (m, 2H), 1.62-1.70 (m, 1H), 1.78-1.84 (m, 1H), 2.40 (s, 3H), 3.10-3.17 (m, 1H), 3.38-3.45 (m, 1H), 3.65-3.72 (m, 1H), 7.28-7.32 (m, 2H), 7.69-7.72 (m, 2H). ^{13}C NMR: δ = 21.5, 22.9, 23.9, 33.5, 49.0, 56.1, 127.5, 129.6, 143.2, 161.6.

***N*-(4-Toluenesulfonyl)-2-(4-methylphenyl)pyrrolidine (2c)**[7] Following general procedure D, 316 mg (1.00 mmol) of *N*-(4-toluenesulfonyl)-(*Z*)-4-(4-methylphenyl)but-3-enylamine (**1c**) were allowed to react with 17.6 μL (0.20 mmol) of trifluoromethanesulfonic acid for 2 h. Purification by flash chromatography (ethyl acetate/hexanes: 40/60) led to isolation of 243 mg (77%) of *N*-(4-toluenesulfonyl)-2-(4-methylphenyl)pyrrolidine (**2c**) as a colorless solid. Reaction with 10.6 μL (0.20 mmol) of sulfuric acid for 4 h yielded 235 mg (75%) of **2c**. ^{1}H NMR: δ = 1.55-1.65 (m, 1H), 1.75-1.85 (m, 2H), 1.90-1.98 (m, 1H), 2.30 (s, 3H), 2.40 (s, 3H), 3.39 (dt, *J* = 7.5, 10.1 Hz, 1H), 3.58 (ddd, *J* = 4.7, 7.2, 10.4 Hz, 1H), 4.72 (dd, *J* = 3.3, 7.3 Hz, 1H), 7.05-7.30 (m, 6H), 7.63-7.68 (m, 2H). ^{13}C NMR: δ = 20.9, 21.4, 23.9, 35.7, 49.3, 62.9, 125.9, 127.4, 128.9, 129.4, 135.1, 136.4, 140.0, 143.1.

***N*-(4-Toluenesulfonyl)-2-(3-methylphenyl)pyrrolidine (2d)** Following general procedure D, 316 mg (1.00 mmol) of *N*-(4-toluenesulfonyl)-(*Z*)-4-(3-methylphenyl)but-3-enylamine (**1d**) were allowed to react with 17.6 μL (0.20 mmol) of trifluoromethanesulfonic acid for 2 h. Purification by flash chromatography (ethyl acetate/hexanes: 40/60) led to isolation of 314 mg (99%) of *N*-(4-toluenesulfonyl)-2-(3-methylphenyl)pyrrolidine (**2d**) as a colorless solid. Reaction with 10.6 μL (0.20 mmol) of sulfuric acid for 6 h yielded 283 mg (90%) of **2d**. ^{1}H NMR: δ = 1.55-1.65 (m, 1H), 1.70-1.90 (m, 2H), 1.90-1.98 (m, 1H), 2.28 (s, 3H), 2.40 (s, 3H), 3.40 (dt, *J* = 7.6, 10.1 Hz, 1H), 3.58 (dt, *J* = 5.0, 10.1 Hz, 1H), 4.74 (dd, *J* = 3.6, 7.5 Hz, 1H), 6.95-7.25 (m, 6H), 7.60-7.70

(m, 2H). ^{13}C NMR: δ = 21.3, 21.3, 23.8, 35.7, 49.3, 63.1, 123.2, 126.7, 127.3, 127.7, 128.1, 129.4, 134.9, 137.6, 142.9, 143.2. MS (EI): m/z = 315, 300, 224, 160, 131, 118, 105, 91, 65, 51. Anal. Calc´d for $C_{18}H_{21}NSO_2$: C 68.54; H 6.71; N 4.44. Found: C 68.82; H 6.66; N 4.30.

***N*-(4-Toluenesulfonyl)-2-(2-methylphenyl)pyrrolidine (2e)** Following general procedure D, 316 mg (1.00 mmol) of *N*-(4-toluenesulfonyl)-(*Z*)-4-(2-methylphenyl)but-3-enylamine (**1e**) were allowed to react with 17.6 μL (0.20 mmol) of trifluoromethanesulfonic acid for 2 h. Purification by flash chromatography (ethyl acetate/hexanes: 40/60) led to isolation of 256 mg (81%) of *N*-(4-toluenesulfonyl)-2-(2-methylphenyl)pyrrolidine (**2e**) as a colorless solid. Reaction with 10.6 μL (0.20 mmol) of sulfuric acid for 10 h yielded 255 mg (80%) of **2e**. ^{1}H NMR: δ = 1.60-1.70 (m, 2H), 1.80-1.90 (m, 1H), 1.95-2.05 (m, 1H), 2.30 (s, 3H), 2.40 (s, 3H), 3.45 (dt, *J* = 7.7, 10.0 Hz, 1H), 3.58 (ddd, *J* = 4.1, 7.0, 10.0 Hz, 1H), 4.98 (dd, *J* = 4.0, 8.6 Hz, 1H), 7.05-7.38 (m, 6H), 7.65-7.70 (m, 2H). ^{13}C NMR: δ = 19.3, 21.4, 23.7, 34.3, 49.4, 60.3, 125.9, 126.7, 127.4, 129.5, 129.7, 130.2, 133.5, 134.9, 141.3, 143.2. MS (EI): m/z = 315, 300, 224, 184, 160, 155, 132, 131, 117, 105, 91, 65, 51. Anal. Calc´d for $C_{18}H_{21}NSO_2$: C 68.54; H 6.71; N 4.44. Found: C 68.29; H 6.68; N 4.05.

