

Supporting Information

for

Intramolecular hydroamination of alkynic sulfonamides catalyzed by a gold–triethynylphosphine complex: construction of azepine frameworks by 7-*exo-dig* cyclization

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Experimental procedures and NMR spectra for 4a–o and 5a, b, g–m, o, 6a, n, 7, 8, 9, 10.

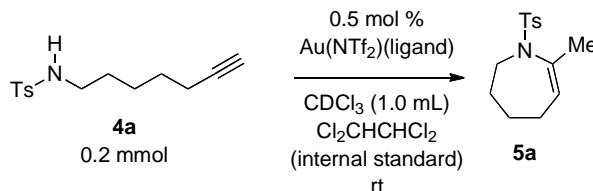
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1. General

NMR spectra were recorded on a Varian Gemini 2000 spectrometer, operating at 300 MHz for ^1H NMR, 75.4 MHz for ^{13}C NMR and 121.4 MHz for ^{31}P NMR. Chemical shift values for ^1H , ^{13}C and ^{31}P NMR are referenced to Me_4Si , the residual solvent resonances and external aqueous 85% H_3PO_4 respectively. Mass spectrometry (JEOL JMS-FABmate for EI-MS, JEOL JMS-700TZ for ESI-MS) and elemental analysis were performed at the Instrumental Analysis Division, Equipment Management Center, Creative Research Institution, Hokkaido University. Triethynylphosphine ligand **L1** was prepared according to the reported procedure [1]. AgNTf_2 was prepared from Ag_2O and $\text{HN}(\text{SO}_2\text{CF}_3)_2$ [2]. AgSbF_6 , AgBF_4 and AgOTf were purchased from Aldrich. Phosphine ligands, PPh_3 and $\text{P}(\text{OPh})_3$ were commercially available. Gold complexes $[\text{AuCl}(\text{ligand})]$ were synthesized by the reported method.¹MS4A was purchased from Junsei Chemical Co. Anhydrous solvents used in the synthesis of materials were purchased from Kanto Chemical Co. and used without further purification. Anhydrous CH_2Cl_2 and DCE were purchased from Kanto Chemical Co. and Aldrich, respectively, and these were degassed and dried with MS4A before use. Gel permeation chromatography (GPC) was performed by LC-908 (Japan Analytical Industry Ltd., two in-line JAIGEL-2H, CHCl_3 , 3.5 mL/min, UV and RI detectors). TLC analyses were performed on commercial glass plates bearing 0.25-mm layer of Merck Silica gel 60F₂₅₄. Silica gel (Kanto Chemical Co., Silica gel 60 N, spherical, neutral) was used for column chromatography. PTLC purification was performed on commercial glass plates bearing 1-mm layer of Merck Silica gel 60F₂₅₄. All reactions were carried out under argon atmosphere unless otherwise noted.

2. Time–Conversion Profiles for the Gold-Catalyzed Cyclization of **4a** with **L1**, X-Phos and IPr Ligands



$[\text{Au}(\text{NTf}_2)(\text{L1})]$ (2.6 mg, 1.0 μmol , 0.5 mol %) was placed in a NMR tube equipped with a screw cap. Separately, the alkyne sulfonamide **4a** (55 mg, 0.20 mmol) was weighed into a micro tube. The tubes were placed in a glove box. The gold complex and **4a** were dissolved in degassed dry CDCl_3 (0.25 mL), in their respective tubes. Then $\text{Cl}_2\text{CHCHCl}_2$ as an internal standard was added to a solution of the gold complex. A solution of **4a** was transferred to a solution of the catalyst with a syringe. The remaining solutions in the micro tube and the syringe were washed with CH_2Cl_2 (2×0.25 mL) and added to the reaction mixture. The tube was sealed with a cap equipped with a Teflon-coated silicon rubber septum. The tube was taken from the glove box, and was shaken at room temperature. The results with the corresponding ligands are shown in Table S1 and Figure S1.

Table S1: Time–Conversion/Yield Profiles for the Gold-Catalyzed Cyclization of **4a** with **L1**, X-Phos and IPr Ligands.

| entry | Au cat. | | time | | | | | | | |
|-------|--|-------|-------|-----|-----|-----|-----|------|------|------|
| | | | 0.5 h | 1 h | 2 h | 4 h | 8h | 20 h | 38 h | 58 h |
| 1 | $\text{Au}(\text{NTf}_2)(\text{DTBM-P})$ | conv. | 6% | 20% | 45% | 76% | 99% | 100% | - | - |
| | | yield | 6% | 18% | 40% | 67% | 88% | 89% | - | - |
| 2 | $\text{Au}(\text{NTf}_2)(\text{IPr})$ | conv. | 0% | 0% | 1% | 7% | 20% | 43% | 67% | 88% |
| | | yield | 0% | 0% | 1% | 7% | 18% | 38% | 60% | 84% |
| 3 | $\text{Au}(\text{NTf}_2)(\text{X-phos})$ | conv. | 1% | 6% | 14% | 25% | 44% | 73% | 96% | 100% |
| | | yield | 1% | 5% | 12% | 22% | 39% | 65% | 85% | 88% |

