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Studies on Palladium-Catalyzed Synthesis of Dihydrocycloocta-[*b*]indoles and their Thermal Reactivities with Maleimide or Maleic Anhydride

Can Zhu[a] and Shengming Ma[a,b,*]

[a] State Key Laboratory of Organometallic Chemistry, Shanghai Institute of Organic Chemistry, Chinese Academy of Sciences, 345 Lingling Lu, Shanghai 200032, People's Republic of China
Fax: (+86)-21-6260-9305; e-mail: masm@sioc.ac.cn
[b] Department of Chemistry, Fudan University, 220 Handan Lu, Shanghai 200433, People's Republic of China

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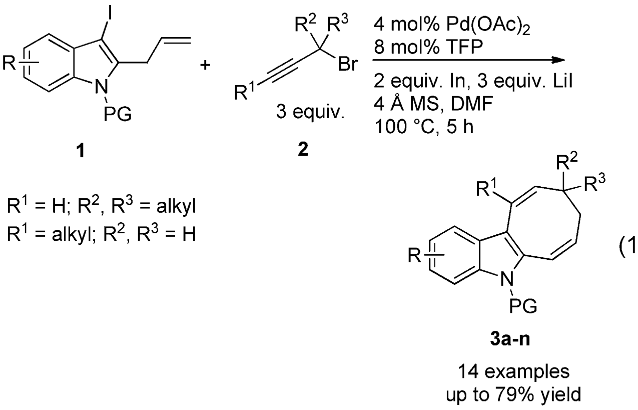
Abstract: A palladium(0)-catalyzed reaction of 2-allyl-3-indolyl boronates/propargylic carbonates was observed to afford dihydrocycloocta[*b*]indoles highly efficiently *via* carbon-carbon coupling, [1,5]-hydrogen migration involving dearomatization, and electrocyclization involving rearomatization. Their thermal reactions with the addition of dienophiles involving eletrocyclization and [4+2] cycloaddition have been studied.

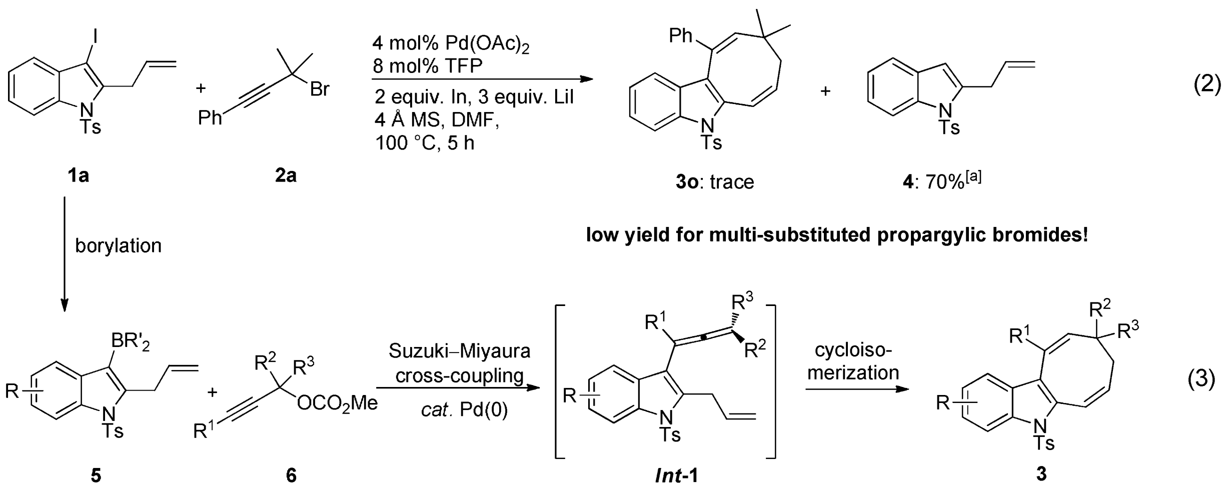
Keywords: allenes; coupling; cyclization; cycloaddition; dihydrocycloocta[*b*]indoles; palladium

The structure of cycloalka[*b*]indoles, a class of ring-fused heteroaromatic compounds, has been widely observed in various artificial compounds displaying interesting biological and pharmacological activities, as well as in natural products, and has, thus, attracted considerable attention.[1] Typical approaches towards cycloalka[*b*]indoles are based on the formation of an indole unit starting from cyclic substrates, for example, Fischer indole synthesis,[2] which suffers from some drawbacks such as harsh reaction conditions together with the use of non-readily-available starting materials, and ring-formation reaction of indole-containing substrates, which is usually favored for the formation of five- or six-membered rings.[3,4] Up to now, methodologies for the efficient synthesis of this type of skeleton, especially those involving the formation of unfavorable fused 8-membered rings are limited and, thus, highly desirable. On the other hand, allenes have been proven to be efficient building blocks for the construction of potentially useful carbo- and heterocycles.[5] Recently, we have reported a tandem [1,5]-hydrogen migration/8π-electrocyclization to construct eight-membered compounds from 1,2,4*Z*,7-tetraenes.[6] The Pd(0)-catalyzed coupling reaction has been considered as an efficient approach to produce arylallenes. Recently, an efficient protocol has been developed in this group for the synthesis of dihydrocycloocta[*b*]indoles from 2-allyl-3-iodoindoles **1** and propargylic bromides **2** directly, with the intermediacy of 2-allyl-3-allenylindoles [Eq. (1)].[7]



(1)

Further substrate scope examination showed that the reaction worked quite well with terminal propargylic bromides, as well as primary propargylic bromides, giving the corresponding products in moderate to good yields, however, non-terminal tertiary propargylic bromides (R^1, R^2, R^3≠H) led to disappointing results: Conducting the coupling reaction of 2-allyl-3-iodo-1-tosyl-1*H*-indole **1a** with internal tertiary propargylic bromides, such as 2-methyl-4-phenylbut-2-ynyl bromide **2a**, under the standard conditions afforded a trace amount of the corresponding dihydrocycloocta[*b*]indole **3o**, with a 70% yield of the reduced product, i.e., indole **4** [Eq. (2), Scheme 1]. Thus, a new ap-



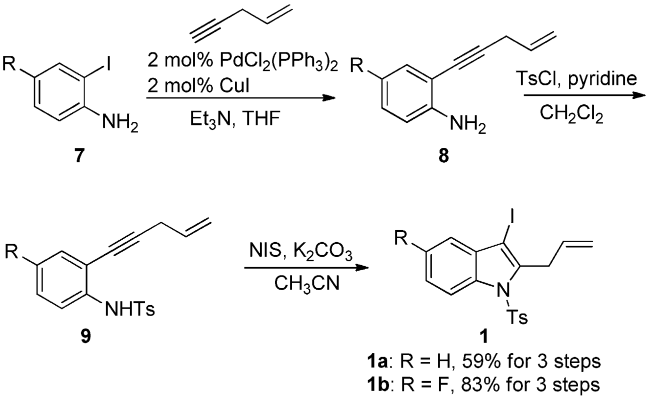
[a] NMR yield determined using CH_3NO_2 as the internal standard.

Scheme 1. The Suzuki–Miyaura cross-coupling approach towards a highly efficient synthesis of dihydrocycloocta[*b*]indoles.

proach is highly desirable. On the other hand, the highly efficient Suzuki–Miyaura cross-coupling reaction has been proven to be an extremely important tool for the formation of C–C bonds.[8,9] Thus, we envisioned that the Suzuki–Miyaura cross-coupling reaction of propargylic carbonates **6** with 2-allyl-3-indolyl boronates **5** would generate 3-allenylindoles ***Int*-1** in principle, which will be followed by cycloisomerization to afford diversified dihydrocycloocta[*b*]indoles **3** [Eq. (3), Scheme 1].

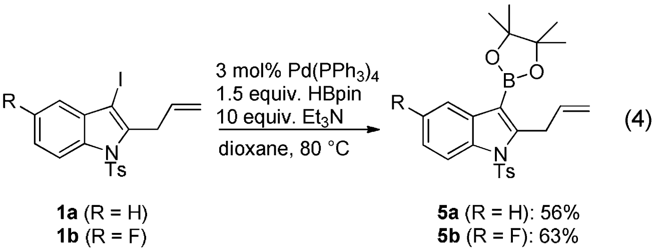
The *N*-subtituted 2-allyl-3-iodoindole derivatives **1** were synthesized *via* the palladium-catalyzed Sonogashira cross-coupling, *N*-substitution and electrophilic cyclization. The results are listed in Scheme 2.

Transformation of the iodoindoles **1** to 3-indolyl boronates **5**[10] could be achieved *via* Pd-catalyzed coupling with B_2pin_2[11] or HBpin.[9d,e,12] When the reaction was carried out in dioxane at 80 °C catalyzed by 3 mol% $Pd(PPh_3)_4$ in the presence of HBpin and Et_3N, 2-allyl-3-indolyl boronates **5a** and **5b** were easily obtained in 56% and 63% yields, respectively, which could be used for further studies [Eq. (4)].



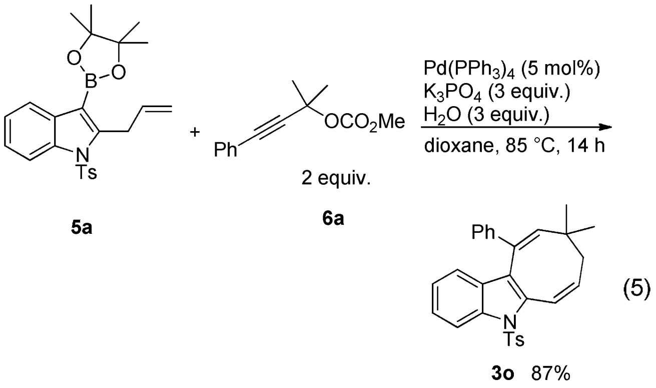
1a: R = H, 59% for 3 steps
1b: R = F, 83% for 3 steps

Scheme 2. Synthesis of substituted 2-allyl-3-iodoindoles **1**.



1a (R = H)
1b (R = F)
5a (R = H): 56%
5b (R = F): 63%

With these results in hand, we turned to examine the coupling of *N*-tosyl 2-allyl-3-indolyl boronate **5a** with internal tertiary propargylic carbonate **6a**. When the reaction was carried out in dioxane at 85 °C catalyzed by 5 mol% $Pd(PPh_3)_4$ in the presence of 3.0 equiv. of K_3PO_4 and 3.0 equiv. of H_2O, dihydrocycloocta[*b*]indole **3o** was obtained in 87% yield in one step [Eq. (5)]. The structure of **3o** was determined by X-ray single crystal diffraction analysis (Figure 1).[13]



3o 87%

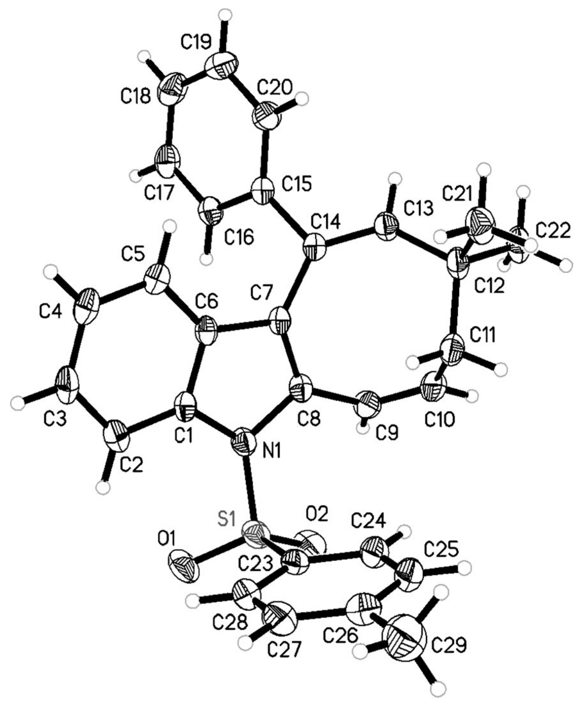
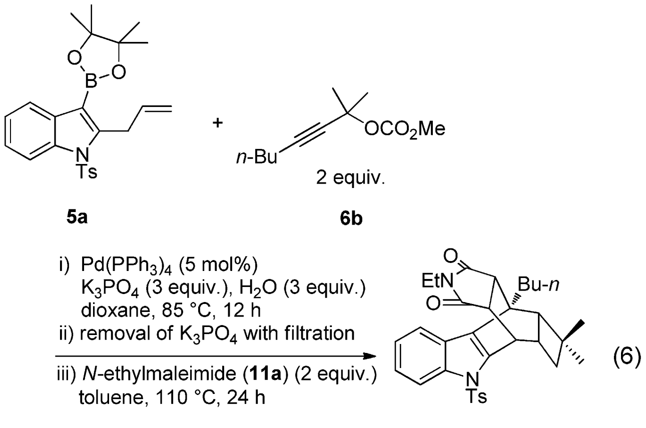


Figure 1. ORTEP drawing of **3o**.