***N*-(4-Toluenesulfonyl)-2-(4-chlorophenyl)pyrrolidine (2f)** Following general procedure D, 336 mg (1.00 mmol) of *N*-(4-toluenesulfonyl)-(*Z*)-4-(4-chlorophenyl)but-3-enylamine (**1f**) were allowed to react with 17.6 μL (0.20 mmol) of trifluoromethanesulfonic acid for 2 h. Purification by flash chromatography (ethyl acetate/hexanes: 40/60) led to isolation of 294 mg (88%) of *N*-(4-toluenesulfonyl)-2-(4-chlorophenyl)pyrrolidine (**2f**) as a colorless solid. Reaction with 10.6 μL (0.20 mmol) of sulfuric acid for 4 h yielded 312 mg (93%) of **2f**. ^{1}H NMR: δ = 1.55-1.95 (m, 4H), 2.41 (s, 3H), 3.36 (dt, *J* = 7.1, 10.1 Hz, 1H), 3.57 (ddd, *J* = 4.5, 6.7, 10.0 Hz, 1H), 4.70 (dd, *J* = 3.8, 7.9 Hz, 1H), 7.10-7.28 (m, 6H), 7.63-7.67 (m, 2H). ^{13}C NMR: δ = 21.4, 23.8, 35.6, 49.4, 62.5, 127.3, 127.5, 128.0, 129.5, 132.5, 134.7, 141.7, 143.4. MS (EI): m/z = 335, 224, 180, 155, 138, 125, 91, 65, 51. Anal. Calc´d for $C_{17}H_{18}NSO_2Cl$: C 60.80; H 5.40; N 4.17. Found: C 60.53; H 5.44; N 4.12.

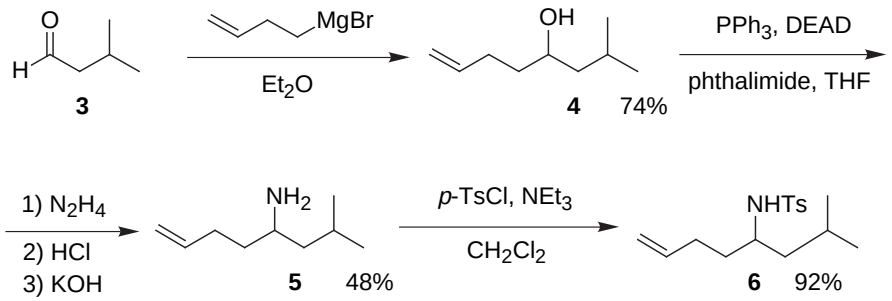
***N*-(4-Toluenesulfonyl)-2-(4-methoxyphenyl)pyrrolidine (2g)** Following general procedure D, 336 mg (1.00 mmol) of *N*-(4-toluenesulfonyl)-(*Z*)-4-(4-chlorophenyl)but-3-enylamine (**1f**) were allowed to react with 17.6 μL (0.20 mmol) of trifluoromethanesulfonic acid for 2 h. The formation of a black polymer was observed and no product was obtained. Reaction with 10.6 μL (0.20 mmol) of sulfuric acid for 4 h yielded 89 mg (27%) of *N*-(4-toluenesulfonyl)-2-(4-methoxyphenyl)pyrrolidine (**2g**) by flash chromatography (ethyl acetate/hexanes: 40/60). ^{1}H NMR: δ = 1.60-1.68 (m, 1H), 1.75-1.88 (m, 2H), 1.90-1.98 (m, 1H), 2.40 (s, 3H), 3.40 (dt, *J* =

7.5, 10.1 Hz, 1H), 3.58 (ddd, *J* = 3.9, 7.2, 10.3 Hz, 1H), 3.77 (s, 3H), 4.72 (dd, *J* = 3.9, 7.5 Hz, 1H), 6.80-6.85 (m, 2H), 7.20-7.30 (m, 4H), 7.60-7.70 (m, 2H). ^{13}C NMR: δ = 21.4, 23.9, 35.7, 49.2, 55.2, 62.8, 113.6, 127.3, 127.4, 129.5, 135.1, 135.2, 143.1, 158.6. MS (EI): m/z = 331, 224, 176, 147, 133, 121, 105, 91, 77, 65, 51. Anal. Calc´d for $C_{17}H_{18}NSO_2Cl$: C 65.23; H 6.39; N 4.23. Found: C 64.79; H 6.37; N 4.03.

***N*-(4-Toluenesulfonyl)-2-phenylpiperidine (2i)**[11] Following general procedure D, 315 mg (1.00 mmol) of *N*-(4-toluenesulfonyl)-(*Z*)-5-phenylpent-4-enylamine (**1i**) were allowed to react with 17.6 µL (0.20 mmol) of trifluoromethanesulfonic acid for 2 h. Purification by flash chromatography (ethyl acetate/hexanes: 40/60) led to isolation of 263 mg (83%) of *N*-(4-toluenesulfonyl)-2-phenylpiperidine (**2i**) as a yellow oil. Reaction with 10.6 µL (0.20 mmol) of sulfuric acid for 24 h yielded 251 mg (80%) of **2i**. ^{1}H NMR: δ = 1.20-1.75 (m, 6H), 2.40 (s, 3H), 2.98 (dt, *J* = 3.2, 14.4 Hz, 1H), 3.82 (d, *J* = 14.2 Hz, 1H), 5.25 (broad s, 1H), 7.10-7.35 (m, 7H), 7.70-7.80 (m, 2H). ^{13}C NMR: δ = 18.7, 21.3, 24.1, 27.0, 41.7, 55.0, 126.6, 126.8, 126.9, 128.4, 129.6, 138.6, 138.8, 142.8.