^a Conversions and yields were determined by ^1H NMR

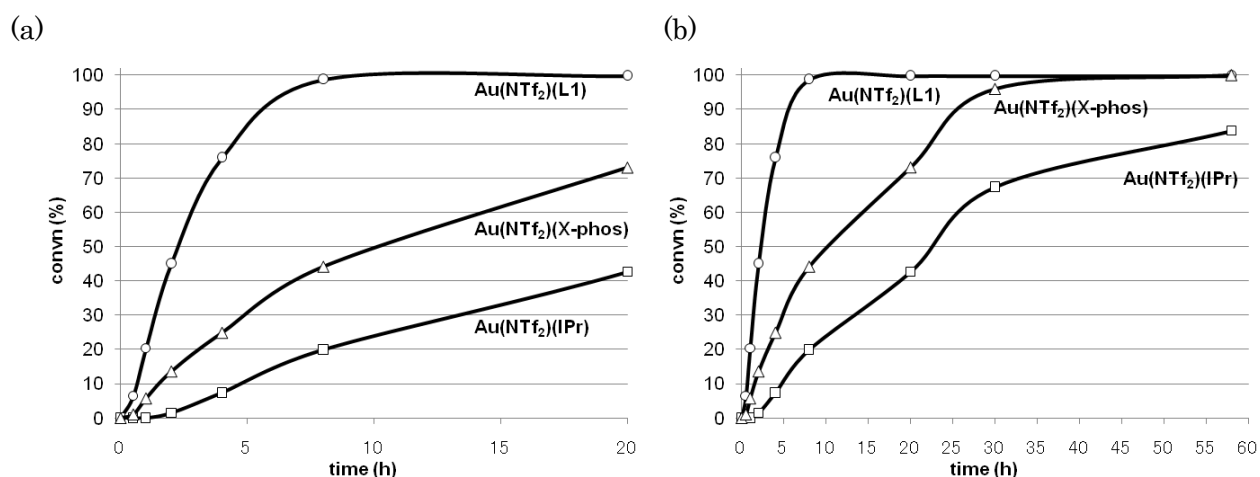


Figure S1: Time–Conversion Profiles for the Gold-Catalyzed Cyclization of **4a** with L1, X-Phos and IPr Ligands. (a) the reactions between 0 to 20 h. (b) the reactions between 0 to 58 h.

3. Preparation of Substrates

Alkynyl sulfonamides **4a**, **4b** and alkynyl amine **4f** were prepared by the alkylation of TsNH₂, NsNH₂ or PMBNH₂ (2.0 eq) with the 7-iodo-1-trimethylsilyl-1-heptyne (1.0 eq) in the presence of CsCO₃ (1.2 eq) in DMF at 80 °C to 120 °C, followed by the deprotection of TMS group by K₂CO₃ (1.2 eq) in MeOH at rt.

Alkynyl carbamates **4c**, **4d** and **4e** were prepared by the protection of 6-heptyn-1-yl amine hydrochloride (1.0 eq) with *N,N*-dimethylaminopyridine (0.10 eq), Et₃N (3.0 eq) and CbzCl or Ac₂O or (Boc)₂O (2.0 eq) in CH₂Cl₂ at rt.

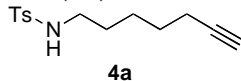
α -Substituted alkynyl sulfonamides **4g**, **4h**, **4i** and **4o** were synthesized by the aziridine opening reactions of the corresponding *N*-tosyl aziridines (1.0 eq) with alkyl cuprates (1.5 eq) prepared from ^tBuLi (6.0 eq), 5-iodo-1-trimethylsilyl-1-pentyne (3.0 eq) and CuCN (1.5 eq) in THF at –78 °C, followed by the deprotection of TMS group by K₂CO₃ (1.2 eq) in MeOH at rt.

β -Disubstituted alkynyl sulfonamides **4j**, **4k**, **4l** and benzyl sulfonamide **4m** were prepared by the reaction of the corresponding alkynyl amines (1.0 eq) with TsCl (1.5 eq), Et₃N (2.0 eq) and Me₃NHCl (0.1 eq) in CH₂Cl₂ at 0 °C. These amines were synthesized by the reductions of corresponding nitriles (1.0 eq) with LiAlH₄ (2.0 eq) in Et₂O at reflux.

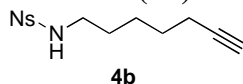
N-Tosylbenzamide **4n** was prepared by the reaction of *N*-tosyl isocyanate (1.0 eq) and *o*-alkynyl benzoic acid (1.0 eq) in the presence of Et₃N (1.0 eq) in THF at reflux.

6a was synthesized by the reaction of *N*-tosyl ϵ -caprolactam (1.0 eq) with Cp₂TiMe₂ (5.0 eq) in toluene at 70 °C [3].

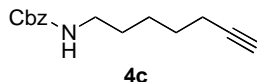
N-(6-Heptyn-1-yl)-4-toluenesulfonamide (**4a**)



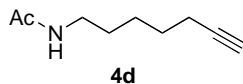
White solid. Mp = 63.9–64.3 °C. ¹H NMR (CDCl₃) δ 1.32–1.53 (m, 6H), 1.94 (t, *J* = 2.7 Hz, 1H), 2.14 (td, *J* = 6.9, 2.7 Hz, 2H), 2.44 (s, 3H), 2.95 (q, *J* = 6.9 Hz, 2H), 4.34 (br s, 1H), 7.32 (d, *J* = 8.1 Hz, 2H), 7.75 (d, *J* = 8.1 Hz, 2H). ¹³C NMR (CDCl₃) δ 17.95, 21.29, 25.34, 27.59, 28.75, 42.80, 68.35, 84.05, 127.06, 129.68, 136.85, 143.34. Anal. Calcd for C₁₄H₁₉NO₂S: C, 63.36; H, 7.22; N, 5.28%. Found: C, 63.27; H, 7.27; N, 5.27%.

N-(6-Heptyn-1-yl)-2-nitrobenzenesulfonamide (4b)

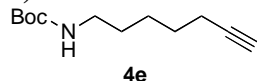
Pale yellow solid. Mp = 70.9–72.7 °C. ¹H NMR (CDCl₃) δ 1.36–1.62 (m, 6H), 1.94 (t, *J* = 2.7 Hz, 1H), 2.16 (td, *J* = 6.6, 2.7 Hz, 2H), 3.12 (q, *J* = 6.6 Hz, 2H), 5.27 (br s, 1H), 7.72–7.80 (m, 2H), 7.84–7.92 (m, 1H), 8.11–8.19 (m, 1H). ¹³C NMR (CDCl₃) δ 18.01, 25.33, 27.59, 28.94, 43.57, 68.51, 83.98, 125.45, 131.10, 132.88, 133.65, 133.70, 147.82. Anal. Calcd for C₁₃H₁₆N₂O₄S: C, 52.69; H, 5.44; N, 9.45%. Found: C, 52.62; H, 5.30; N, 9.42%.