Based on the successful attempt to construct a multi-substituted dihydrocycloocta[*b*]indole skeleton, we envisioned its subsequent thermal reaction with dienophiles: Coupling/cyclization reaction of **5a** with **6b**, followed by the removal of K_3PO_4 *via* filtration and cycloaddition with *N*-ethylmaleimide (**11a**), afforded the bridged product **10a** in 96% NMR yield, directly [Eq. (6)].



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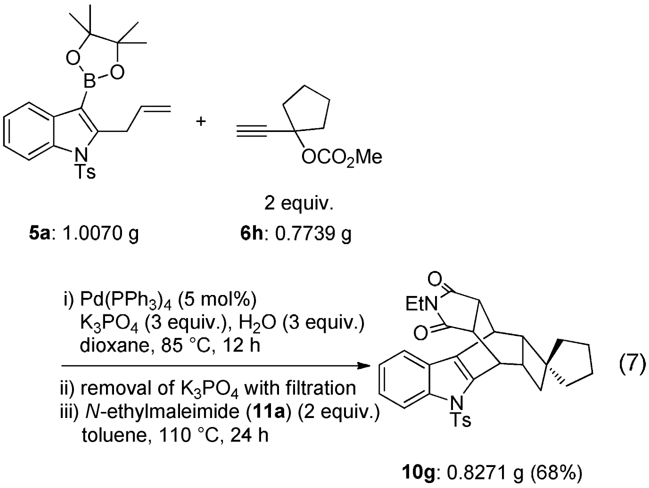
[a] Determined by ^{1}H NMR analysis with nitromethane as the internal standard.

With the standard protocol shown in Eq. (6), the scope of the propargylic carbonates is quite general: Various substituents could be introduced to the terminal position (Table 1, entries 1–5), i.e., $R^1 = H$, *n*-Bu, allyl, cinnamyl and CH_2OMe, leading to the corresponding bridged-ring products in good to excellent yields. The reaction worked very well using a tertiary propargylic carbonate ($R^2 = R^3 = Et$), thus, producing **10f** in 81% yield (Table 1, entry 6). It is worth mentioning that propargylic carbonates with a cyclic unit [R^2=-$(CH_2)_n$-] are also compatible under the standard protocol, forming spiro compounds in decent yields (Table 1, entries 7–10). Further studies showed that the dienophiles have a great influence on the reaction (Table 1, entries 11 and 12). A fluorine substituent may be introduced to the indole unit, producing the corresponding indole derivative **10m** in 67% yield (Table 1, entry 13).

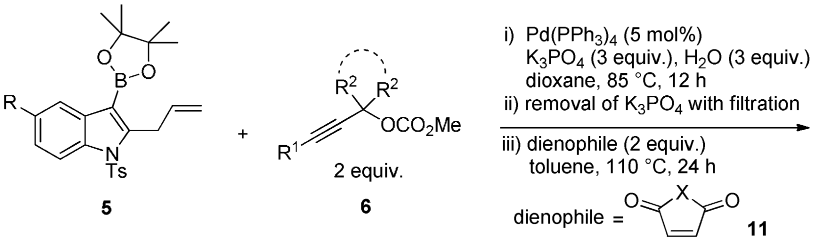
Finally, the reaction could be conducted on a 1 g scale to afford **10g** in 68% yield [Eq. (7)].



The octatomic and bridged-ring structure of these products **10a–m** was further confirmed by the X-ray single crystal diffraction study of (a) **10b** and (b) **10i** (Figure 2).[14,15]

Based on our previous observation and theoretical calculation,[6,7] a mechanism was proposed to explain the coupling/cyclization–cycloaddition reaction: The Suzuki–Miyaura coupling reaction of 2-allyl-3-indolyl boronates **5** and propargylic carbonates **6** produced 3-allenylindoles ***Int*-1**, which would be followed by cycloisomerization to generate dihydrocycloocta[*b*]indoles **3** *via* palladium(0)-catalyzed carbon-carbon coupling, [1,5]-hydrogen migration, and electrocyclization, involving a dearomatization and aromatization. Subsequent thermal reaction occurred upon heating with the dienophiles: electrocyclization of dihydrocycloocta[*b*]indoles **3** would form tetracyclic intermediates ***Int*-5** *via* the reversible 6π-pericyclic process. The cyclic diene unit in ***Int*-5** would react with dienophiles **11** *via* [4+2] cycloaddition to generate *endo*-type indole derivatives highly diastereoselectively (Scheme 3).

Table 1. Palladium-catalyzed cross-coupling reaction and cyclization of **5** with **6** and the subsequent thermal reaction with dienophiles **11**.[a]



Entry	**5** R	**6** R¹	 R²	**11** X	Yield of **10** [%][b]
1	H (**5a**)	*n*-Bu	Me (**6b**)	NEt (**11a**)	88 (**10a**)
2[c]	H (**5a**)	H	Me (**6c**)	NEt (**11a**)	64 (**10b**)
3	H (**5a**)	allyl	Me (**6d**)	NEt (**11a**)	68 (**10c**)
4	H (**5a**)	cinnamyl	Me (**6e**)	NEt (**11a**)	66 (**10d**)
5	H (**5a**)	CH_2OMe	Me (**6f**)	NEt (**11a**)	90 (**10e**)
6	H (**5a**)	H	Et (**6g**)	NEt (**11a**)	81 (**10f**)
7	H (**5a**)	H	-$(CH_2)_4$- (**6h**)	NEt (**11a**)	73 (**10g**)
8	H (**5a**)	H	-$(CH_2)_5$- (**6i**)	NEt (**11a**)	77 (**10h**)
9	H (**5a**)	Me	-$(CH_2)_5$- (**6j**)	NEt (**11a**)	81 (**10i**)
10	H (**5a**)	H	-$(CH_2)_6$- (**6k**)	NEt (**11a**)	74 (**10j**)
11[c,d]	H (**5a**)	H	Me (**6b**)	NPh (**11b**)	68 (**10k**)
12[c,e]	H (**5a**)	H	Me (**6b**)	O (**11c**)	55 (**10l**)
13	F (**5b**)	H	-$(CH_2)_4$- (**6h**)	NEt (**11a**)	67 (**10m**)

[a] The reactions were carried out on a 1.0 mmol scale in 10 mL of dioxane for the first step and 10 mL of toluene for the second step.
[b] Yield of isolated product.
[c] The reactions were carried out without H_2O (3.0 equiv.) for the first step.
[d] The reactions were carried out at 110 °C for 16 h for the second step.
[e] The reactions were carried out at 110 °C for 30 h for the second step.

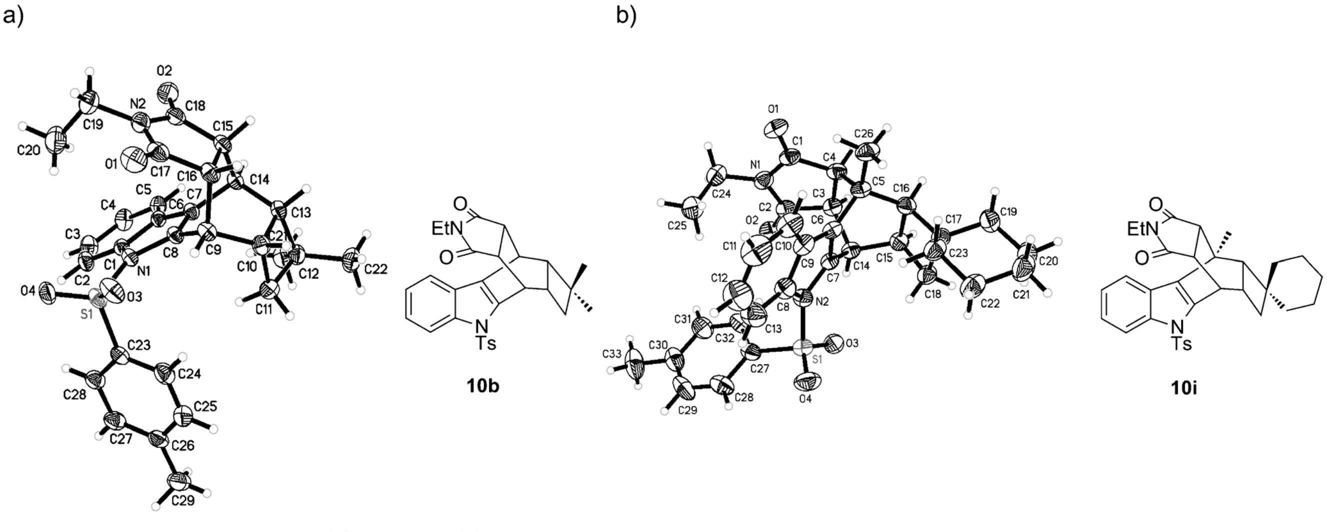
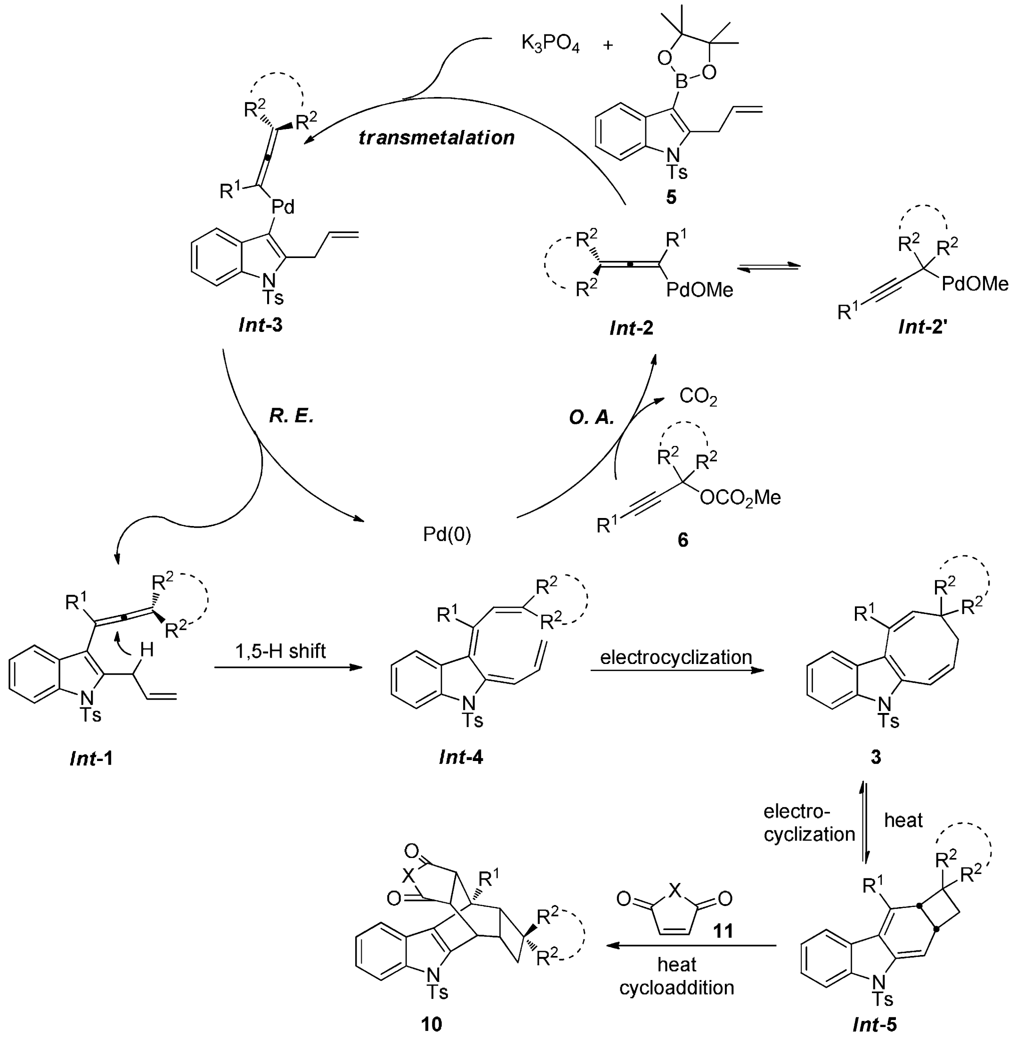


Figure 2. ORTEP drawings of (a) **10b** and (b) **10i**.