***N*-(*p*-Toluenesulfonyl)-2-benzylpiperidine (2j)** Following general procedure D, 329 mg (1.00 mmol) of *N*-(*p*-toluenesulfonyl)-6-phenyl-hex-5-enylamine (**1j**) (*E*/*Z*-ratio: 43/57) were allowed to react with 17.6 µL (0.20 mmol) of trifluoromethanesulfonic acid for 4 h. Purification by flash chromatography (ethyl acetate/hexanes: 70/30) led to isolation of 168 mg (51%) of *N*-(*p*-toluenesulfonyl)-2-benzylpiperidine (**2j**) as a yellow oil. ^{1}H NMR: δ = 1.10-1.20 (m, 2H), 1.35-1.45 (m, 2H), 1.92 (dt, *J* = 7.4, 7.4 Hz, 2H), 2.40 (s, 3H), 2.88 (q, *J* = 6.8 Hz, 2H), 3.76 (t, *J* = 7.7 Hz, 1H), 4.64 (t, *J* = 6.3 Hz, 1H), 7.05-7.30 (m, 7H), 7.70-7.80 (m, 2H). ^{13}C NMR: δ = 21.4, 26.4, 27.4, 29.3, 35.4, 43.0, 50.7, 125.9, 127.0, 128.3, 129.0, 129.6, 136.9, 142.0, 143.2. MS (EI): m/z = 331, 266, 181, 176, 155, 91, 65. HRMS: Calc´d for $C_{19}H_{23}NSO_2$ [M^++2H]: 331.1606 Found: 331.1606.

Scheme S1: Synthesis of Substrate 6



5-Hydroxy-7-methyloctene (4)[12] Magnesium turnings (1.45 g, 60.0 mmol) were covered with 5 mL of dry diethyl ether. A solution of 5.40 g (40.0 mmol) of 4-bromo-1-butene in 50 mL of dry diethyl ether was added dropwise. At the end of the exothermic reaction, the reaction mixture was refluxed for 1 h. After cooling to room temperature, 3.27 g (38.0 mmol) of *iso*-valeraldehyde (**3**) was added dropwise. Then, the mixture was stirred at room temperature for 1 h. It was poured in 300 mL of ice, and the suspension was made acidic by addition of concentrated sulfuric acid. The organic layer was separated and the aqueous phase was extracted with diethyl ether (3 x 50mL). The combined organic phases were dried over magnesium sulfate, and the solvent was evaporated under vacuum. 4.00 g (74%) of 5-hydroxy-7-methyloctene (**4**) were obtained as a colorless liquid. ^{1}H NMR: δ = 0.90 (d, J = 6.7 Hz, 3H), 0.93 (d, J = 7.0 Hz, 3H), 1.23 (ddd, J = 4.1, 8.7, 13.5 Hz, 1H), 1.37 (ddd, J = 5.3, 8.8, 14.0 Hz, 1H), 1.45-1.55 (m, 2H), 1.72-1.82 (m, 1H), 2.08-2.28 (m, 3H), 3.68 (sext, J = 4.3 Hz, 1H), 4.94 (d, J = 10.2 Hz, 1H), 5.03 (d, J = 17.1 Hz, 1H), 5.75-5.88 (m, 1H). ^{13}C NMR: δ = 22.0, 23.4, 24.5, 29.9, 36.9, 46.7, 69.3, 114.6, 138.6.

5-Amino-7-methyloctene (5) 5-Hydroxy-7-methyloctene (**4**) (3.87 g, 27.2 mmol), 7.84 g (29.9 mmol) of triphenylphosphine and 4.20 g (28.6 mmol) of phthalimide were dissolved in 75 mL of dry tetrahydrofuran and cooled to 0 °C. A solution of 5.21 g (29.9 mmol) of diethyl-*azo*-dicarboxylate in 50 mL of dry tetrahydrofuran was added dropwise. The reaction mixture was stirred for 12 h. The solvent was evaporated under vacuum, and the residue was subjected to Purification by flash chromatography (ethyl acetate/hexanes: 40/60) to yield 6.03 g (82%) of 5-phthalimido-7-methyloctene as a yellow liquid. ^{1}H NMR: δ = 0.88 (d, J = 5.6 Hz, 3H), 0.92 (d, J = 5.7 Hz, 3H), 1.40-1.50 (m, 2H), 1.70-1.80 (m, 1H), 1.95-2.05 (m, 2H), 2.10-2.20 (m, 2H), 4.30-4.40 (m, 1H), 4.89 (d, J = 10.2 Hz, 1H), 4.95 (d, J = 17.1 Hz, 1H), 5.70-5.80 (m, 1H), 7.65-7.75 (m, 2H), 7.80-7.85 (m, 2H). ^{13}C NMR: δ = 21.0, 22.6, 25.2, 30.9, 31.9, 42.2, 49.7, 115.1, 123.0, 131.8, 133.8, 137.5, 168.7. Following general procedure B, 5.78 g (21.3 mmol) of 5-phthalimido-7-methyloctene and 2.50 mL (40.0 mmol) of hydrazine hydrate in 50 mL of methanol were allowed to react for 16 h to give 1.75 g (58%) of 5-amino-7-methyloctene (**5**) as a yellow liquid that was used crude in the next step. ^{1}H NMR: δ = 0.87 (d, J = 7.1 Hz, 3H), 0.90 (d, J = 6.6 Hz, 3H), 1.15-1.38 (m, 4H), 1.43-1.53 (m, 1H), 1.65-1.75 (m, 1H), 2.03-2.20 (m, 2H), 2.72-2.81 (m, 1H), 4.92 (d, J = 10.2 Hz, 1H), 5.05 (d, J = 17.1 Hz, 1H), 5.75-5.85 (m, 1H). ^{13}C NMR: δ = 21.8, 23.3, 25.8, 30.2, 37.5, 47.4, 48.1, 114.2, 138.4.