Benzyl 6-heptyn-1-ylcarbamate (4c)

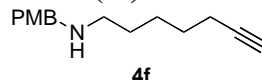
Colorless oil. ¹H NMR (CDCl₃) δ 1.36–1.60 (m, 6H), 1.94 (t, *J* = 2.7 Hz, 1H), 2.19 (td, *J* = 6.6, 2.7 Hz, 2H), 3.20 (q, *J* = 6.3 Hz, 2H), 4.75 (br s, 1H), 5.10 (s, 2H), 7.28–7.39 (m, 5H). ¹³C NMR (CDCl₃) δ 18.09, 25.58, 27.82, 29.28, 40.76, 66.48, 68.38, 84.21, 126.96, 128.10, 128.52, 136.64, 156.47. HRMS (ESI⁺) Calcd for C₁₅H₁₉NO₂Na [M+Na]⁺: *m/z* 268.13066. Found: *m/z* 268.13080.

N-(6-Heptyn-1-yl)-acetamide (4d)

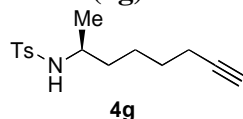
Colorless oil. ¹H NMR (CDCl₃) δ 1.30–1.62 (m, 6H), 1.95 (t, *J* = 2.7 Hz, 1H), 1.98 (s, 3H), 2.20 (td, *J* = 6.6, 2.7 Hz, 2H), 3.26 (q, *J* = 6.6 Hz, 2H), 5.46 (br s, 1H). ¹³C NMR (CDCl₃) δ 17.56, 22.28, 25.33, 27.40, 28.27, 38.76, 68.07, 83.63, 170.28. HRMS (ESI⁺) Calcd for C₉H₁₅NONa [M+Na]⁺: *m/z* 176.10459. Found: *m/z* 176.10457.

tert-Butyl 6-heptyn-1-ylcarbamate (4e)

Colorless oil. ¹H NMR (CDCl₃) δ 1.44 (s, 9H), 1.38–1.66 (m, 6H), 1.95 (t, *J* = 2.7 Hz, 1H), 2.20 (td, *J* = 6.9, 2.7 Hz, 2H), 3.12 (q, *J* = 6.9 Hz, 2H), 4.52 (br s, 1H). ¹³C NMR (CDCl₃) δ 18.10, 25.66, 27.87, 28.23, 29.40, 40.27, 68.29, 78.89, 84.22, 156.03. HRMS (ESI⁺) Calcd for C₁₂H₂₁NO₂Na [M+Na]⁺: *m/z* 234.14645. Found: *m/z* 234.14614.

N-(6-Heptyn-1-yl)-4-methoxybenzylamine (4f)

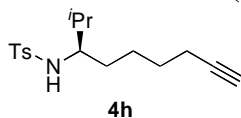
Colorless oil. ¹H NMR (CDCl₃) δ 1.31 (br s, 1H), 1.36–1.62 (m, 6H), 1.94 (t, *J* = 2.4 Hz, 1H), 2.15–2.50 (m, 2H), 2.62 (t, *J* = 6.9 Hz, 2H), 3.72 (s, 2H), 3.80 (s, 3H), 6.87 (d, *J* = 8.4 Hz, 2H), 7.24 (d, *J* = 8.4 Hz, 2H). ¹³C NMR (CDCl₃) δ 18.12, 26.26, 28.16, 29.38, 49.01, 53.30, 55.65, 68.14, 84.40, 113.68, 129.23, 132.65, 158.59. HRMS (ESI⁺) Calcd for C₁₅H₂₂NO [M+H]⁺: *m/z* 232.16959. Found: *m/z* 232.16932.

(S)-N-(7-Octyn-2-yl)-4-toluenesulfonamide (4g)

White solid. Mp = 79.8–81.0 °C. ¹H NMR (CDCl₃) δ 1.03 (d, *J* = 6.6 Hz, 3H), 1.20–1.46 (m, 6H),

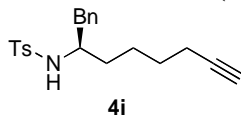
1.93 (t, $J = 2.7$ Hz, 1H), 2.09 (td, $J = 6.6, 2.7$ Hz, 2H), 2.43 (s, 3H), 3.25–3.36 (m, 1H), 4.18 (d, $J = 8.1$ Hz, 1H), 7.30 (d, $J = 8.4$ Hz, 2H), 7.76 (d, $J = 8.4$ Hz, 2H). ^{13}C NMR (CDCl_3) δ 18.05, 21.39, 21.57, 24.42, 27.82, 36.74, 49.72, 68.35, 84.17, 127.09, 129.71, 138.24, 143.32. Anal. Calcd for $\text{C}_{15}\text{H}_{21}\text{NO}_2\text{S}$: C, 64.48; H, 7.58; N, 5.01%. Found: C, 63.27; H, 7.79; N, 4.99%.