In conclusion, we have developed a Pd(0)-catalyzed coupling/cyclization reaction of 2-allyl-3-indolyl boronates with propargylic carbonates to construct dihydrocycloocta[*b*]indoles.[16] The novel approach starting from 2-allyl-3-indolyl boronates and propargylic carbonates takes advantage of the classic Suzuki–Miyaura coupling and, thus, shows much better substrate scope with the poly-substituted propargylic compounds. Further cycloaddition of dienophiles forms bridged products highly diastereoselectively.



Scheme 3. Proposed mechanism.

This tandem coupling-cyclization and subsequent thermal reaction is highly efficient, which proceeds through palladium(0)-catalyzed carbon-carbon coupling, [1,5]-hydrogen migration, electrocyclization, and cycloaddition, involving overall dearomatization and aromatization twice. Further studies in this area are currently under way in our laboratory.

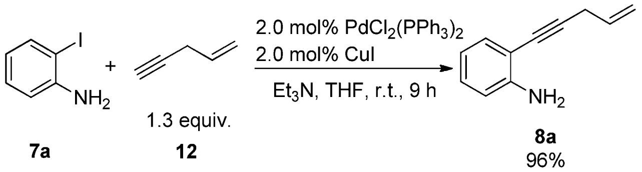
Experimental Section

General Experimental Methods

Dioxane used in these experiments was distilled over sodium wire, acetonitrile used in the experiments was distilled over CaH_2, dichloromethane used in the experiments was dried over CaH_2. All the temperatures are referred to the oil baths used. K_3PO_4 was purchased from Alfa. $Pd(PPh_3)_4$ was purchased from Sigma-Aldrich. Pinacol borane was purchased from TCI. *N*-Iodosuccinimide was purchased from Darui Chemistry. All ^{1}H NMR spectra were measured with tetramethylsilane (0 ppm) as the internal reference in $CDCl_3$ and ^{13}C NMR spectra were measured relative to the signal of $CDCl_3$ (77.0 ppm). ^{19}F NMR spectra were measured with Cl_3CF (0 ppm) as the internal reference.

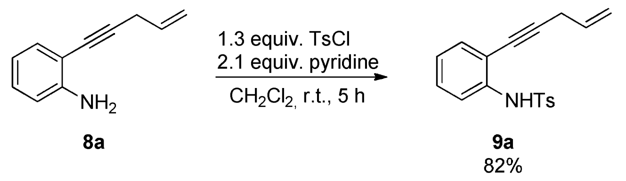
Synthesis of Starting Materials 1

2-(Pent-4-en-1-ynyl)aniline (8a): To a flame-dried three-necked flask were added $PdCl_2(PPh_3)_2$ (1.408 g, 2.0 mmol), CuI (382 mg, 2.0 mmol), 2-iodoaniline **7a** (21.982 g, 0.10 mol), pent-1-en-4-yne[17] (260 mL, 0.13 mol, 0.50 M in THF), and Et_3N (150 mL) sequentially under an Ar atmosphere. The resulting mixture was stirred at room temperature. After 9 h, the reaction was complete as monitored by TLC.

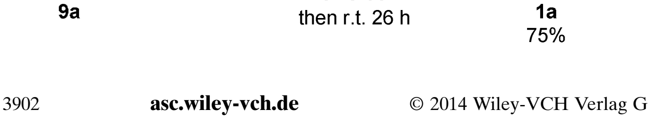


Evaporation and column chromatography on silica gel (eluent: petroleum ether/ethyl acetate = 20/1) afforded the desired product **8a** as an oil; yield; 15.130 g (96%). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.31–7.23 (m, 1H, Ar-H), 7.13–7.04 (m, 1H, Ar-H), 6.71–6.62 (m, 2H, Ar-H), 5.98–5.83 (m, 1H, =CH), 5.41 (dd, J = 16.8 Hz, 1.2 Hz, 1H, one proton of =CH_2), 5.16 (d, J = 10.1 Hz, 1.4 Hz, 1H, one proton of =CH_2), 4.15 (brs, 2H, NH_2), 3.28–3.18 (m, 2H, CH_2); ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 147.7, 132.5, 132.1, 129.0, 117.8, 116.2, 114.1, 108.4, 91.8, 79.3, 23.9; MS (EI): m/z = 158 (M^+ + 1, 12.25), 157 (M^+, 100); IR (neat): ν = 3472, 3378, 3187, 3079, 3027, 2981, 2885, 2810, 1640, 1613, 1573, 1492, 1456, 1417, 1402, 1308, 1263, 1245, 1158, 1141, 1031 cm^{-1}; HR-MS (EI): m/z = 157.0891, calcd. for $C_{11}H_{11}N$ [M^+]: 157.0891.

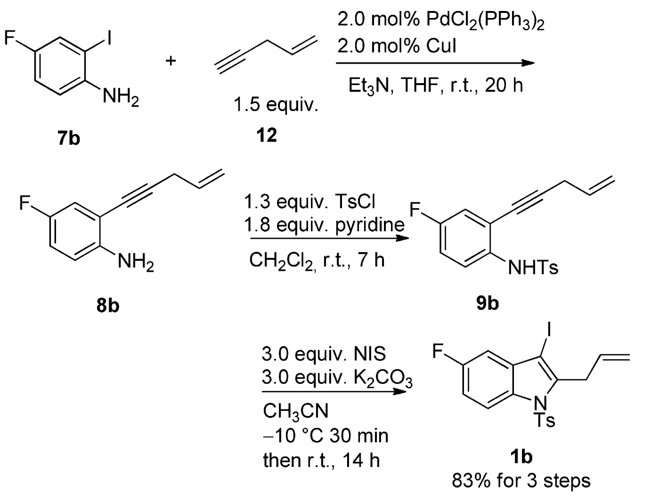
***N*-[2-(Pent-4-en-1-ynyl)phenyl]-4-methylbenzenesulfonamide (9a):** To a three-necked flask were added **8a** (544 mg, 3.5 mmol), pyridine (0.6 mL, d = 0.98 g mL^{-1}, 588 mg, 7.4 mmol), CH_2Cl_2 (20 mL), and TsCl (TsCl = *para*-toluenesulfonyl chloride) (860 mg, 4.5 mmol) sequentially. The resulting mixture was stirred at room temperature. After 5 h, the reaction was over as monitored by TLC, and quenched with 20 mL of HCl (aq., 1.0 M). After separation of the organic layer, the water layer was extracted with CH_2Cl_2 (3 × 50 mL). The combined organic layer was dried over anhydrous Na_2SO_4, filtered, evaporated, and purified *via* column chromatography on silica gel (eluent: petroleum ether/ethyl acetate = 10/1) to afford the desired product **9a** as a solid; yield; 883 mg (82%); mp 82–85 °C (petroleum ether/CH_2Cl_2). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.66 (d, J = 7.2 Hz, 2H, Ar-H), 7.57 (d, J = 8.7 Hz, 1H, Ar-H), 7.30–7.15 (m, 5H, Ar-H and NH), 6.99 (t, J = 7.8 Hz, 1H, Ar-H), 5.93–5.78 (m, 1H, =CH), 5.31 (d, J = 17.4 Hz, 1H, one proton of =CH_2), 5.20 (d, J = 9.9 Hz, 1H, one proton of =CH_2), 3.22–3.15 (m, 2H, CH_2), 2.35 (s, 3H, CH_3); ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 143.8, 137.4, 135.9, 131.9, 131.5, 129.4, 128.9, 127.1, 124.2, 119.5, 116.6, 114.5, 93.9, 77.3, 23.6, 21.4; MS (EI): m/z = 312 (M^+ + 1, 22.35), 311 (M^+, 100); IR (KBr): ν = 3255, 1641, 1598, 1487, 1450, 1393, 1329, 1290, 1256, 1187, 1165, 1092, 1042, 1019 cm^{-1}; anal. calcd for $C_{18}H_{17}NO_2S$: C 69.43, H 5.50, N 4.50J found: C 69.06, H 5.70, N 4.21.



2-Allyl-3-iodo-1-tosyl-1*H*-indole (1a): To a flame-dried three-necked flask were added **9a** (9.999 g, 32 mmol), K_2CO_3 (13.476 g, 98 mmol), NIS (NIS = *N*-iodosuccinimide, 21.721 g, 97 mmol), and MeCN (200 mL) sequentially under an Ar atmosphere. The resulting mixture was stirred at −10 °C for 30 min. The resulting mixture was allowed to warm up to room temperature. After 26 h, the reaction was over as monitored by TLC. After filtration through a short column (100–200 mesh, 5 cm) of silica gel to remove the salts (3 × 20 mL of CH_2Cl_2), the combined solvent was washed with saturated $Na_2S_2O_3$ (aq., 100 mL), extracted with CH_2Cl_2 (3 × 100 mL), and dried over anhydrous Na_2SO_4. After filtration, evaporation of the solvent and chromatography on silica gel (eluent: petroleum ether/ethyl acetate = 20/1) afforded the desired product **1a** as a solid; yield: 10.532 g (75%); mp 88–90 °C (petroleum ether/CH_2Cl_2). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.18–8.08 (m, 1H, Ar-H), 7.63 (d, J = 8.0 Hz, 2H, Ar-H), 7.37–7.20 (m, 3H, Ar-H), 7.12 (d, J = 8.0 Hz, 2H, Ar-H), 6.06–5.92 (m, 1H, =CH), 5.20–5.05 (m, 2H, =CH_2), 3.94 (d, J = 5.2 Hz, 2H, CH_2), 2.25 (s, 3H, CH_3); ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 145.0, 138.6, 136.3, 135.5, 133.6, 131.6, 129.8, 126.4, 125.4, 124.1, 121.5, 117.0, 114.9, 74.3, 33.2, 21.4; MS (EI): m/z = 438 (M^+ + 1, 6.22), 437 (M^+, 28.53), 155 (100); IR (KBr): ν = 1638, 1597, 1552, 1493, 1447, 1403, 1371, 1306, 1252, 1219, 1190, 1172, 1151, 1119, 1089, 1054, 1023 cm^{-1}; anal. calcd. for $C_{18}H_{16}INO_2S$: C 49.44, H 3.69, N 3.20; found: C 49.46, H 3.58, N 3.05.



2-Allyl-5-fluoro-3-iodo-1-tosyl-1*H*-indole (1b): To a flame-dried three-necked flask were added $PdCl_2(PPh_3)_2$ (143 mg, 0.20 mmol), CuI (39 mg, 0.20 mmol), 4-fluoro-2-iodoaniline **7b** (2.375 g, 10 mmol), pent-1-en-4-yne (30 mL, 0.50 M in THF, 15 mmol), and Et_3N (30 mL) sequentially under an Ar atmosphere. The resulting mixture was stirred at room temperature. After 20 h, the reaction was over as monitored by TLC. The mixture was evaporated to afford the crude product **8b**, which was used as the starting material in the next step without further purification and characterization.

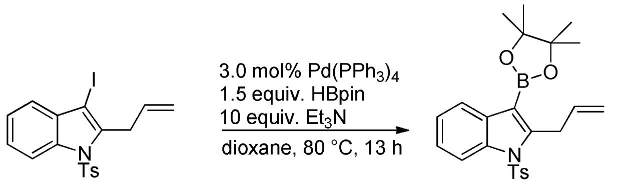


To a one-necked flask were added crude **8b** (10 mmol), pyridine (1.45 mL, d = 0.98 g mL^{-1}, 1.421 g, 18 mmol), CH_2Cl_2 (30 mL), and TsCl (TsCl = *para*-toluenesulfonyl chloride) (2.472 g, 13 mmol) sequentially. The resulting mixture was stirred at room temperature. After 7 h, the reaction was over as monitored by TLC, which was quenched with 20 mL of HCl (aq., 1.0M). After separation of the organic layer, the water layer was extracted with CH_2Cl_2 (3× 50 mL). The combined organic layer was dried over anhydrous Na_2SO_4. After filtration, evaporation of the solvent afforded the crude product **9b**, which was used as the starting material in the next step without further purification and characterization.