***N*-(4-Toluenesulfonyl)-5-amino-7-methyloctene (6)** Following general procedure C, 1.56 g (11.0 mmol) of 5-amino-7-methyloctene **(6)**, 1.68 g (16.5 mmol) of triethylamine and 2.09 g (10.9 mmol) of *p*-toluenesulfonylchloride were allowed to react in 50 mL of dichloromethane to give 2.99 g (92%) of *N*-(4-toluenesulfonyl)-5-amino-7-methyloctene (**6**) as a black oil. ^{1}H NMR:

δ = 0.68 (d, *J* = 6.6 Hz, 3H), 0.75 (d, *J* = 6.6 Hz, 3H), 0.85-0.95 (m, 1H), 1.12-1.20 (m, 1H), 1.30-1.55 (m, 3H), 1.95-2.05 (m, 2H), 2.42 (s, 3H), 3.20-3.30 (m, 1H), 4.85-5.05 (m, 3H), 5.60-5.70 (m, 1H), 7.20-7.30 (m, 2H), 7.70-7.80 (m, 2H). ^{13}C NMR: δ = 21.2, 22.0, 22.5, 24.3, 29.2, 34.4, 44.2, 51.6, 114.8, 126.9, 129.5, 137.7, 138.4, 142.9. MS (EI): m/z = 278, 277, 183, 152, 128, 91, 77, 51. Anal. Calc´d for $C_{16}H_{25}NSO_2$: C 65.05; H 8.53; N 4.74. Found: C 65.00; H 8.57; N 4.65.

***N*-(4-Toluenesulfonyl)-2-(2-methylpropyl)-5-methylpyrrolidine (7)** Following general procedure D, 296 mg (1.00 mmol) of *N*-(4-toluenesulfonyl)-5-amino-7-methyloctene (**6**) were allowed to react with 17.6 µL (0.20 mmol) of trifluoromethanesulfonic acid for 2 h. Purification by flash chromatography (ethyl acetate/hexanes/triethylamine: 10/90/1) led to isolation of 172 mg (58%) of *N*-(4-toluenesulfonyl)-2-(2-methylpropyl)-5-methylpyrrolidine (**7**) [ratio of (2*R S*), (5*SR*) / (2*RS*), (5*RS*)-Isomer: 68:32 (^{1}H-NMR)] as a yellow oil. The relative stereochemistry was determined by NOESY-experiments. (2*RS*), (5*SR*)-Isomer: ^{1}H NMR: δ = 0.87 (d, *J* = 6.7 Hz, 3H), 0.91 (d, *J* = 6.6 Hz, 3H), 1.18 (d, *J* = 6.2 Hz, 3H), 1.45-1.52 (m, 2H), 1.60-1.70 (m, 2H), 1.72-1.80 (m, 2H), 1.90-2.00 (m, 1H), 2.40 (s, 3H), 3.85 (ddd, *J* = 2.5, 7.6, 10.5 Hz, 1H), 4.00 (broad quint, *J* = 6.3 Hz, 1H), 7.24-7.28 (m, 2H), 7.70-7.74 (m, 2H). ^{13}C NMR: δ = 20.9, 21.2, 21.4, 24.0, 25.9, 27.9, 31.2, 43.0, 56.0, 59.1, 127.0, 129.3, 139.6, 142.5. (2RS), (5*RS*)-Isomer: ^{1}H NMR: δ = 0.93 (d, *J* = 7.5 Hz, 3H), 0.95 (d, *J* = 6.7 Hz, 3H), 1.32 (d, *J* = 6.2 Hz, 3H), 1.45-1.52 (m, 2H), 1.60-1.70 (m, 2H), 1.72-1.80 (m, 2H), 2.00-2.40 (m, 1H), 2.42 (s, 3H), 3.60-3.70 (m, 2H), 7.28-7.32 (m, 2H), 7.68-7.72 (m, 2H). ^{13}C NMR: δ = 21.4, 21.8, 23.5, 23.7, 25.4, 27.9, 32.1, 46.6, 57.2, 60.2, 127.4, 129.8, 139.6, 143.0. MS (EI): m/z = 295, 280, 238, 155, 91, 84, 65. Anal. Calc´d for $C_{16}H_{25}NSO_2$: C 65.05; H 8.53; N 4.74. Found: C 65.41; H 8.57; N 4.41.

***N*-(4-Nitrophenylsulfonyl)-(*Z*)-4-phenyl-but-3-enylamine (8a)** Following general procedure C, 1.03 g (7.00 mmol) of (*Z*)-4-phenylbut-3-enylamine, 1.06 g (10.5 mmol) of triethylamine and 1.55 g (7.00 mmol) of *p*-nitrobenzenesulfonylchloride were allowed to react in 30 mL of dichloromethane to give 2.33 g (100%) of *N*-(4-nitrophenylsulfonyl)-(*Z*)-4-phenylbut-3-enylamine (**8a**) as an orange oil. ^{1}H NMR: δ = 2.43 (ddt, *J* = 1.2, 6.8, 6.8 Hz, 2H), 3.15 (t, *J* = 6.8 Hz, 2H), 4.20 (broad s, 1H), 5.47 (dt, *J* = 7.0, 11.6 Hz, 1H), 6.51 (broad d, *J* = 11.5 Hz, 1H), 7.10-7.15 (m, 2H), 7.20-7.30 (m, 3H), 7.90-8.00 (m, 2H), 8.15-8.25 (m, 2H). ^{13}C NMR: δ = 28.6, 43.1, 124.3, 127.0, 127.2, 128.1, 128.3, 128.5, 132.4, 136.5, 146.1, 149.8. MS (EI): m/z = 332, 215, 186, 130, 122, 115, 91, 76, 65. Anal. Calc´d for $C_{16}H_{16}N_2SO_4$: C 57.82; H 4.85; N 8.43. Found: C 58.08; H 4.82; N 8.26.