(R)-N-(2-Methyl-8-nonyn-3-yl)-4-toluenesulfonamide (4h)



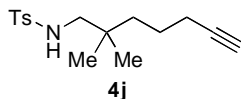
White solid. Mp = 61.5–63.8 °C. ^1H NMR (CDCl_3) δ 0.79 (d, $J = 6.9$ Hz, 6H), 1.10–1.45 (m, 6H), 1.66–1.82 (m, 1H), 1.92 (t, $J = 2.7$ Hz, 1H), 2.04 (td, $J = 6.9, 2.7$ Hz, 2H), 2.43 (s, 3H), 3.03–3.13 (m, 1H), 4.25 (br s, 1H), 7.29 (d, $J = 8.1$ Hz, 2H), 7.76 (d, $J = 8.1$ Hz, 2H). ^{13}C NMR (CDCl_3) δ 17.46, 18.03, 18.18, 21.40, 24.60, 27.99, 31.08, 59.03, 68.34, 84.17, 127.11, 129.64, 138.57, 143.24. HRMS (ESI^+) Calcd for $\text{C}_{17}\text{H}_{25}\text{NO}_2\text{SNa}$ [$\text{M}+\text{Na}$] $^+$: m/z 330.14982. Found: m/z 330.14923.

(R)-N-(1-Phenyl-7-octyn-2-yl)-4-toluenesulfonamide (4i)



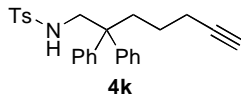
White solid. Mp = 49.6–51.7 °C. ^1H NMR (CDCl_3) δ 1.20–1.52 (m, 6H), 1.92 (t, $J = 2.4$ Hz, 1H), 2.06 (td, $J = 6.3, 2.4$ Hz, 2H), 2.42 (s, 3H), 2.68 (d, $J = 6.3$ Hz, 2H), 3.42 (sextet, $J = 6.9$ Hz, 1H), 4.22 (d, $J = 8.1$ Hz, 1H), 6.98–7.03 (m, 2H), 7.19–7.30 (m, 5H), 7.66 (d, $J = 8.4$ Hz, 2H). ^{13}C NMR (CDCl_3) δ 18.05, 21.39, 24.29, 27.81, 33.62, 41.16, 54.67, 68.37, 84.19, 126.67, 127.07, 128.59, 129.55, 129.70, 137.06, 137.81, 143.30. HRMS (ESI^+) Calcd for $\text{C}_{21}\text{H}_{25}\text{NO}_2\text{SNa}$ [$\text{M}+\text{Na}$] $^+$: m/z 378.14982. Found: m/z 378.14953.

N-(2,2-Dimethyl-6-heptyn-1-yl)-4-toluenesulfonamide (4j)

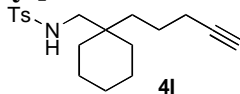


White solid. Mp = 74.3–75.0 °C. ^1H NMR (CDCl_3) δ 0.85 (s, 6H), 1.23–1.33 (m, 2H), 1.33–1.45 (m, 2H), 1.97 (t, $J = 2.7$ Hz, 1H), 2.12 (td, $J = 6.9, 2.7$ Hz, 2H), 2.44 (s, 3H), 2.69 (d, $J = 6.9$ Hz, 2H), 4.37 (br s, 1H), 7.32 (d, $J = 8.4$ Hz, 2H), 7.74 (d, $J = 8.4$ Hz, 2H). ^{13}C NMR (CDCl_3) δ 18.68, 21.27, 22.64, 24.63, 33.43, 38.19, 52.56, 68.32, 84.34, 127.00, 129.65, 136.89, 143.23. Anal. Calcd for $\text{C}_{16}\text{H}_{23}\text{NO}_2\text{S}$: C, 65.49; H, 7.90; N, 4.77%. Found: C, 65.37; H, 7.93; N, 4.75%.

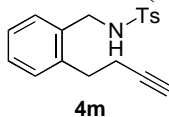
N-(2,2-Diphenyl-6-heptyn-1-yl)-4-toluenesulfonamide (4k)



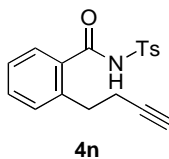
White solid. Mp = 150.0–152.2 °C. ^1H NMR (CDCl_3) δ 1.06–1.18 (m, 2H), 1.91 (t, $J = 2.7$ Hz, 1H), 2.03 (td, $J = 7.2, 2.7$ Hz, 2H), 2.15–2.24 (m, 2H), 2.43 (s, 3H), 3.55 (d, $J = 6.6$ Hz, 2H), 3.85 (t, $J = 6.6$ Hz, 1H), 7.04–7.09 (m, 4H), 7.17–7.32 (m, 8H), 7.62 (d, $J = 8.4$ Hz, 2H). ^{13}C NMR (CDCl_3) δ 18.46, 21.32, 22.77, 35.46, 49.23, 49.28, 68.47, 83.94, 126.63, 127.06, 127.63, 128.39, 129.71, 136.29, 143.48, 144.77. HRMS (ESI^+) Calcd for $\text{C}_{26}\text{H}_{27}\text{NO}_2\text{SNa}$ [$\text{M}+\text{Na}$] $^+$: m/z 440.16547. Found: m/z 440.16518.

N-[[1-(4-Pentyn-1-yl)cyclohexyl]methyl]-4-toluenesulfonamide (4l)

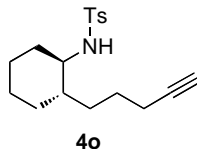
White solid. Mp = 85.8–87.5 °C. ^1H NMR (CDCl_3) δ 1.16–1.52 (m, 14H), 2.00 (t, J = 2.7 Hz, 1H), 2.11 (td, J = 6.6, 2.7 Hz, 2H), 2.44 (s, 3H), 2.75 (d, J = 6.9 Hz, 2H), 4.36 (t, J = 6.9 Hz, 1H), 7.32 (d, J = 8.4 Hz, 2H), 7.75 (d, J = 8.4 Hz, 2H). ^{13}C NMR (CDCl_3) δ 18.81, 21.07, 21.42, 21.68, 25.92, 33.36, 33.96, 35.57, 48.88, 68.54, 84.62, 127.17, 129.78, 136.93, 143.43. Anal. Calcd for $\text{C}_{19}\text{H}_{27}\text{NO}_2\text{S}$: C, 68.43; H, 8.16; N, 4.20%. Found: C, 68.26; H, 8.43; N, 4.22%.