To a flame-dried three-necked flask were added crude **9b** (10 mmol), K_2CO_3 (4.145 g, 30 mmol), NIS (6.749 g, 30 mmol), and MeCN (80 mL) sequentially under an Ar atmosphere. The resulting mixture was stirred at −10 °C for 30 min. The resulting mixture was then allowed to warm up to room temperature and after 14 h the reaction was over as monitored by TLC. After filtration, the mixture was washed with an aqueous solution of $Na_2S_2O_3$ (1%, 50 mL), extracted with Et_2O (3×50 mL), and dried over anhydrous Na_2SO_4. After filtration, evaporation of the solvent and chromatography on silica gel (eluent: petroleum ether/ethyl acetate/dichloromethane = 40/1/1) afforded the desired product **1b** as a solid; yield: 3.800 g (83% for 3 steps); mp 81–83 °C (petroleum ether/ethyl ether). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.10 (dd, *J* = 9.0 Hz, 4.2 Hz, 1H, Ar-H), 7.63 (d, *J* = 8.0 Hz, 2H, Ar-H), 7.18 (d, *J* = 7.6 Hz, 2H, Ar-H), 7.08–6.97 (m, 2H, Ar-H), 6.03–5.89 (m, 1H, =CH), 5.20–5.04 (m, 2H, = CH_2), 3.92 (d, *J* = 5.6 Hz, 2H, CH_2), 2.31 (s, 3H, Ar-CH_3); ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 160.0 (d, *J* = 240.6 Hz), 145.3, 140.5, 135.3, 133.3, 133.1 (d, *J* = 10.2 Hz), 132.6, 129.9, 126.4, 117.2, 116.3 (d, *J* = 8.7 Hz), 113.2 (d, *J* = 24.9 Hz), 107.3 (d, *J* = 24.9 Hz), 73.3 (d, *J* = 3.6 Hz), 33.4, 21.5; ^{19}F NMR ($CDCl_3$, 376 MHz): δ = −118.8; MS (EI): *m/z* = 456 (M^++1, 25.50), 455 (M^+, 93.57), 172 (100); IR (KBr): ν = 3080, 2981, 2923, 1638, 1612, 1596, 1548, 1494, 1468, 1444, 1373, 1338, 1307, 1294, 1258, 1215, 1156, 1121, 1089, 1058 cm^{-1}; anal. calcd. for $C_{18}H_{15}FINO_2S$: C 47.49, H 3.32, N 3.08; found: C 47.49, H 3.33, N 2.98.

Synthesis of 2-Allyl-3-indolyl Boronates 5

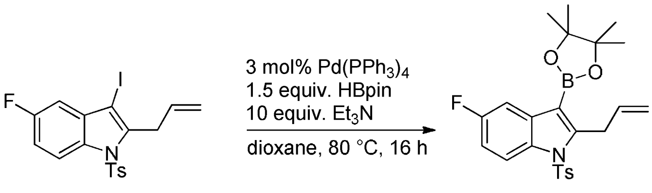
2-Allyl-3-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)-1-tosyl-1*H*-indole (5a): To a flame-dried three-necked flask were added $Pd(PPh_3)_4$ (348 mg, 0.30 mmol), **1a** (4.373 g, 10.0 mmol)/dioxane (20 mL), Et_3N (13.9 mL, *d* = 0.73 g mL^{-1}, 10.147 g, 100 mmol), HBpin (1.921 g, 15.0 mmol)/dioxane (20 mL) sequentially under an Ar atmosphere. After the mixture was stirred at 80 °C for 13 h, the reaction was complete as monitored by TLC. After evaporation of the solvent, purification *via* column chromatography on silica gel (eluent: petroleum ether/ethyl ether = 100/1 then petroleum ether/ethyl ether = 80/1) afforded the desired product **5a** as a solid; yield: 2.450 g (56%); mp 115–117 °C (petroleum ether/ethyl ether). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.13–8.06 (m, 1H, Ar-H), 7.97–7.93 (m, 1H, Ar-H), 7.66 (d, *J* = 8.0 Hz, 2H, Ar-H), 7.27–7.18 (m, 2H, Ar-H), 7.15 (d, *J* = 8.0 Hz, 2H, Ar-H), 6.18–6.02 (m, 1H, =CH), 5.15 (dd, *J* = 17.2 Hz, 1.6 Hz, 1H, one proton of =CH_2), 5.01 (dd, *J* = 10.0 Hz, 1.6 Hz, 1H, one proton of =CH_2), 4.14 (d, *J* = 6.4 Hz, 2H, CH_2), 2.30 (s, 3H, Ar-CH_3), 1.34 (s, 12H, 4× CH_3); ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 149.4, 144.7, 137.0, 136.6, 136.2, 133.2, 129.7, 126.5, 123.9, 123.5, 122.2, 116.0, 114.3, 83.2, 32.0, 24.9, 21.5; MS (EI): *m/z* = 438 (M^++1, 11.88), 437 (M^+, 20.92), 101 (100); IR (KBr): ν = 3077, 3050, 2979, 2931, 1637, 1600, 1558, 1494, 1474, 1452, 1422, 1400, 1372, 1316, 1289, 1243, 1214, 1191, 1173, 1191, 1173, 1145, 1119, 1090, 1060, 1027, 1018 cm^{-1}; anal. calcd. for $C_{24}H_{28}BNO_4S$: C 65.91, H 6.45, N 3.20; found: C 66.17, H 6.65, N 3.16.



1a

5a: 56%

2-Allyl-5-fluoro-3-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)-1-tosyl-1*H*-indole (5b): Following the procedure for the preparation of **5a**, the reaction of $Pd(PPh_3)_4$ (209 mg, 0.18 mmol), **1b** (2.740 g, 6.0 mmol)/dioxane (12 mL), Et_3N (8.3 mL, *d* = 0.73 g mL^{-1}, 6.059 g, 60 mmol), HBpin (1.156 g, 9.0 mmol)/dioxane (12 mL) afforded the desired product **5b** as an oil: yield: 1.720 g (63%). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.03 (dd, *J* = 9.4 Hz, 4.6 Hz, 1H, Ar-H), 7.67–7.59 (m, 3H, Ar-H), 7.18 (d, *J* = 8.0 Hz, 2H, Ar-H), 6.96 (td, *J* = 9.0 Hz, 2.7 Hz, 1H, Ar-H), 6.14–6.02 (m, 1H, =CH), 5.16 (dd, *J* = 17.2 Hz, 1.6 Hz, 1H, one proton of =CH_2), 5.02 (dd, *J* = 10.0 Hz, 1.6 Hz, 1H, one proton of =CH_2), 4.12 (d, *J* = 6.4 Hz, 2H, CH_2), 2.32 (s, 3H, Ar-CH_3), 1.34 (s, 12H, 4× CH_3); ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 159.8 (d, *J* = 237.6 Hz), 151.1, 144.9, 136.3, 136.0, 134.5 (d, *J* = 10.6 Hz), 133.3 (d, *J* = 1.2 Hz), 129.8, 126.4, 116.3, 115.3 (d, *J* = 9.2 Hz), 111.6 (d, *J* = 24.7 Hz), 107.9 (d, *J* = 23.6 Hz), 83.3, 32.1, 24.9, 21.5; ^{19}F NMR ($CDCl_3$, 376 MHz): δ = −120.5; MS (EI): *m/z* = 456 (M^++1, 15.6), 455 (M^+, 53.85), 200 (100); IR (neat): ν = 3083, 2979, 2932, 1637, 1612, 1589, 1558, 1494, 1466, 1452, 1395, 1372, 1317, 1266, 1254, 1214, 1192, 1173, 1154, 1144, 1121, 1090, 1063 cm^{-1}; HR-MS (EI): *m/z* = 454.1769, calcd. for $C_{24}H_{27}{}^{10}BFNO_4S$ [M^+]: 454.1774; *m/z* = 455.1735, calcd. for $C_{24}H_{27}{}^{11}BFNO_4S$ [M^+]: 455.1738.

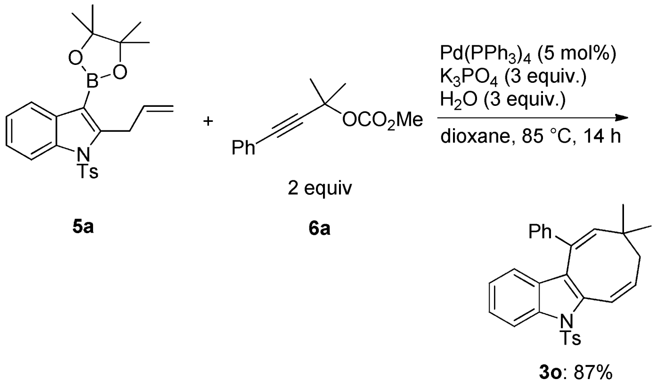


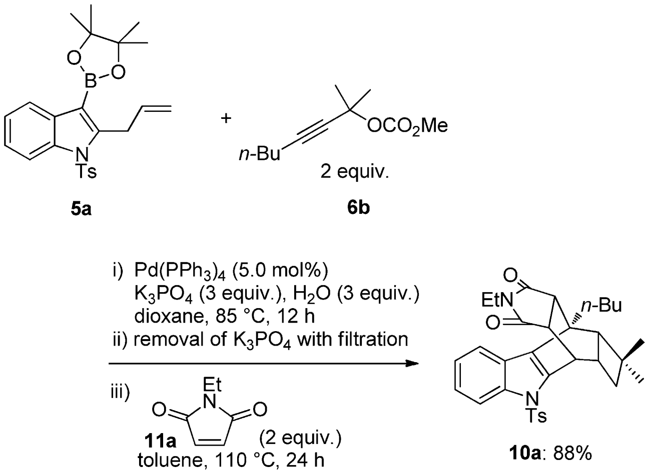
1b

5b: 63%

Synthesis of (6*Z*,10*Z*)-9,9-Dimethyl-11-phenyl-5-tosyl-8,9-dihydro-5*H*-cycloocta[*b*]indole (3o)

To a flame-dried Schlenk tube were added **5a** (87.4 mg, 0.2 mmol), $Pd(PPh_3)_4$ (11.7 mg, 0.010 mmol), K_3PO_4 (129.5 mg, 0.6 mmol)/dioxane (1 mL), propargylic carbonate **6a** (89.0 mg, 0.4 mmol), and H_2O (10.8 µL, *d* = 1.0, 0.6 mmol)/dioxane (1 mL) sequentially under an Ar atmos-





phere. After the mixture was stirred at 85 °C for 14 h, the reaction was complete as monitored by TLC. Et_2O (20 mL) was added to the resulting mixture. The mixture was then filtered to remove the inorganic salts through a short column of silica gel (2 cm, 100–200 mesh, eluent: 3×20 mL of Et_2O). After evaporation of the solvent, purification *via* column chromatography on silica gel (eluent: petroleum ether/ethyl ether = 30/1 then petroleum ether/dichloromethane = 1/1) and then recrystallization from dichloromethane and petroleum ether (1/40) afforded the desired product **3o** as a solid; yield: 78.5 mg (87%); mp 229–232 °C (petroleum ether/dichloromethane). ^1H NMR (400 MHz, $CDCl_3$): δ = 8.20 (d, J = 8.4 Hz, 1 H, Ar-H), 7.70 (d, J = 8.4 Hz, 2 H, Ar-H), 7.22–7.09 (m, 7 H, Ar-H), 7.05–6.95 (m, 2 H, Ar-H), 6.92 (t, J = 7.4 Hz, 1 H, Ar-H), 6.64 (d, J = 8.0 Hz, 1 H, CH=), 6.52–6.41 (m, 1 H, CH=), 5.99 (s, 1 H, CH=), 2.33 (s, 3 H, Ar-CH_3), 2.26 (t, J = 11.0 Hz, 1 H, one proton of CH_2), 1.69 (dd, J = 12.2 Hz, 6.2 Hz, 1 H, one proton of CH_2), 1.24 (s, 3 H, CH_3), 0.98 (s, 3 H, CH_3); ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 144.7, 144.6, 143.3, 136.91, 136.88, 135.6, 133.4, 130.3, 129.9, 129.5, 127.9, 127.3, 126.8, 126.7, 124.3, 123.3, 123.1, 121.6, 121.3, 114.3, 39.5, 38.6, 31.8, 31.5, 21.5; MS (EI): m/z = 454 (M^++1, 0.94), 453 (M^+, 1.85), 242 (100); IR (KBr): ν = 2960, 2863, 1597, 1492, 1469, 1452, 1411, 1369, 1306, 1293, 1230, 1208, 1187, 1174, 1150, 1138, 1117, 1089, 1029 cm^{-1}; anal. calcd. for $C_{29}H_{27}NO_2S$: C 76.79, H 6.00, N 3.09; found: C 76.56, H 6.08, N 2.82.