***N*-(9-Fluorenylmethoxycarbonyl)-(*Z*)-4-phenyl-but-3-enylamine (8b)** Following general procedure C, 1.03 g (7.00 mmol) of (*Z*)-4-phenylbut-3-enylamine, 1.06 g (10.5 mmol) of triethylamine and 1.81 g (7.00 mmol) of 9-fluorenylmethyl chloroformate were allowed to react in 20 mL of dichloromethane to give 2.29 g (89%) of *N*-(9-fluorenylmethoxycarbonyl)-(*Z*)-4-phenyl-but-3-enylamine (**8b**) as a yellow oil. ^{1}H NMR: δ = 2.40-2.60 (m, 2H), 3.20-3.40 (m, 2H), 4.20 (t, *J* = 6.8 Hz, 1H), 4.38 (d, *J* = 7.0 Hz, 2H), 4.80 (broad s, 1H), 5.60 (dt, *J* = 6.0 Hz, 11.5 Hz, 1H), 6.58 (d, *J* = 11.3 Hz, 1H), 7.18-7.40 (m, 9H), 7.50-7.60 (m, 2H), 7.70-7.80 (m, 2H). ^{13}C NMR: δ = 29.0, 40.8, 47.2, 66.5, 119.9, 125.0, 126.8, 127.0, 127.6, 128.2, 128.6, 131.4, 141.3, 143.9, 156.3. MS (EI): m/z = 277, 207, 194, 178, 152, 130, 118, 84, 76, 63, 51. Anal. Calc´d for $C_{25}H_{23}NO_2$: C 81.27; H 6.27; N 3.79. Found: C 81.28; H 6.28; N 3.75.

***N*-(Benzyloxycarbonyl)-(*Z*)-4-phenyl-but-3-enylamine (8c)** Following general procedure C, 1.03 g (7.00 mmol) of (*Z*)-4-phenylbut-3-enylamine, 1.06 g (10.5 mmol) of triethylamine and 1.19 g (7.00 mmol) of benzyl chloroformate were allowed to react in 30 mL of dichloromethane to give 1.59 g (81%) of *N*-(9-benyloxycarbonyl)-(*Z*)-4-phenyl-but-3-enylamine (**8c**) as a yellow liquid. ^{1}H NMR: δ = 2.40-2.60 (m, 2H), 3.20-3.30 (m, 2H), 4.85 (broad s, 1H), 5.08 (broad s, 2H), 5.58 (dt, *J* = 6.6 Hz, 11.6 Hz, 1H), 6.53 (d, *J* = 11.6 Hz, 1H), 7.10-7.40 (m, 10H). ^{13}C NMR: δ = 29.3, 40.2, 65.2, 126.9, 128.0, 128.2, 128.4, 128.6, 131.4, 136.5, 137.2, 156.3. MS (EI): m/z = 281, 220, 190, 160, 129, 117, 115, 91, 65, 51. HRMS: Calc´d for $C_{18}H_{19}NO_2$: 281.1414 Found: 281.1416.

***N*-Acetyl-(*Z*)-4-phenyl-but-3-enylamine (8d)**[13] Following general procedure C, 1.03 g (7.00 mmol) of (*Z*)-4-phenylbut-3-enylamine, 1.06 g (10.5 mmol) of triethylamine and 550 mg (7.00 mmol) of acetyl chloride were allowed to react in 30 mL of dichloromethane to give 1.11 g (84%) of *N*-acetyl-(*Z*)-4-phenyl-but-3-enylamine (**8d**) as a yellow liquid. ^{1}H NMR: δ = 1.90 (s, 3H), 2.53 (ddt, *J* = 1.7, 7.0, 7.0 Hz, 2H), 3.33 (dt, *J* = 6.9, 6.9 Hz, 2H), 5.60 (dt, *J* = 7.2, 11.6 Hz, 1H), 5.70 (broad s, 1H), 6.53 (d, *J* = 11.6 Hz, 1H), 7.15-7.30 (m, 5H). ^{13}C NMR: δ = 23.2, 28.6, 39.4, 126.9, 128.2, 128.5, 128.6, 131.3, 137.1, 170.1.

***N*-(4-Nitrophenylsulfonyl)-2-phenylpyrrolidine (9a)** Following general procedure D, 332 mg (1.00 mmol) of *N*-(4-nitrophenylsulfonyl)-(*Z*)-4-phenyl-but-3-enylamine (**8a**) were allowed to react with 17.6 µL (0.20 mmol) of trifluoromethanesulfonic acid for 4 h. Purification by flash chromatography (ethyl acetate/hexanes: 40/60) led to isolation of 316 mg (95%) of *N*-(4-nitrophenylsulfonyl)-2-phenylpyrrolidine (**9a**) as a yellow oil. ^{1}H NMR: δ = 1.70-2.00 (m, 3H), 2.05-2.18 (m, 1 H), 3.50-3.54 (m, 2H), 4.85 (dd, *J* = 4.2, 7.9 Hz, 1H), 7.10-7.30 (m, 5H), 7.75-7.82 (m, 2H), 8.15-8.22 (m, 2H). ^{13}C NMR: δ = 24.1, 35.8, 49.4, 63.6, 124.0, 126.3, 127.4, 128.2,

128.3, 141.9, 144.3, 149.7. MS (EI): m/z = 332, 255, 186, 146, 117, 104, 91, 77, 65, 51. Anal. Calc´d for $C_{16}H_{16}N_2SO_4$: C 57.82; H 4.85; N 8.43. Found: C 58.13; H 4.84; N 8.19.