N-{2-(3-Butyn-1-yl)benzyl}-4-toluenesulfonamide (4m)

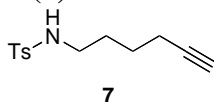
White solid. Mp = 89.8–90.2 °C. ^1H NMR (CDCl_3) δ 1.98 (t, J = 2.7 Hz, 1H), 2.44 (td, J = 7.2, 2.7 Hz, 2H), 2.45 (s, 3H), 2.75 (t, J = 7.2 Hz, 2H), 4.13 (d, J = 5.7 Hz, 2H), 4.63 (br s, 1H), 7.13–7.31 (m, 4H), 7.34 (d, J = 8.1 Hz, 2H), 7.79 (d, J = 8.1 Hz, 2H). ^{13}C NMR (CDCl_3) δ 19.86, 21.41, 30.30, 44.75, 69.50, 83.58, 126.94, 127.29, 128.49, 129.71, 129.77, 129.77, 129.82, 133.81, 136.49, 138.91, 143.66. Anal. Calcd for $\text{C}_{18}\text{H}_{19}\text{NO}_2\text{S}$: C, 68.98; H, 6.11; N, 4.47%. Found: C, 68.99; H, 6.07; N, 4.60%.

2-(3-Butyn-1-yl)-N-tosylbenzamide (4n)

White solid. Mp = 101.0–104.0 °C. ^1H NMR (CDCl_3) δ 1.96 (t, J = 2.4 Hz, 1H), 2.41 (td, J = 6.9, 2.4 Hz, 2H), 2.46 (s, 3H), 2.86 (t, J = 6.9 Hz, 2H), 7.20–7.33 (m, 2H), 8.03 (d, J = 8.4 Hz, 2H). The peak of N-H (1H) was not found. ^{13}C NMR (CDCl_3) δ 20.10, 21.56, 31.51, 69.70, 83.54, 126.82, 127.56, 128.51, 129.68, 131.21, 131.76, 132.51, 135.49, 139.83, 145.28, 166.45. Anal. Calcd for $\text{C}_{18}\text{H}_{17}\text{NO}_3\text{S}$: C, 66.03; H, 5.23; N, 4.28%. Found: C, 66.08; H, 5.32; N, 4.34%.

N-{trans-2-(4-Pentyn-1-yl)cyclohexyl}-4-toluenesulfonamide (4o)

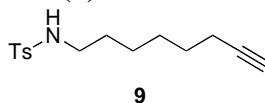
White solid. Mp = 117.0–117.9 °C. ^1H NMR (CDCl_3) δ 0.85–1.21 (m, 7H), 1.22–1.38 (m, 1H), 1.39–1.53 (m, 1H), 1.54–1.70 (m, 2H), 1.74–1.87 (m, 2H), 1.94 (t, J = 2.7 Hz, 1H), 1.98–2.08 (m, 2H), 2.43 (s, 3H), 2.68–2.84 (m, 1H), 4.19 (d, J = 8.7 Hz, 1H), 7.30 (d, J = 8.1 Hz, 2H), 7.76 (d, J = 8.1 Hz, 2H). ^{13}C NMR (CDCl_3) δ 18.35, 21.32, 24.78, 24.89, 25.16, 30.49, 31.18, 34.28, 42.26, 56.96, 68.18, 84.45, 126.97, 129.59, 138.57, 143.11. HRMS (ESI^+) Calcd for $\text{C}_{18}\text{H}_{25}\text{NO}_2\text{SNa}$ [$\text{M}+\text{Na}$] $^+$: m/z 342.14982. Found: m/z 342.14962.

N-(5-Hexyn-1-yl)-4-toluenesulfonamide (7)

White solid. Mp = 61.8–63.5 °C. ^1H NMR (CDCl_3) δ 1.46–1.68 (m, 4H), 1.93 (t, J = 2.4 Hz, 1H),

2.16 (td, $J = 6.6, 2.4$ Hz, 2H), 2.45 (s, 3H), 2.97 (q, $J = 6.6$ Hz, 2H), 4.45 (br s, 1H), 7.32 (d, $J = 8.1$ Hz, 2H), 7.75 (d, $J = 8.4$ Hz, 2H). ^{13}C NMR (CDCl_3) δ 17.61, 21.31, 25.01, 28.23, 42.44, 68.67, 83.70, 127.06, 129.71, 136.80, 143.39. Anal. Calcd for $\text{C}_{13}\text{H}_{17}\text{NO}_2\text{S}$: C, 62.12; H, 6.82; N, 5.57%. Found: C, 62.16; H, 6.88; N, 5.54%.

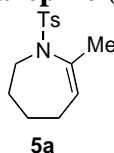
***N*-(7-Octyn-1-yl)-4-toluenesulfonamide (9)**



White solid. Mp = 52.8–54.2 °C. ^1H NMR (CDCl_3) δ 1.20–1.40 (m, 4H), 1.42–1.52 (m, 4H), 1.93 (t, $J = 2.7$ Hz, 1H), 2.15 (td, $J = 6.9, 2.7$ Hz, 2H), 2.94 (q, $J = 6.9$ Hz, 2H), 4.37 (br s, 1H), 7.32 (d, $J = 8.1$ Hz, 2H), 7.75 (d, $J = 8.1$ Hz, 2H). ^{13}C NMR (CDCl_3) δ 18.11, 21.41, 25.85, 27.97, 28.04, 29.33, 43.07, 68.29, 84.39, 127.18, 129.78, 137.05, 143.50. Anal. Calcd for $\text{C}_{15}\text{H}_{21}\text{NO}_2\text{S}$: C, 64.48; H, 7.58; N, 5.01%. Found: C, 64.49; H, 7.61; N, 5.02%.