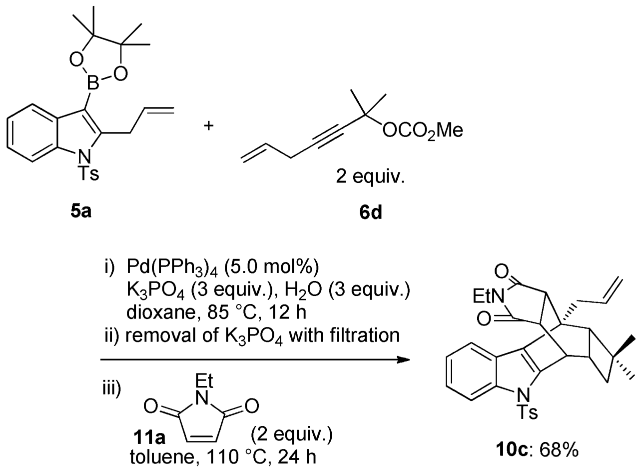
Synthesis of 10 *via* Palladium-Catalyzed Cross-Coupling Reaction and Cyclization of 5 with 6 and the Subsequent Thermal Reaction with Dienophiles 11

Synthesis of 10a (Typical Procedure I): To a flame-dried Schlenk tube were added **5a** (438.8 mg, 1.0 mmol), $Pd(PPh_3)_4$ (57.9 mg, 0.050 mmol), K_3PO_4 (636.6 mg, 3.0 mmol)/dioxane (5 mL), **6b** (396.4 mg, 2.0 mmol), and H_2O (54.0 μL, d = 1.0 g mL^{-1}, 54.0 mg, 3.0 mmol)/dioxane (5 mL) sequentially under an Ar atmosphere. After the mixture was stirred at 85 °C for 12 h, the reaction was complete as monitored by TLC. Et_2O (15 mL) was added to the resulting mixture. The reaction mixture was then filtered to remove the inorganic salts through a short column of silica gel (3 cm, 100–200 mesh, petroleum ether as the eluent before adding the sample, eluent: 3×15 mL of Et_2O). Evaporation of the solvent afforded the crude product, which was used for the next step directly without further purification and charactization.

To a flame-dried Schlenk tube were added the obtained crude product/toluene (5 mL), N-ethylmaleimide **11a** (249.6 mg, 2.0 mmol)/toluene (5 mL) sequentially under an Ar atmosphere. After the mixture was stirred at 110 °C for 24 h, the reaction was complete as monitored by TLC. After evaporation, the mixture was purified by column chromatography on silica gel (eluent: petroleum ether/ethyl acetate = 7/1 then petroleum ether/ethyl acetate = 5/1) to afford the desired product **10a** as a solid; yield: 493.7 mg (88%); mp 205–208 °C (petroleum ether/dichloromethane). ^1H NMR (300 MHz, $CDCl_3$): δ = 8.11 (d, J = 7.8 Hz, 1 H, Ar-H), 7.89 (d, J = 8.4 Hz, 2 H, Ar-H), 7.75 (d, J = 8.1 Hz, 1 H, Ar-H), 7.32–7.16 (m, 4 H, Ar-H), 4.75–4.68 (m, 1 H, CH), 3.20–2.80 (m, 6 H, 2×CH_2 and 2×CH), 2.53–2.40 (m, 1 H, CH), 2.37 (s, 3 H, Ar-CH_3), 2.22 (d, J = 8.7 Hz, 1 H, CH), 1.75–1.48 (m, 3 H, CH_2 and CH), 1.48–1.30 (m, 2 H, CH_2), 1.12 (s, 3 H, CH_3), 1.05 (t, J = 6.9 Hz, 3 H, CH_3), 0.57–0.40 (m, 4 H, CH_3 and CH), 0.15 (t, J = 7.1 Hz, 3 H, CH_3); ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 176.6, 176.0, 145.0, 136.1, 135.8, 135.7, 129.7, 127.6, 127.2, 123.4, 123.3, 120.1, 120.0, 114.1, 48.7, 45.1, 44.9, 44.8, 36.3, 36.0, 35.9, 32.82, 32.80, 32.6, 30.2, 25.8, 24.2, 23.3, 21.5, 14.1, 11.9; MS (EI): m/z = 559 (M^++1, 1.26), 558 (M^+, 3.09), 84 (100); IR (KBr): ν = 2952, 2927, 2862, 1770, 1698, 1598, 1444, 1403, 1374, 1350, 1227, 1188, 1178, 1155, 1133, 1090, 1027 cm^{-1}; anal. calcd. for $C_{33}H_{38}N_2O_4S$: C 70.94, H 6.86, N 5.01; found: C 70.95, H 7.00, N 4.86.

Synthesis of 10c: Following the procedure for the preparation of **10a**, the reaction of **5a** (437.9 mg, 1.0 mmol), $Pd(PPh_3)_4$ (57.4 mg, 0.050 mmol), K_3PO_4 (636.9 mg, 3.0 mmol)/dioxane (5 mL), **6d** (366.0 mg, 2.0 mmol), and H_2O (54.0 μL, d = 1.0 g mL^{-1}, 54.0 mg, 3.0 mmol)/dioxane (5 mL) afforded the crude product after filtration.

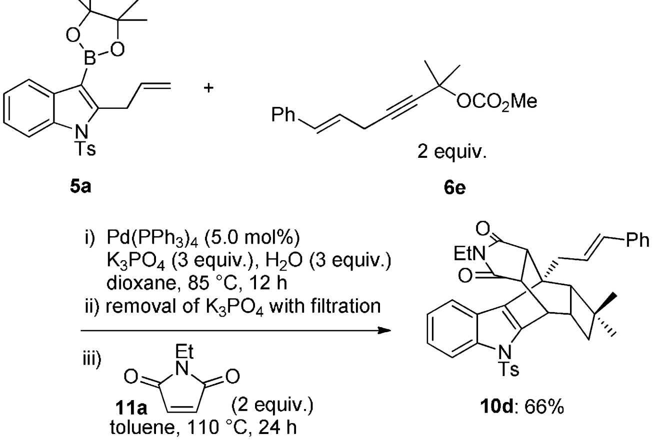
The reaction of the obtained crude product/toluene (5 mL), N-ethylmaleimide **11a** (251.9 mg, 2.0 mmol)/toluene (5 mL) afforded the desired product **10c** as a solid (eluent: petroleum ether/ethyl acetate = 7/1); yield: 369.7 mg (68%); mp 100–103 °C (petroleum ether/dichloromethane). ^1H NMR (400 MHz, $CDCl_3$): δ = 8.12 (d, J = 7.6 Hz, 1 H, Ar-H), 7.89 (d, J = 8.4 Hz, 2 H, Ar-H), 7.73–7.68 (m, 1 H, Ar-H), 7.30–7.20 (m, 4 H, Ar-H), 6.11–5.98 (m, 1 H, =CH), 5.38 (dd, J = 17.2 Hz, 1.6 Hz, 1 H, one proton of =CH_2), 5.30 (dd, J =



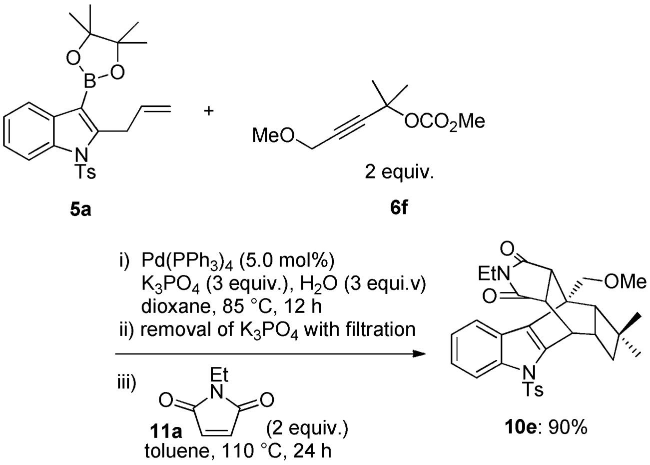
10.0 Hz, 2.0 Hz, 1H, one proton of =CH$_2$), 4.73 (dd, J= 4.2 Hz, 3.0 Hz, 1H, CH), 3.97 (dd, J=13.0 Hz, 7.8 Hz, 1H, one proton of CH$_2$), 3.18 (dd, J=13.2 Hz, 7.6 Hz, 1H, one proton of CH$_2$), 3.10–2.91 (m, 3H, NCH$_2$ and CH), 2.91–2.81 (m, 2H, 2×CH), 2.37 (s, 3H, Ar-CH$_3$), 2.19 (d, J= 8.8 Hz, 1H, CH), 1.43 (ddd, J=12.4 Hz, 8.4 Hz, 1.4 Hz, 1H, one proton of CH$_2$), 1.11 (s, 3H, CH$_3$), 0.57–0.45 (m, 4H, CH$_3$ and one proton of CH$_2$), 0.16 (t, J=7.2 Hz, 3H, CH$_3$); ^{13}C NMR (CDCl$_3$, 100 MHz): δ=176.5, 176.1, 145.0, 136.0, 135.82, 135.77, 133.3, 129.7, 127.4, 127.2, 123.5, 123.4, 119.7, 119.5, 114.1, 48.6, 45.1, 44.9, 44.6, 36.3, 35.8, 34.7, 32.8, 32.6, 32.5, 24.2, 21.5, 11.9; MS (EI): m/z=543 (M$^+$+1, 3.70), 542 (M$^+$, 11.91), 361 (100); IR (KBr): ν=2949, 2926, 1769, 1697, 1597, 1442, 1402, 1376, 1367, 1349, 1227, 1188, 1177, 1151, 1134, 1091, 1028 cm^{-1}; anal. calcd. for $C_{32}H_{34}N_2O_4S$: C 70.82, H 6.31, N 5.16; found: C 70.67, H 6.33, N 4.88.

Synthesis of 10d: Following the procedure for the preparation of **10a**, the reaction of **5a** (436.8 mg, 1.0 mmol), Pd(PPh$_3$)$_4$ (57.9 mg, 0.050 mmol), K$_3$PO$_4$ (636.3 mg, 3.0 mmol)/dioxane (5 mL), **6e** (516.8 mg, 2.0 mmol), and H$_2$O (54.0 μL, d=1.0 g mL^{-1}, 54.0 mg, 3.0 mmol)/dioxane (5 mL) afforded the crude product after filtration.

The reaction of the obtained crude product/toluene (5 mL), N-ethylmaleimide **11a** (250.9 mg, 2.0 mmol)/toluene (5 mL) afforded the desired product **10d** as a solid (eluent: petroleum ether/ethyl acetate=7/1 then petroleum ether/ethyl acetate=5/1); yield: 407.4 mg (66%); mp 138–140 °C (petroleum ether/dichloromethane). ^{1}H NMR (400 MHz, CDCl$_3$): δ=8.13 (d, J=7.6 Hz, 1H, Ar-H), 7.90 (d, J= 8.8 Hz, 2H, Ar-H), 7.74 (d, J=6.8 Hz, 1H, Ar-H), 7.42 (d, J=7.6 Hz, 2H, Ar-H), 7.38–7.20 (m, 7H, Ar-H), 6.73 (d, J= 15.6 Hz, 1H, =CH), 6.49–6.38 (m, 1H, =CH), 4.73 (dd, J= 4.0 Hz, 2.8 Hz, 1H, CH), 4.11 (dd, J=13.2 Hz, 7.6 Hz, 1H, one proton of CH$_2$), 3.33 (dd, J=13.4 Hz, 7.8 Hz, 1H, one proton of CH$_2$), 3.12–2.93 (m, 2H, NCH$_2$), 2.93–2.79 (m, 3H, 3×CH), 2.37 (s, 3H, Ar-CH$_3$), 2.22 (d, J=8.8 Hz, 1H, CH), 1.44 (dd, J=11.6 Hz, 8.4 Hz, 1H, one proton of CH$_2$), 1.15 (s, 3H, CH$_3$), 0.60 (s, 3H, CH$_3$), 0.53 (dd, J=12.0 Hz, 7.6 Hz, 1H, CH), 0.18 (t, J=7.2 Hz, 3H, CH$_3$); ^{13}C NMR (CDCl$_3$, 100 MHz): δ=176.5, 176.2, 145.0, 137.2, 136.1, 135.9, 135.8, 134.7, 129.8, 128.5, 127.4, 127.3, 127.2, 126.1, 125.0, 123.6, 123.5, 119.8, 119.6, 114.2, 48.9, 45.8, 45.1, 44.7, 36.34, 36.30, 35.9, 33.8, 32.9, 32.7, 32.6, 24.4, 21.5, 12.0; MS (ESI): m/z=641 (M+Na$^+$), 619 (M+H$^+$); IR (KBr): ν= 3055, 3026, 2973, 2949, 2926, 2862, 1769, 1697, 1597, 1495, 1442, 1403, 1376, 1368, 1349, 1265, 1228, 1188, 1177, 1152, 1134, 1125, 1091, 1028 cm^{-1}; anal. calcd. for $C_{38}H_{38}N_2O_4S$: C 73.76, H 6.19, N 4.53; found: C 73.65, H 6.20, N 4.40.