(*Z*)-4-(3-Pyridyl)-but-3-enylamine[14] Following general procedure A, 3.75 g (35.0 mmol) of 3-pyridinecarboxaldehyde, 18.6 g (35.0 mmol) of triphenyl(3-phthalimidopropyl)phosphonium bromide and 3.92 g (35.0 mmol) of potassium *tert* butoxide in 200 mL of tetrahydrofuran were allowed to react for 100 h. Purification by flash chromatography (ethyl acetate/hexanes: 40/60) led to isolation of 3.01 g (31%) of (*Z*)-4-(3-pyridyl)-but-3-enylphthalimide as a yellow oil. ^{1}H NMR: δ = 2.70-2.80 (m, 2H), 3.70 (t, *J* = 7.0 Hz, 2H), 5.85 (dt, *J* = 6.5, 11.8 Hz, 1H), 6.47 (d, *J* = 11.6 Hz, 1H), 7.15-7.25 (m, 1H), 7.50-7.60 (m, 1H), 7.65-7.75 (m, 2H), 7.80-7.90 (m, 2H), 8.40-8.50 (m, 2H). ^{13}C NMR: δ = 27.8, 37.4, 123.1, 123.2, 128.1, 130.2, 131.9, 132.5, 133.9, 135.5, 147.9, 149.8, 168.2. Following general procedure B, 2.84 g (10.2 mmol) of (*Z*)-4-(3-pyridyl)-but-3-enylphthalimide and 2.50 mL (40.0 mmol) of hydrazine hydrate in 40 mL of methanol were allowed to react for 14 h to give 833 mg (55%) of (*Z*)-4-(3-pyridyl)-but-3-enylamine as a yellow liquid. ^{1}H NMR: δ = 2.30 (s, 2H), 2.45 (t, *J* = 7.0 Hz, 2H), 2.82 (q, *J* = 6.6 Hz, 2H), 5.80 (dt, *J* = 7.3, 11.7 Hz, 1H), 6.48 (d, *J* = 11.7 Hz, 1H), 7.20-7.30 (m, 1H), 7.45-7.55 (m, 1H), 8.38-8.45 (m, 1H), 8.50-8.55 (m, 1H). ^{13}C NMR: δ = 32.1, 41.4, 122.4, 126.6, 132.0, 132.2, 135.4, 147.1, 149.2.

***N*-(4-Toluenesulfonyl)-4-(3-pyridyl)-but-3-enylamine (10)** Following general procedure C, 629 mg (4.24 mmol) of (*Z*)-4-(3-pyridyl)-but-3-enylamine, 644 mg (6.36 mmol) of triethylamine and 808 mg (4.24 mmol) of *p*-toluenesulfonylchloride were allowed to react in 25 mL of dichloromethane to give 983 mg (77%) of *N*-(4-toluenesulfonyl)-4-(3-pyridyl)-but-3-enylamine (**10**) as a brown oil. ^{1}H NMR: δ = 2.41 (s, 3H), 2.48 (dq, *J* = 1.8, 7.0 Hz, 2H), 3.01 (t, *J* = 6.9 Hz, 2H), 5.18 (broad s, 1H), 5.67 (dt, *J* = 7.3, 11.6 Hz, 1H), 6.45 (d, *J* = 11.5 Hz, 1H), 7.20-7.30 (m, 3H), 7.45-7.55 (m, 1H), 7.65-7.75 (m, 2H), 8.40-8.50 (m, 2H). ^{13}C NMR: δ = 21.5, 28.8, 42.7, 123.2, 127.0, 128.1, 129.7, 130.3, 132.5, 135.7, 136.9, 143.4, 147.8, 149.6. MS (EI): m/z = 302, 277, 260, 184, 155, 119, 91, 65. HRMS: Calc´d for $C_{16}H_{18}NSO_2$: 302.1091 Found: 302.1089.

3,3-Dimethylpent-4-enoic acid[15] In a distillation apparatus a solution of 25.8 g (300 mmol) of 3-methyl-but-2-enol in 100 mL of triethylorthoacetate was heated to 130 °C for 4 d. During this period, 2 mL of propionic acid were added daily. The ethanol formed during the reaction was distilled off from the reaction mixture. After cooling to room temperature, the reaction mixture was washed with water (50 mL) and 1 N sodium bicarbonate (50 mL). The organic layer was made basic with sodium hydroxide, and the solution was refluxed for 1 h. After cooling to 0 °C, the reaction mixture was acidified by addition of concentrated hydrochloric acid. The solution

was extracted with diethyl ether (3 x 50 mL), and the combined organic phases were dried over sodium sulfate. After evaporation of the solvent under vacuum, the residue was subjected to fractional distillation. 10.5 g (27%) of 3,3-dimethylpent-4-enoic acid (b.p.: 100 °C/12 mbar) were obtained as a colorless liquid. ^{1}H NMR: δ = 1.18 (s, 6H), 2.33 (s, 2H), 4.95 (dd, *J* = 0.9, 10.7 Hz, 1H), 5.00 (dd, *J* = 0.8, 17.4 Hz, 1H), 5.90 (dd, *J* = 10.7, 17.3 Hz, 1H), 10.5 (broad s, 1H). ^{13}C NMR: δ = 26.7, 36.0, 46.8, 110.8, 146.8, 178.4.

3,3-Dimethylpent-4-enoyl chloride[15] 3,3-Dimethylpent-4-enoic acid (9.61 g, 75.0 mmol), 9.60 g (80.0 mmol) of thionyl chloride and 0.30 mL of *N,N*-dimethylformamide were dissolved in 150 mL of dry benzene. The solution was refluxed for 2.5 h. The solvent and excess thionyl chloride were removed by distillation at atmospheric pressure. Fractional distillation of the residue under vacuum yielded 9.38 g (85%) of 3,3-dimethylpent-4-enoyl chloride (b.p.: 110 °C / 12 mbar) as a yellow liquid. ^{1}H NMR: δ = 1.15 (s, 6H), 2.95 (s, 2H), 4.95 (d, *J* = 10.3 Hz, 1H), 5.00 (d, *J* = 17.2 Hz, 1H), 5.80 (dd, *J* = 10.8, 17.3 Hz, 1H). ^{13}C NMR: δ = 26.4, 37.0, 58.7, 112.1, 145.0, 170.9.