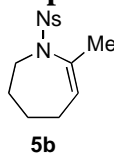
4. Cyclization Products

7-Methyl-1-tosyl-2,3,4,5-tetrahydro-1*H*-azepine (5a)



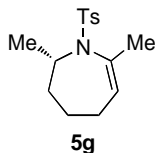
White solid. Mp = 65.8–66.1 °C. ^1H NMR (CDCl_3) δ 1.30–1.40 (m, 2H), 1.73 (quint, $J = 5.7$ Hz, 2H), 1.84 (q, $J = 6.3$ Hz, 2H), 1.96 (s, 3H), 2.42 (s, 3H), 3.41 (t, $J = 5.4$ Hz, 2H), 5.51 (t, $J = 6.9$ Hz, 1H), 7.28 (d, $J = 8.7$ Hz, 2H), 7.77 (d, $J = 8.7$ Hz, 2H). ^{13}C NMR (CDCl_3) δ 21.14, 21.78, 23.53, 25.86, 29.49, 49.38, 126.36, 126.84, 129.27, 138.89, 139.33, 142.87. Anal. Calcd for $\text{C}_{14}\text{H}_{19}\text{NO}_2\text{S}$: C, 63.36; H, 7.22; N, 5.28%. Found: C, 63.29; H, 7.16; N, 5.21%.

7-Methyl-1-nosyl-2,3,4,5-tetrahydro-1*H*-azepine (5b)



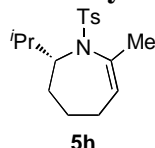
Pale yellow solid. Mp = 93.7–95.7 °C. ^1H NMR (CDCl_3) δ 1.41–1.52 (m, 2H), 1.77–1.90 (m, 2H), 1.83 (s, 3H), 2.01–2.11 (m, 2H), 3.54 (t, $J = 5.4$ Hz, 2H), 5.63 (t, $J = 6.6$ Hz, 1H), 7.61–7.77 (m, 3H), 8.03–8.08 (m, 1H). ^{13}C NMR (CDCl_3) δ 21.70, 23.59, 26.27, 30.51, 50.48, 124.12, 127.91, 129.99, 131.68, 133.47, 135.13, 138.72, 148.21. Anal. Calcd for $\text{C}_{13}\text{H}_{16}\text{N}_2\text{O}_4\text{S}$: C, 52.69; H, 5.44; N, 9.45%. Found: C, 52.44; H, 5.29; N, 9.30%.

(*S*)-2,7-Dimethyl-1-tosyl-2,3,4,5-tetrahydro-1*H*-azepine (5g)



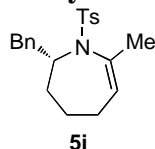
White solid. Mp = 101.2–102.5 °C. ^1H NMR (CDCl_3) δ 1.11 (d, $J = 7.2$ Hz, 3H), 1.28–1.42 (m, 2H), 1.46–1.58 (m, 1H), 1.70–1.91 (m, 3H), 1.96 (s, 3H), 2.42 (s, 3H), 4.18–4.31 (m, 1H), 5.58–5.68 (m, 1H), 7.28 (d, $J = 7.8$ Hz, 2H), 7.78 (d, $J = 8.1$ Hz, 2H). ^{13}C NMR (CDCl_3) δ 17.01, 18.24, 21.38, 24.04, 26.35, 34.72, 51.91, 127.19, 127.97, 129.52, 134.85, 139.17, 142.94. Anal. Calcd for $\text{C}_{15}\text{H}_{21}\text{NO}_2\text{S}$: C, 64.48; H, 7.58; N, 5.01%. Found: C, 64.48; H, 7.82; N, 4.81%.

(R)-2-Isopropyl-7-methyl-1-tosyl-2,3,4,5-tetrahydro-1H-azepine (5h)



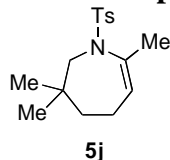
White solid. Mp = 108.1–109.0 °C. ¹H NMR (CDCl₃) δ 0.84 (d, *J* = 6.6 Hz, 3H), 0.88 (d, *J* = 6.3 Hz, 3H), 1.13–1.34 (m, 2H), 1.64–1.74 (m, 2H), 1.75–1.90 (m, 2H), 2.04 (s, 3H), 2.42 (s, 3H), 3.60–3.69 (m, 1H), 5.54–5.61 (m, 1H), 7.26 (d, *J* = 8.1 Hz, 2H), 7.77 (d, *J* = 8.1 Hz, 2H). ¹³C NMR (CDCl₃) δ 18.93, 19.47, 21.40, 21.54, 24.03, 26.94, 28.68, 30.65, 64.00, 127.51, 128.27, 129.36, 135.12, 138.82, 142.90. HRMS (EI⁺) Calcd for C₁₇H₂₅NO₂S [M]⁺: *m/z* 307.16060. Found: *m/z* 307.16042.

(R)-2-Benzyl-7-methyl-1-tosyl-2,3,4,5-tetrahydro-1H-azepine (5i)



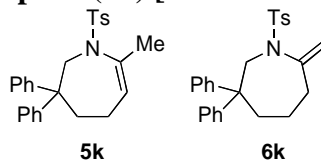
Colorless viscous oil. ¹H NMR (CDCl₃) δ 1.31–1.44 (m, 2H), 1.44–1.57 (m, 1H), 1.62–1.84 (m, 1H), 1.84–1.96 (m, 1H), 1.99 (s, 3H), 2.42 (s, 3H), 2.77–2.85 (m, 1H), 4.28–4.38 (m, 1H), 5.63–5.72 (m, 1H), 7.05–7.10 (m, 2H), 7.17–7.30 (m, 5H), 7.73 (d, *J* = 8.3 Hz, 2H). ¹³C NMR (CDCl₃) δ 18.58, 21.39, 24.03, 26.40, 31.18, 37.77, 57.89, 126.40, 127.29, 128.00, 128.51, 129.08, 129.52, 135.01, 138.60, 138.76, 143.04. HRMS (ESI⁺) Calcd for C₂₁H₂₅NO₂SNa [M+Na]⁺: *m/z* 378.14982. Found: *m/z* 378.14954.