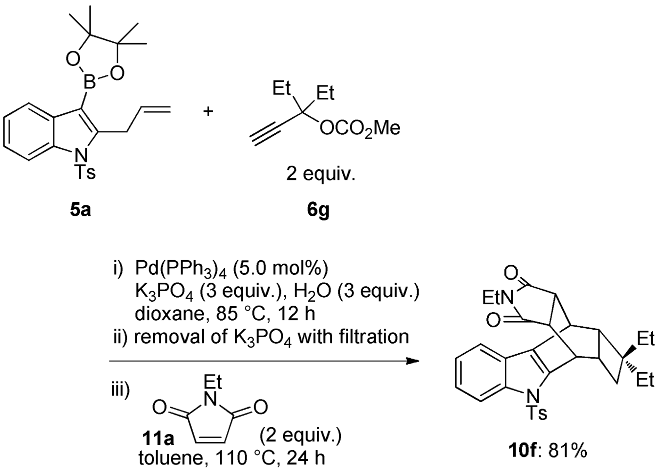
Synthesis of 10e: Following the procedure for the preparation of **10a**, the reaction of **5a** (438.0 mg, 1.0 mmol), Pd(PPh$_3$)$_4$ (58.0 mg, 0.050 mmol), K$_3$PO$_4$ (637.8 mg, 3.0 mmol)/dioxane (5 mL), **6f** (372.5 mg, 2.0 mmol), and H$_2$O (54.0 μL, d=1.0 g mL^{-1}, 54.0 mg, 3.0 mmol)/dioxane (5 mL) afforded the crude product after filtration.



The reaction of the obtained crude product/toluene (5 mL), N-ethylmaleimide **11a** (250.8 mg, 2.0 mmol)/toluene (5 mL) afforded the desired product **10e** as a solid (eluent: petroleum ether/ethyl acetate=5/1); yield: 490.5 mg (90%); mp 203–206 °C (petroleum ether/dichloromethane). ^{1}H NMR (300 MHz, CDCl$_3$): δ=8.12 (d, J=7.5 Hz, 1H, Ar-H), 7.89 (d, J=8.1 Hz, 2H, Ar-H), 7.47 (d, J=7.5 Hz, 1H, Ar-H), 7.33–7.18 (m, 4H, Ar-H), 4.96 (d, J=9.0 Hz, 1H, one proton of OCH$_2$), 4.78–4.68 (m, 1H, CH), 4.29 (d, J= 8.7 Hz, 1H, one proton of OCH$_2$), 3.58 (s, 3H, OCH$_3$), 3.15 (d, J=7.8 Hz, 1H, CH), 3.10–2.80 (m, 4H, NCH$_2$ and 2× CH), 2.45 (d, J=8.7 Hz, 1H, CH), 2.37 (s, 3H, Ar-CH$_3$), 1.42 (t, J=9.8 Hz, 1H, one proton of CH$_2$), 1.12 (s, 3H, CH$_3$), 0.56–0.42 (m, 4H, one proton of CH$_2$ and CH$_3$), 0.17

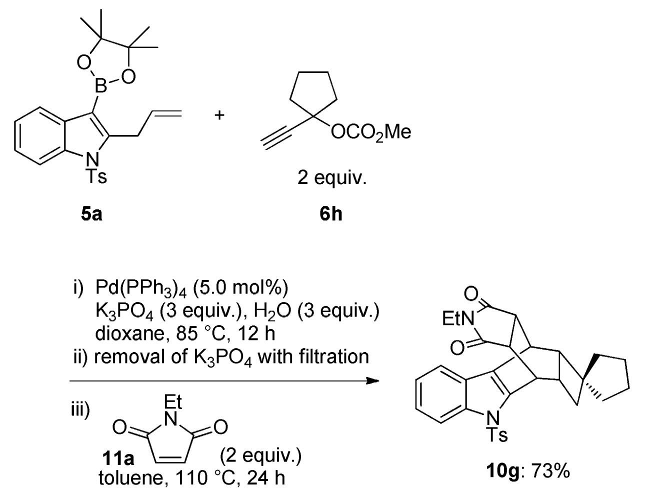
(t, $J=7.2$ Hz, 3H, CH_3); ^{13}C NMR ($CDCl_3$, 100 MHz): $\delta=$ 176.6, 176.2, 145.0, 136.0, 135.9, 135.7, 129.7, 127.2, 126.8, 123.6, 123.5, 119.6, 117.9, 114.2, 70.5, 59.3, 47.2, 46.1, 44.5, 44.2, 36.5, 36.2, 35.8, 33.0, 32.7, 32.6, 24.0, 21.5, 11.9; MS (ESI): $m/z=547$ ($M+H^+$), 569 ($M+Na^+$); IR (KBr): $\nu=$ 3053, 2976, 2949, 2814, 1770, 1698, 1598, 1494, 1476, 1445, 1403, 1377, 1351, 1308, 1294, 1265, 1227, 1188, 1177, 1146, 1135, 1125, 1092, 1059, 1028, 1013 cm^{-1}; anal. calcd. for $C_{31}H_{34}N_2O_5S$: C 68.11, H 6.27, N 5.12; found: C 68.09, H 6.47, N 4.97.

Synthesis of 10f: Following the procedure for the preparation of **10a**, the reaction of **5a** (437.8 mg, 1.0 mmol), $Pd(PPh_3)_4$ (58.1 mg, 0.050 mmol), K_3PO_4 (636.1 mg, 3.0 mmol)/dioxane (5 mL), **6g** (341.5 mg, 2.0 mmol), and H_2O (54.0 μL, $d=1.0$ $g\,mL^{-1}$, 54.0 mg, 3.0 mmol)/dioxane (5 mL) afforded the crude product after filtration.



The reaction of the obtained crude product/toluene (5 mL), *N*-ethylmaleimide **11a** (250.8 mg, 2.0 mmol)/toluene (5 mL) afforded the desired product **10f** as a solid (eluent: petroleum ether/ethyl acetate = 5/1); yield: 430.0 mg (81%); mp 193–196 °C (petroleum ether/dichloromethane). ^1H NMR (300 MHz, $CDCl_3$): $\delta=8.13$–8.07 (m, 1H, Ar-H), 7.86 (d, $J=8.4$ Hz, 2H, Ar-H), 7.55–7.46 (m, 1H, Ar-H), 7.34–7.19 (m, 4H, Ar-H), 4.67 (t, $J=3.8$ Hz, 1H, CH), 4.06 (t, $J=2.7$ Hz, 1H, CH), 3.10–2.80 (m, 5H, NCH_2 and 3×CH), 2.36 (s, 3H, Ar-CH_3), 2.17 (d, $J=8.1$ Hz, 1H, CH), 1.50–1.33 (m, 3H, CH_2 and CH), 0.98–0.82 (m, 1H, one proton of CH_2), 0.77–0.58 (m, 4H, CH_3 and one proton of CH_2), 0.47–0.26 (m, 4H, CH_3 and one proton of CH_2), 0.06 (t, $J=7.2$ Hz, 3H, CH_3); ^{13}C NMR ($CDCl_3$, 100 MHz): $\delta=$ 177.1, 176.7, 145.0, 136.2, 136.05, 135.99, 129.7, 127.6, 127.1, 123.9, 123.6, 119.3, 118.0, 114.2, 46.3, 45.0, 44.7, 41.7, 36.6, 33.8, 33.7, 32.8, 31.7, 31.5, 23.4, 21.5, 11.7, 7.8, 7.5; MS (EI): $m/z=531$ (M^++1, 4.80), 530 (M^+, 12.26), 166 (100); IR (KBr): $\nu=2961$, 2935, 2875, 1773, 1699, 1597, 1447, 1401, 1372, 1348, 1225, 1187, 1177, 1135, 1121, 1090, 1022 cm^{-1}; anal. calcd. for $C_{31}H_{34}N_2O_4S$: C 70.16, H 6.46, N 5.28; found: C 70.14, H 6.44, N 5.22.

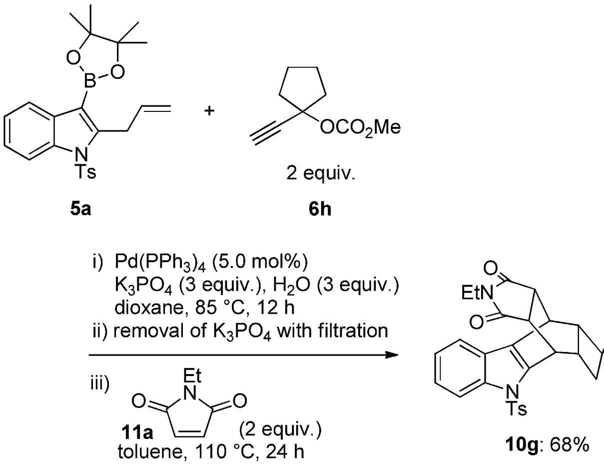
Synthesis of 10g: Following the procedure for the preparation of **10a**, the reaction of **5a** (438.8 mg, 1.0 mmol), $Pd(PPh_3)_4$ (57.9 mg, 0.050 mmol), K_3PO_4 (634.5 mg, 3.0 mmol)/dioxane (5 mL), **6h** (336.0 mg, 2.0 mmol), and H_2O (54.0 μL, $d=1.0$ $g\,mL^{-1}$, 54.0 mg, 3.0 mmol)/dioxane (5 mL) afforded the crude product after filtration.



The reaction of the obtained crude product/toluene (5 mL), *N*-ethylmaleimide **11a** (252.0 mg, 2.0 mmol)/toluene (5 mL) afforded the desired product **10g** as a solid (eluent: petroleum ether/ethyl acetate = 5/1 then petroleum ether/ethyl acetate = 3/1); yield: 388.1 mg (73%); mp 256–258 °C (petroleum ether/dichloromethane). ^1H NMR (400 MHz, $CDCl_3$): $\delta=8.10$–8.04 (m, 1H, Ar-H), 7.89 (d, $J=8.4$ Hz, 2H, Ar-H), 7.54–7.48 (m, 1H, Ar-H), 7.30–7.23 (m, 4H, Ar-H), 4.68 (t, $J=3.8$ Hz, 1H, CH), 4.00 (t, $J=3.2$ Hz, 1H, CH), 3.08–2.88 (m, 5H, NCH_2 and 3×CH), 2.41 (d, $J=8.4$ Hz, 1H, CH), 2.36 (s, 3H, Ar-CH_3), 1.65–1.48 (m, 3H, CH_2 and one proton of CH_2), 1.48–1.37 (m, 1H, one proton of CH_2), 1.37–1.19 (m, 3H, CH_2 and one proton of CH_2), 1.17–1.05 (m, 1H, one proton of CH_2), 0.54 (dd, $J=12.4$ Hz, 6.8 Hz, 1H, one proton of CH_2), 0.40–0.31 (m, 1H, one proton of CH_2), 0.07 (t, $J=7.2$ Hz, 3H, CH_3); ^{13}C NMR ($CDCl_3$, 100 MHz): $\delta=177.1$, 176.7, 144.9, 136.1, 135.9, 135.8, 129.7, 127.6, 127.1, 123.8, 123.5, 118.8, 118.1, 114.0, 46.7, 45.5, 44.7, 44.3, 42.8, 36.55, 36.50, 33.54, 33.50, 32.7, 32.1, 23.4, 22.6, 21.4, 11.7; MS (EI): $m/z=529$ (M^++1, 5.98), 528 (M^+, 16.16), 166 (100); IR (KBr): $\nu=3054$, 2949, 2869, 1773, 1705, 1597, 1494, 1481, 1448, 1403, 1378, 1292, 1269, 1226, 1177, 1145, 1092, 1022, 1009 cm^{-1}; anal. calcd. for $C_{31}H_{32}N_2O_4S$: C 70.43, H 6.10, N 5.30; found: C 70.27, H 5.98, N 5.23.