***N*-Phenyl-3,3-dimethyl-pent-4-enylamide (11a)**[16] Following general procedure C, 2.56 g (27.0 mmol) of aniline and 3.69 g (25.0 mmol) of 3,3-dimethylpent-4-enoyl chloride were allowed to react in 50 mL of diethyl ether to give 3.00 g (59%) of *N*-phenyl-3,3-dimethyl-pent-4-enylamide (**11a**) as a colorless solid. ^{1}H NMR: δ = 1.15 (s, 6H), 2.35 (s, 2H), 5.12 (d, *J* = 11.0 Hz, 1H), 5.13 (d, *J* = 17.7 Hz, 1H), 6.00 (dd, *J* = 10.5, 17.7 Hz, 1H), 7.05-7.10 (m, 1H), 7.20-7.30 (m, 3H), 7.30-7.40 (s, 1H), 7.40-7.50 (m, 1H). ^{13}C NMR: δ = 26.9, 36.6, 50.4, 112.3, 119.8, 124.2, 128.9, 137.8, 147.2, 169.4.

***N*-(4-Tolyl)-3,3-dimethyl-pent-4-enylamide (11b)** Following general procedure C, 1.61 g (15.0 mmol) of 4-toluidine, 1.01 g (10.0 mmol) of triethylamine and 1.50 g (10.2 mmol) of 3,3-dimethylpent-4-enoyl chloride were allowed to react in 50 mL of dichloromethane to give 2.02 g (91%) of *N*-(4-tolyl)-3,3-dimethyl-pent-4-enylamide (**11b**) as a colorless solid. ^{1}H NMR: δ = 1.18 (s, 6H), 2.28 (s, 3H), 2.35 (s, 2H), 5.10 (d, *J* = 11.0 Hz, 1H), 5.11 (d, *J* = 17.0 Hz, 1H), 5.98 (dd, *J* = 10.7, 17.6 Hz, 1H), 7.00-7.10 (m, 2H), 7.25-7.35 (m, 3H). ^{13}C NMR: δ = 20.8, 26.9, 36.6, 50.4, 112.9, 119.9, 129.4, 133.8, 135.2, 147.3, 169.3. MS (EI): m/z = 217, 202, 149, 107, 91, 69. HRMS: Calc´d for C14H19NO: 217.1466 Found: 217.1466.

***N*-Phenyl-pent-4-enylamide (11c)**[17] Following general procedure C, 931 mg (10.0 mmol) of aniline, 1.52 g (15.0 mmol) of triethylamine and 1.19 g (10.0 mmol) of pent-4-enoyl chloride were allowed to react in 30 mL of dichloromethane to give 1.50 g (86%) of *N*-phenyl-pent-4-enylamide (**11c**) as a colorless solid. ^{1}H NMR: δ = 2.40-2.50 (m, 4H), 5.02 (d, *J* = 10.0 Hz, 1 H),

5.10 (d, *J* = 17.1 Hz, 1H), 5.80-5.90 (m, 1H), 7.00-7.10 (m, 1H), 7.25-7.30 (m, 2H), 7.45-7.50 (m, 2H), 7.55 (broad s, 1H). ^{13}C NMR: δ = 29.4, 36.7, 115.8, 119.9, 124.2, 128.9, 136.8, 137.9, 170.7.

***N*-(4-Tolyl)-pent-4-enylamide (11d)**[18] Following general procedure C, 1.07 g (10.0 mmol) of 4-toluidine, 1.52 g (15.0 mmol) of triethylamine and 1.19 g (10.2 mmol) of pent-4-enoyl chloride were allowed to react in 30 mL of dichloromethane to give 1.54 g (81%) of *N*-(4-tolyl)-pent-4-enylamide (**11d**) as a yellow solid. ^{1}H NMR: δ = 2.25 (s, 3H), 2.35-2.45 (m, 4H), 5.00 (d, *J* = 9.8 Hz, 1H), 5.08 (d, *J* = 17.1 Hz, 1H), 5.80-5.90 (m, 1H), 7.00-7.10 (m, 2H), 7.30-7.40 (m, 2H), 7.60 (broad s, 1H). ^{13}C NMR: δ = 20.8, 29.5, 36.6, 115.7, 120.1, 129.4, 133.8, 135.3, 136.9, 170.7.

***N*-(4-Nitrophenyl)-3,3-dimethyl-pent-4-enylamide (11e)** Following general procedure C, 933 mg (6.75 mmol) of 4-nitroaniline, 455 mg (4.50 mmol) of triethylamine and 664 mg (4.50 mmol) of 3,3-dimethylpent-4-enoyl chloride were allowed to react in 30 mL of dichloromethane to give 1.12 g (100%) of *N*-(4-nitrophenyl)-3,3-dimethyl-pent-4-enylamide (**11e**) as a yellow solid. ^{1}H NMR: δ = 1.18 (s, 6H), 2.40 (s, 2H), 4.45 (broad s, 1H), 4.95 (d, *J* = 10.3 Hz, 1H), 5.00 (d, *J* = 17.0 Hz, 1H), 5.88 (dd, *J* = 10.7, 17.4 Hz, 1H), 6.60-6.70 (m, 2H), 8.00-8.10 (m, 2H). ^{13}C NMR: δ = 26.7, 36.7, 47.3, 111.5, 113.3, 126.3, 145.9, 146.9, 152.5, 170.0. MS (EI): m/z = 248, 233, 180, 138, 108, 95, 83, 69, 55.