3,3,7-Trimethyl-1-tosyl-2,3,4,5-tetrahydro-1H-azepine (5j)



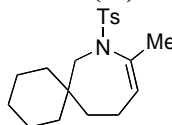
White solid. Mp = 62.9–64.4 °C. ¹H NMR (CDCl₃) δ 0.99 (s, 6H), 1.16–1.23 (m, 2H), 1.75 (s, 3H), 2.05 (q, *J* = 6.0 Hz, 2H), 2.42 (s, 3H), 3.17 (s, 2H), 5.38 (t, *J* = 6.3 Hz, 1H), 7.27 (d, *J* = 8.1 Hz, 2H), 7.75 (d, *J* = 8.1 Hz, 2H). ¹³C NMR (CDCl₃) δ 20.56, 21.37, 21.72, 26.94, 34.64, 37.65, 59.37, 125.73, 127.08, 129.50, 139.36, 139.83, 142.95. Anal. Calcd for C₁₆H₂₃NO₂S: C, 65.49; H, 7.90; N, 4.77%. Found: C, 65.41; H, 7.96; N, 4.78%.

3,3-Diphenyl-7-methyl-1-tosyl-2,3,4,5-tetrahydro-1H-azepine (5k) and 2-Methylene-6,6-diphenyl-1-tosylazepane (6k) [5k/6k = 92/8]



White solid. Mp = 152.1–152.4 °C. ¹H NMR of **5k** (CDCl₃) δ 1.94 (br s, 5H), 2.31–2.41 (m, 2H), 2.39 (s, 3H), 4.40 (s, 2H), 5.15 (t, *J* = 4.8 Hz, 1H), 7.10–7.30 (m, 12H), 7.35 (d, *J* = 8.4 Hz, 2H) {**6k**: δ 4.16 (s, 2H), 4.69 (s, 1H), 4.84 (s, 1H), 7.65 (d, *J* = 8.1 Hz, 2H)}. ¹³C NMR of **5k** (CDCl₃) δ 21.37, 22.31, 23.65, 33.14, 49.64, 57.71, 125.14, 126.03, 126.91, 127.83, 128.08, 129.33, 137.29, 138.51, 142.73, 147.30. HRMS (EI⁺) Calcd for C₂₆H₂₇NO₂S [M]⁺: *m/z* 471.17625. Found: *m/z* 417.17611.

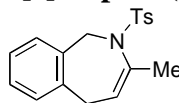
9-Methyl-8-tosyl-8-aza-9-spiro[5.6]dodecene (5l)



5l

White solid. Mp = 73.6–74.8 °C. ^1H NMR (CDCl_3) δ 1.22–1.50 (m, 12H), 1.77 (s, 3H), 1.97–2.08 (m, 2H), 2.42 (s, 3H), 3.27 (s, 2H), 5.35 (t, J = 6.6 Hz, 1H), 7.27 (d, J = 8.1 Hz, 2H), 7.54 (d, J = 8.1 Hz, 2H). ^{13}C NMR (CDCl_3) δ 20.76, 21.04, 21.28, 21.37, 26.29, 34.06, 35.12, 36.40, 59.11, 125.44, 127.00, 129.49, 139.13, 139.80, 142.91. Anal. Calcd for $\text{C}_{19}\text{H}_{27}\text{NO}_2\text{S}$: C, 68.43; H, 8.16; N, 4.20%. Found: C, 68.45; H, 8.37; N, 4.18%.

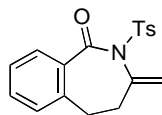
3-Methyl-2-tosyl-2,5-dihydro-1H-benzo[*c*]azepine (5m)



5m

White solid. Mp = 109.0–112.8 °C. ^1H NMR (CDCl_3) δ 2.07 (s, 3H), 2.30 (s, 3H), 3.31 (br d, J = 3.6 Hz, 2H), 4.82 (s, 2H), 5.18–5.24 (m, 1H), 6.77 (d, J = 6.9 Hz, 1H), 6.98 (d, J = 8.1 Hz, 2H), 7.06–7.21 (m, 4H), 7.25 (d, J = 8.4 Hz, 1H). ^{13}C NMR (CDCl_3) δ 21.27, 23.86, 33.96, 54.11, 118.65, 126.33, 127.14, 127.68, 128.93, 129.27, 129.33, 135.76, 136.93, 137.33, 137.79, 142.60. Anal. Calcd for $\text{C}_{18}\text{H}_{19}\text{NO}_2\text{S}$: C, 68.98; H, 6.11; N, 4.47%. Found: C, 69.04; H, 6.26; N, 4.47%.