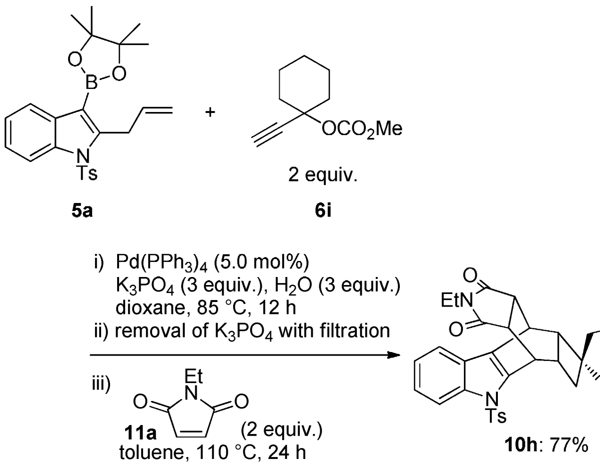
Gram-Scale Synthesis of 10g: To a flame-dried Schlenk tube were added **5a** (1.0070 g, 2.3 mmol), $Pd(PPh_3)_4$ (132.7 mg, 0.115 mmol), K_3PO_4 (1.4650 g, 6.9 mmol)/dioxane (12 mL), **6h** (773.9 mg, 4.6 mmol), and H_2O (124.2 μL, $d=1.0$ $g\,mL^{-1}$, 124.2 mg, 6.9 mmol)/dioxane (11 mL) sequentially under an Ar atmosphere. After the mixture was stirred at 85 °C for 12 h, the reaction was complete as monitored by TLC. Et_2O (30 mL) was added to the resulting mixture. The reaction mixture was then filtered to remove the inorganic salts through a short column of silica gel (3 cm, 100–200 mesh, eluent: 3×15 mL of Et_2O). Evaporation of the solvent afforded the crude product which was used for the next step directly without further purification and charactization.

To a flame-dried Schlenk tube were added the obtained crude product/toluene (12 mL), *N*-ethylmaleimide **11a** (575.7 mg, 4.6 mmol)/toluene (11 mL) sequentially under an



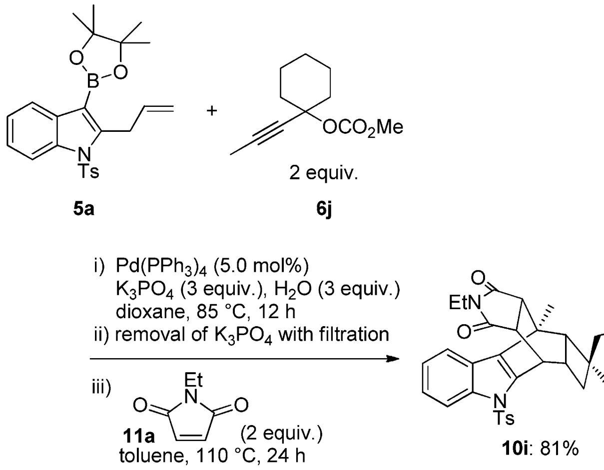
Ar atmosphere. After the mixture was stirred at 110 °C for 24 h, the reaction was complete as monitored by TLC. After evaporation, the mixture was purified by column chromatography on silica gel (eluent: petroleum ether/ethyl acetate = 5/1) to afford the desired product **10g** as a solid; yield: 827.1 mg (68%); mp 256–258 °C (petroleum ether/dichloromethane). ^{1}H NMR (400 MHz, $CDCl_3$): $\delta = 8.12$–8.04 (m, 1H, Ar-H), 7.89 (d, $J = 8.0$ Hz, 2H, Ar-H), 7.55–7.47 (m, 1H, Ar-H), 7.32–7.21 (m, 4H, Ar-H), 4.69 (t, $J = 3.4$ Hz, 1H, CH), 4.01 (t, $J = 2.4$ Hz, 1H, CH), 3.08–2.86 (m, 5H, NCH_2 and 3 × CH), 2.41 (d, $J = 7.6$ Hz, 1H, CH), 2.36 (s, 3H, Ar-CH_3), 1.65–1.48 (m, 3H, CH_2 and one proton of CH_2), 1.48–1.37 (m, 1H, one proton of CH_2), 1.37–1.18 (m, 3H, CH_2 and one proton of CH_2), 1.18–1.04 (m, 1H, one proton of CH_2), 0.53 (dd, $J = 12.4$ Hz, 6.8 Hz, 1H, one proton of CH_2), 0.40–0.29 (m, 1H, one proton of CH_2), 0.07 (t, $J = 7.2$ Hz, 3H, CH_3); ^{13}C NMR ($CDCl_3$, 100 MHz): $\delta = 177.1$, 176.7, 144.9, 136.0, 135.84, 135.78, 129.7, 127.5, 127.1, 123.7, 123.5, 118.7, 118.1, 114.0, 46.6, 45.5, 44.6, 44.3, 42.7, 36.52, 36.46, 33.50, 33.46, 32.7, 32.0, 23.4, 22.6, 21.4, 11.7.

Synthesis of 10h: Following the procedure for the preparation of **10a**, the reaction of **5a** (438.0 mg, 1.0 mmol), $Pd(PPh_3)_4$ (57.0 mg, 0.050 mmol), K_3PO_4 (635.0 mg, 3.0 mmol)/dioxane (5 mL), **6i** (365.1 mg, 2.0 mmol), and H_2O (54.0 µL, $d = 1.0$ g mL^{-1}, 54.0 mg, 3.0 mmol)/dioxane (5 mL) afforded the crude product after filtration.



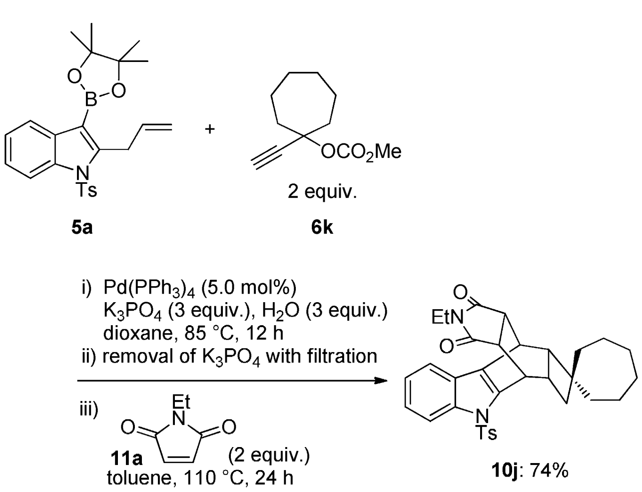
The reaction of the obtained crude product/toluene (5 mL), *N*-ethylmaleimide **11a** (250.7 mg, 2.0 mmol)/toluene (5 mL) afforded the desired product **10h** as a solid (eluent: petroleum ether/ethyl acetate = 5/1 then petroleum ether/ethyl acetate = 3/1); yield: 420.5 mg (77%); mp 217–219 °C (petroleum ether/ethyl acetate). ^{1}H NMR (400 MHz, $CDCl_3$): $\delta = 8.12$–8.04 (m, 1H, Ar-H), 7.87 (d, $J = 8.4$ Hz, 2H, Ar-H), 7.53–7.46 (m, 1H, Ar-H), 7.32–7.22 (m, 4H, Ar-H), 4.69 (t, $J = 3.6$ Hz, 1H, CH), 4.09 (t, $J = 2.8$ Hz, 1H, CH), 3.10–2.85 (m, 5H, NCH_2 and 3 × CH), 2.36 (s, 3H, Ar-CH_3), 2.18 (d, $J = 8.4$ Hz, 1H, CH), 1.55–1.22 (m, 6H, 3 × CH_2), 1.22–1.08 (m, 2H, CH_2), 1.00–0.81 (m, 2H, CH_2), 0.67–0.57 (m, 1H, one proton of CH_2), 0.39 (dd, $J = 12.4$ Hz, 7.2 Hz, 1H, one proton of CH_2), 0.05 (t, $J = 7.2$ Hz, 3H, CH_3); ^{13}C NMR ($CDCl_3$, 100 MHz): $\delta = 177.0$, 176.6, 144.9, 136.1, 136.0, 135.9, 129.7, 127.5, 127.1, 123.8, 123.6, 119.1, 118.0, 114.1, 47.0, 44.8, 44.7, 40.5, 39.0, 36.6, 34.6, 33.5, 32.7, 32.2, 31.3, 25.8, 23.0, 22.4, 21.4, 11.7; MS (EI): $m/z = 543$ ($M^+ + 1$, 5.93), 542 (M^+, 16.39), 166 (100); IR (KBr): $\nu =$ 3054, 2922, 2850, 1773, 1701, 1597, 1494, 1481, 1448, 1402, 1376, 1266, 1225, 1187, 1177, 1142, 1121, 1090, 1023, 1009 cm^{-1}; anal. calcd. for $C_{32}H_{34}N_2O_4S$: C 70.82, H 6.31, N 5.16; found: C 71.02, H 6.59, N 4.86.

Synthesis of 10i: Following the procedure for the preparation of **10a**, the reaction of **5a** (438.2 mg, 1.0 mmol), $Pd(PPh_3)_4$ (57.6 mg, 0.050 mmol), K_3PO_4 (634.5 mg, 3.0 mmol)/dioxane (5 mL), **6j** (392.9 mg, 2.0 mmol), and H_2O (54.0 µL, $d = 1.0$ g mL^{-1}, 54.0 mg, 3.0 mmol)/dioxane (5 mL) afforded the crude product after filtration.



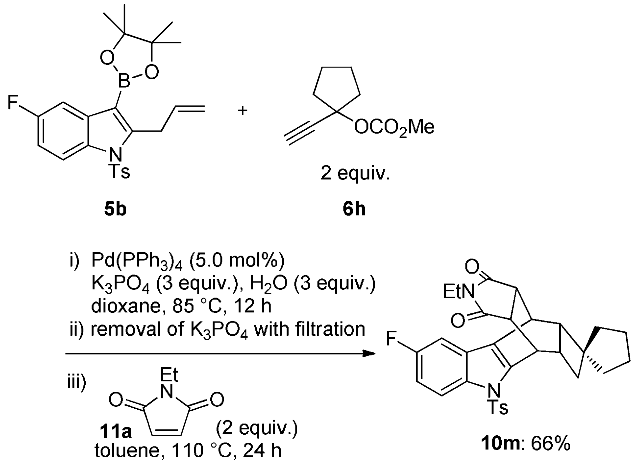
The reaction of the obtained crude product/toluene (5 mL), *N*-ethylmaleimide **11a** (251.9 mg, 2.0 mmol)/toluene (5 mL) afforded the desired product **10i** as a solid (eluent: petroleum ether/ethyl acetate = 5/1 then petroleum ether/ethyl acetate = 3/1); yield: 452.0 mg (81%); mp 81–84 °C (petroleum ether/dichloromethane). ^{1}H NMR (400 MHz, $CDCl_3$): $\delta = 8.13$ (d, $J = 7.6$ Hz, 1H, Ar-H), 7.86 (d, $J = 8.4$ Hz, 2H, Ar-H), 7.67 (d, $J = 7.2$ Hz, 1H, Ar-H), 7.31–7.18 (m, 4H, Ar-H), 4.71 (t, $J = 3.6$ Hz, 1H, CH), 3.10–2.89 (m, 3H, NCH_2 and CH), 2.85–2.76 (m, 1H, CH), 2.51 (d, $J = 7.2$ Hz, 1H, CH), 2.36 (s, 3H, Ar-CH_3), 2.11 (s, 3H, CH_3), 1.79 (d, $J = 8.8$ Hz, 1H, CH), 1.64 (d, $J = 12.4$ Hz, 1H, one proton of CH_2), 1.54 (dd, $J = 12.0$ Hz, 8.8 Hz, 1H, one proton of CH_2), 1.44 (d, $J = 12.4$ Hz, 1H, one proton of CH_2), 1.37 (d, $J = 12.8$ Hz, 1H, one proton of CH_2), 1.33–1.22 (m, 1H, one proton of CH_2), 1.22–0.87 (m, 4H, 2× CH_2), 0.82 (d, $J = 12.4$ Hz, 1H, one proton of CH_2), 0.43–0.27 (m, 2H, CH_2), 0.10 (t, $J = 7.0$ Hz, 3H, CH_3); ^{13}C NMR ($CDCl_3$, 100 MHz): $\delta = 176.4$, 176.2, 144.9, 136.3, 136.1, 135.4, 129.7, 127.5, 127.1, 123.5, 123.4, 120.5, 119.6, 114.2, 55.9, 50.0, 45.1, 41.4, 41.0, 40.7, 36.4, 33.6, 32.9, 32.6, 32.4, 26.0, 22.4, 21.8, 21.5, 20.3, 11.8; MS (EI): $m/z = 557$ ($M^+ + 1$, 1.85), 556 (M^+, 4.85), 180 (100); IR (KBr): $\nu = 2974$, 2925, 2852, 1770, 1697, 1597, 1444, 1402, 1377, 1348, 1227, 1188, 1177, 1150, 1135, 1123, 1091, 1063 cm^{-1}; anal. calcd. for $C_{33}H_{36}N_2O_4S$: C 71.19, H 6.52, N 5.03; found: C 71.20, H 6.66, N 4.75.