***N*-Phenyl-2-methyl-3,3-dimethyl-γ-butyrolactam (12a)** Following general procedure D, 203 mg (1.00 mmol) of *N*-phenyl-3,3-dimethyl-pent-4-enylamide (**11a**) were allowed to react with 88 µL (1.00 mmol) of trifluoromethanesulfonic acid for 5 h. Purification by flash chromatography (ethyl acetate/hexanes: 40/60) led to isolation of 202 mg (99%) of *N*-Phenyl-2-methyl-3,3-dimethyl-γ-butyrolactam (**12a**) as a colorless oil. ^{1}H NMR: δ = 1.03 (s, 3H), 1.13 (s, 3H), 1.25 (d, *J* = 6.5 Hz, 3H), 2.30 (d, *J* = 16.9 Hz, 1H), 2.38 (d, *J* = 16.9 Hz, 1H), 4.25 (q, *J* = 6.7 Hz, 1H), 6.65- 6.70 (m, 2H), 6.75-6.80 (m, 1H), 7.10-7.20 (m, 2H). ^{13}C NMR: δ = 14.1, 21.2, 25.1, 39.2, 44.3, 84.8, 121.3, 122.8, 128.5, 146.9, 162.3. MS (EI): m/z = 203, 188, 167, 149, 133, 119, 93, 77, 69. HRMS: Calc´d for $C_{13}H_{17}NO$: 203.1309 Found: 203.1310.

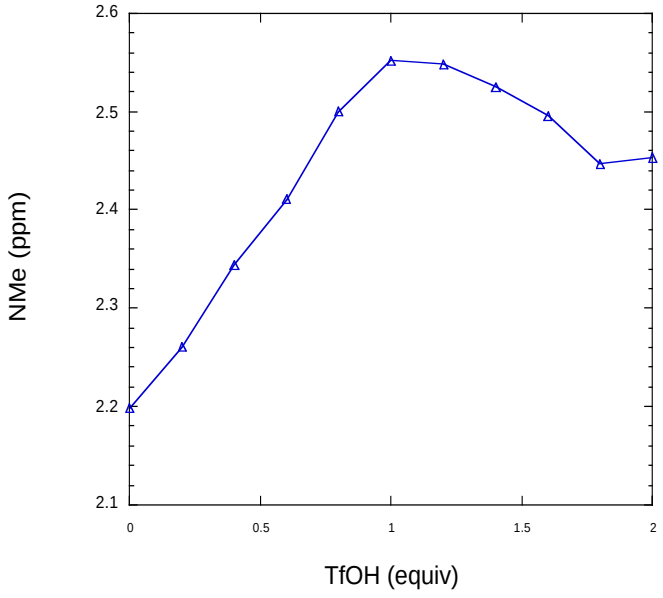
***N*-(4-Tolyl)-2-methyl-3,3-dimethyl-γ-butyrolactam (12b)** Following general procedure D, 109 mg (0.50 mmol) of *N*-(4-tolyl)-3,3-dimethyl-pent-4-enylamide (**11b**) were allowed to react with 44 µL (0.50 mmol) of trifluoromethanesulfonic acid for 5 h. Purification by flash chromatography (ethyl acetate/hexanes: 40/60) led to isolation of 108 mg (99%) of *N*-(4-tolyl)-2-

methyl-3,3-dimethyl-γ-butyrolactam (**12b**) as a colorless oil. ^{1}H NMR: δ = 1.00 (s, 3H), 1.10 (s, 3H), 1.25 (d, *J* = 6.5 Hz, 3H), 2.25 (s, 3H), 2.30 (d, *J* = 17.0 Hz, 1H), 2.38 (d, *J* = 17.0 Hz, 1H), 4.25 (q, *J* = 6.5 Hz, 1H), 6.70-6.80 (m, 2H), 7.00-7.10 (m, 2H). ^{13}C NMR: δ = 14.3, 20.8, 20.9, 24.9, 39.0, 44.3, 84.8, 122.8, 129.1, 129.4, 144.2, 162.1. MS (EI): m/z = 217, 178, 152, 107, 89, 77 HRMS: Calc´d for $C_{14}H_{19}NO$: 217.1461 Found: 217.1466.

***N*-Phenyl-2-methyl-γ-butyrolactam (12c)**[19] Following general procedure D, 175 mg (1.00 mmol) of *N*-phenyl-pent-4-enylamide (**11c**) were allowed to react with 88 µL (1.00 mmol) of trifluoromethanesulfonic acid for 30 h. Evaporation of the solvent under vacuum yielded 174 mg (99%) of *N*-phenyl-2-methyl-γ-butyrolactam (**12c**) as a colorless oil. ^{1}H NMR: δ = 1.57 (d, *J* = 6.3 Hz, 3H), 1.90-2.10 (m, 1H), 2.55 (sext, *J* = 6.5, Hz, 1H), 3.50 (dd, *J* = 7.0, 9.4 Hz, 2H), 5.40 (dq, *J* = 6.3, 9.0 Hz, 1H), 7.30-7.45 (m, 5H). ^{13}C NMR: δ = 20.0, 28.8, 32.5, 92.8, 122.3, 125.3, 128.1, 129.5, 178.9.

***N*-(4-Tolyl)-2-methyl-γ-butyrolactam (12d)**[20] Following general procedure D, 189 mg (1.00 mmol) of *N*-(4-tolyl)-pent-4-enylamide (**11d**) were allowed to react with 88 µL (1.00 mmol) of trifluoromethanesulfonic acid for 30 h. Evaporation of the solvent under vacuum yielded 187 mg (99%) of *N*-(4-tolyl)-2-methyl-γ-butyrolactam (**12d**) as a colorless oil. ^{1}H NMR: δ = 1.57 (d, *J* = 6.3 Hz, 3H), 1.90-2.05 (m, 1H), 2.30 (s, 3H), 2.55 (sext, *J* = 6.3 Hz, 1H), 3.48 (dd, *J* = 6.5, 9.4 Hz, 2H), 5.40 (dq, *J* = 6.3, 9.0 Hz, 1H), 7.10-7.20 (m, 2H), 7.35-7.40 (m, 2H). ^{13}C NMR: δ = 20.1, 21.0, 28.8, 32.4, 92.4, 122.1, 125.3, 128.1, 130.0, 178.3.

Figure S1. Titration of *N*-methyltosylamide with triflic acid.



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