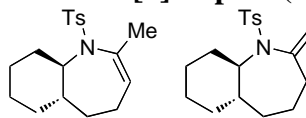
3-Methylene-2-tosyl-2,3,4,5-tetrahydro-1H-1-benzo[*c*]azepinone (6n)



6n

White solid. Mp = 126.0–128.1 °C. ^1H NMR (CDCl_3) δ 2.45 (s, 3H), 2.94 (br s, 4H), 5.09 (s, 1H), 5.14 (s, 1H), 7.13 (d, J = 7.5 Hz, 1H), 7.24–7.32 (m, 1H), 7.35–7.43 (m, 3H), 7.64 (dd, J = 7.8, 1.2 Hz, 1H), 8.08 (J = 8.4 Hz, 2H). ^{13}C NMR (CDCl_3) δ 21.59, 29.95, 37.84, 120.57, 127.32, 128.92, 129.25, 129.57, 129.92, 132.61, 133.42, 136.05, 138.88, 141.97, 145.15, 168.36. HRMS (ESI^+) Calcd for $\text{C}_{18}\text{H}_{17}\text{NO}_3\text{Na}$ [$\text{M}+\text{Na}$] $^+$: m/z 350.08214. Found: m/z 350.08177.

trans-2-Methyl-1-tosyl-4,5,5a,6,7,8,9,9a-octahydro-1H-benzo[*b*]azepine (5o) and *trans*-2-methylene-1-tosyldecahydro-1H-benzo[*b*]azepine (6o) [5o/6o = 98/2]

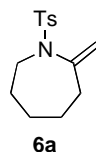


5o

6o

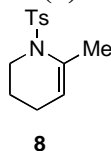
White solid. Mp = 106.6–109.9 °C. ^1H NMR of **5o** (CDCl_3) δ 0.85–1.44 (m, 9H), 1.56–2.05 (m, 4H), 2.06 (s, 3H), 2.42 (s, 3H), 3.25–3.36 (m, 2H), 5.40–5.46 (m, 1H), 7.25 (d, J = 8.4 Hz, 2H), 7.76 (d, J = 8.4 Hz, 2H) {**6o** δ 4.83 (s, 1H), 5.17 (s, 1H)}. ^{13}C NMR of **5o** (CDCl_3) δ 21.41, 23.88, 25.24, 25.99, 26.15, 27.64, 33.84, 35.30, 40.51, 65.15, 126.99, 127.18, 129.43, 133.18, 138.88, 142.89. Anal. Calcd for $\text{C}_{18}\text{H}_{25}\text{NO}_2\text{S}$: C, 67.67; H, 7.89; N, 4.38%. Found: C, 67.76; H, 8.14; N, 4.17%.

2-Methyleneazepane (6a)



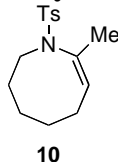
Pale yellow oil. This compound slowly decomposed to the polar unidentified materials at room temperature. ^1H NMR (CDCl_3) δ 1.44–1.56 (m, 4H), 1.69–1.80 (m, 2H), 2.05–2.13 (m, 2H), 2.42 (s, 3H), 3.51–3.57 (m, 2H), 4.82 (s, 1H), 4.98 (s, 1H), 7.28 (d, $J = 8.4$ Hz, 2H), 7.71 (d, $J = 8.4$ Hz, 2H). ^{13}C NMR (CDCl_3) δ 21.31, 27.71, 27.94, 28.38, 34.63, 48.86, 110.03, 127.41, 129.39, 136.72, 143.20, 146.13. HRMS (ESI $^+$) Calcd for $\text{C}_{14}\text{H}_{19}\text{NO}_2\text{SNa}$ [$\text{M}+\text{Na}$] $^+$: m/z 288.10287. Found: m/z 288.10312.

6-Methyl-1-tosyl-1,2,3,4-tetrahydropyridine (7)



White solid. Mp = 77.9–78.9 °C. ^1H NMR (CDCl_3) δ 1.33–1.43 (m, 2H), 1.86–1.92 (m, 2H), 2.11 (br q, $J = 1.8$ Hz, 3H), 2.43 (s, 3H), 3.59–3.65 (m, 2H), 5.00 (br s, 1H), 7.29 (d, $J = 8.1$ Hz, 2H), 7.68 (d, $J = 8.1$ Hz, 2H). ^{13}C NMR (CDCl_3) δ 20.22, 21.30, 22.33, 22.94, 46.71, 113.64, 126.91, 129.62, 134.07, 137.53, 143.26. HRMS (ESI $^+$) Calcd for $\text{C}_{14}\text{H}_{19}\text{NO}_2\text{SNa}$ [$\text{M}+\text{Na}$] $^+$: m/z 288.10287. Found: m/z 288.10312. Anal. Calcd for $\text{C}_{13}\text{H}_{17}\text{NO}_2\text{S}$: C, 62.12; H, 6.82; N, 5.57%. Found: C, 62.18; H, 6.87; N, 5.54%.

(E)- or (Z)-8-Methyl-1-tosyl-1,2,3,4,5,6-hexahydroazocine (10)



White solid. *E/Z* configuration was not determined. Mp = 80.3–80.8 °C. ^1H NMR (CDCl_3) δ 1.43–1.65 (m, 6H), 1.68 (s, 3H), 2.10–2.19 (m, 2H), 2.42 (s, 3H), 3.30 (t, $J = 4.8$ Hz, 2H), 5.71 (td, $J = 8.1, 1.2$ Hz, 1H), 7.29 (d, $J = 8.4$ Hz, 2H), 7.76 (d, $J = 8.4$ Hz, 2H). ^{13}C NMR (CDCl_3) δ 18.45, 21.38, 25.91, 26.93, 26.97, 28.80, 49.18, 127.37, 129.59, 133.04, 133.81, 138.41, 143.06. Anal. Calcd for $\text{C}_{15}\text{H}_{21}\text{NO}_2\text{S}$: C, 64.48; H, 7.58; N, 5.01%. Found: C, 64.51; H, 7.61; N, 5.01%.

5. Reference

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- [2] Williams, D. B.; Stoll, M. E.; Scott, B. L.; Costa, D. A.; Oldham, W. J. Jr. *Chem. Commun.* **2005**, 1438–1440.
- [3] Martínez, I.; Howell, A. R. *Tetrahedron Lett.* **2000**, *41*, 5607–5611.