Synthesis of 10j: Following the procedure for the preparation of **10a**, the reaction of **5a** (437.5 mg, 1.0 mmol), $Pd(PPh_3)_4$ (58.2 mg, 0.050 mmol), K_3PO_4 (636.9 mg, 3.0 mmol)/dioxane (5 mL), **6k** (393.0 mg, 2.0 mmol), and H_2O (54.0 μL, $d = 1.0$ gmL^{-1}, 54.0 mg, 3.0 mmol)/dioxane (5 mL) afforded the crude product after filtration.



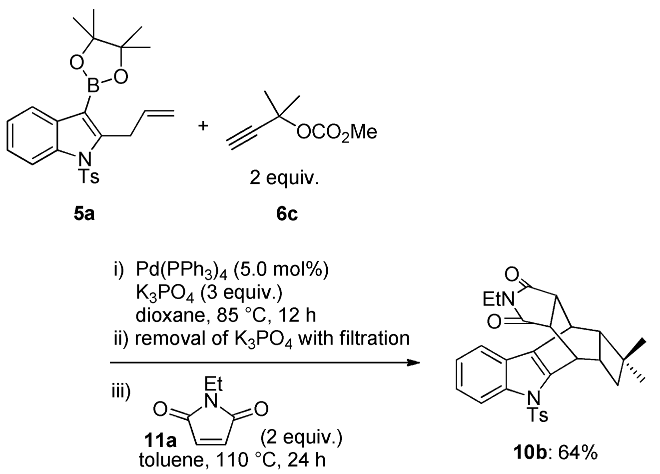
The reaction of the obtained crude product/toluene (5 mL), *N*-ethylmaleimide **11a** (251.2 mg, 2.0 mmol)/toluene (5 mL) afforded the desired product **10j** as a solid (eluent: petroleum ether/ethyl acetate = 7/1 then petroleum ether/ethyl acetate = 5/1); yield: 410.0 mg (74%); mp 101–104 °C (petroleum ether/ethyl acetate). ^1H NMR (400 MHz, $CDCl_3$): $\delta = 8.12$–8.06 (m, 1H, Ar-H), 7.86 (d, $J = 8.4$ Hz, 2H, Ar-H), 7.54–7.48 (m, 1H, Ar-H), 7.31–7.22 (m, 4H, Ar-H), 4.67 (dd, $J = 4.4$ Hz, 3.2 Hz, 1H, CH), 4.08 (t, $J = 3.2$ Hz, 1H, CH), 3.09–2.85 (m, 5H, NCH_2 and 3×CH), 2.36 (s, 3H, Ar-CH_3), 2.20 (d, $J = 8.8$ Hz, 1H, CH), 1.73–1.64 (m, 1H, one proton of CH_2), 1.56–1.07 (m, 10H, 5×CH_2), 1.04–0.93 (m, 1H, one proton of CH_2), 0.80–0.70 (m, 1H, one proton of CH_2), 0.39 (dd, $J = 12.4$ Hz, 7.2 Hz, 1H, one proton of CH_2), 0.07 (t, $J = 7.2$ Hz, 3H, CH_3); ^{13}C NMR ($CDCl_3$, 100 MHz): $\delta = 177.1$, 176.7, 144.9, 136.2, 136.1, 135.9, 129.7, 127.6, 127.1, 123.8, 123.6, 119.0, 118.0, 114.1, 47.6, 44.8, 44.7, 44.1, 41.8, 36.6, 36.5, 34.9, 33.6, 32.8, 31.9, 28.0, 27.6, 22.9, 22.7, 21.5, 11.7; MS (ESI): $m/z = 579$ ($M + Na^+$), 574 ($M + NH_4^+$), 557 ($M + H^+$); IR (KBr): $\nu = 3053$, 2924, 2852, 1773, 1699, 1597, 1494, 1480, 1447, 1401, 1372, 1348, 1271, 1225, 1187, 1176, 1162, 1135, 1121, 1090, 1021, 1010 cm^{-1}; anal. calcd. for $C_{33}H_{36}N_2O_4S$: C 71.19, H 6.52, N 5.03; found: C 71.26, H 6.65, N 4.80.

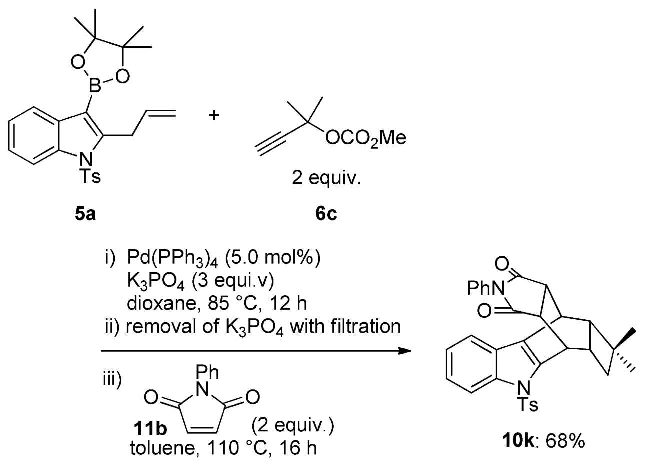
Synthesis of 10m: Following the procedure for the preparation of **10a**, the reaction of **5b** (455.3 mg, 1.0 mmol), $Pd(PPh_3)_4$ (57.5 mg, 0.050 mmol), K_3PO_4 (636.9 mg, 3.0 mmol)/dioxane (5 mL), **6h** (336.9 mg, 2.0 mmol), and H_2O (54.0 μL, $d = 1.0$ gmL^{-1}, 54.0 mg, 3.0 mmol)/dioxane (5 mL) afforded the crude product after filtration.



The reaction of the obtained crude product/toluene (5 mL), *N*-ethylmaleimide **11a** (249.7 mg, 2.0 mmol)/toluene (5 mL) afforded the desired product **10m** as a solid (eluent: petroleum ether/ethyl acetate = 5/1 then petroleum ether/ethyl acetate = 3/1); yield: 361.2 mg (66%); mp 179–181 °C (petroleum ether/ethyl acetate). ^1H NMR (400 MHz, $CDCl_3$): $\delta = 8.02$ (dd, $J = 9.0$ Hz, 4.2 Hz, 1H, Ar-H), 7.86 (d, $J = 8.8$ Hz, 2H, Ar-H), 7.28 (d, $J = 8.0$ Hz, 2H, Ar-H), 7.16 (dd, $J = 8.8$ Hz, 2.4 Hz, 1H, Ar-H), 7.01 (td, $J = 9.0$ Hz, 2.7 Hz, 1H, Ar-H), 4.66 (dd, $J = 4.8$ Hz, 3.2 Hz, 1H, CH), 3.94 (d, $J = 3.0$ Hz, 1H, CH), 3.10–2.87 (m, 5H, NCH_2 and 3×CH), 2.43–2.35 (m, 4H, CH_3 and CH), 1.65–1.07 (m, 8H, 4×CH_2), 0.49 (dd, $J = 12.6$ Hz, 6.6 Hz, 1H, one proton of CH_2), 0.40–0.32 (m, 1H, one proton of CH_2), 0.12 (t, $J = 7.2$ Hz, 3H, CH_3); ^{13}C NMR ($CDCl_3$, 100 MHz): $\delta = 177.0$, 176.6, 159.7 (d, $J = 239.8$ Hz), 145.2, 137.9, 135.9, 132.1 (d, $J = 0.9$ Hz), 129.8, 128.6 (d, $J = 9.9$ Hz), 127.2, 118.6 (d, $J = 4.0$ Hz), 115.0 (d, $J = 9.7$ Hz), 111.7 (d, $J = 25.7$ Hz), 103.9 (d, $J = 23.9$ Hz), 46.6, 45.5, 44.6, 44.3, 42.8, 36.7, 36.6, 33.58, 33.56, 32.8, 32.1, 23.4, 22.7, 21.5, 11.8; ^{19}F NMR ($CDCl_3$, 376 MHz): $\delta = -119.6$; MS (EI): $m/z = 547$ ($M^+ + 1$, 14.67), 546 (M^+, 41.20), 339 (100); IR (KBr): $\nu = 2951$, 2869, 1773, 1701, 1617, 1596, 1494, 1452, 1402, 1377, 1365, 1349, 1291, 1226, 1186, 1174, 1145, 1133, 1091 cm^{-1}; anal. calcd. for $C_{31}H_{31}FN_2O_4S$: C 68.11, H 5.72, N 5.12; found: C 68.04, H 5.86, N 4.90.

Synthesis of 10b (Typical Procedure II): To a flame-dried Schlenk tube were added **5a** (437.6 mg, 1.0 mmol), $Pd(PPh_3)_4$ (57.8 mg, 0.050 mmol), K_3PO_4 (635.7 mg, 3.0 mmol)/dioxane (5 mL), and **6c** (285.6 mg, 2.0 mmol)/dioxane (5 mL) sequentially under an Ar atmosphere. After the mixture was stirred at 85 °C for 12 h, the reaction was complete as monitored by TLC. Et_2O (15 mL) was added to the resulting mixture. The reaction mixture was then filtered





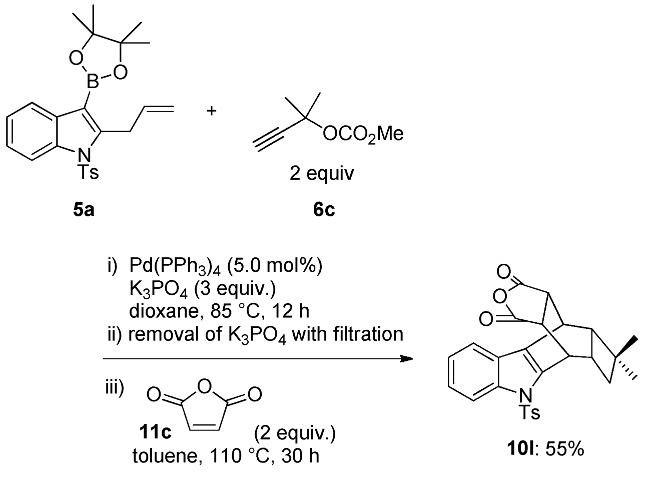
to remove the inorganic salts through a short column of silica gel (3 cm, 100–200 mesh, petroleum ether as the eluent before adding the sample, eluent: 3×15 mL of Et_2O). Evaporation of the solvent afforded the crude product, which was used for the next step directly without further purification and charactization.

To a flame-dried Schlenk tube were added the obtained crude product/toluene (5 mL), *N*-ethylmaleimide **11a** (250.5 mg, 2.0 mmol)/toluene (5 mL) sequentially under an Ar atmosphere. After the mixture was stirred at 110 °C for 24 h, the reaction was complete as monitored by TLC. After evaporation, the mixture was purified by column chromatography on silica gel (eluent: petroleum ether/ethyl acetate = 5/1 then petroleum ether/ethyl acetate = 3/1 twice) to afford the desired product **10b** as a solid; yield: 319.5 mg (64%); mp 195–197 °C (petroleum ether/dichloromethane). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.11–8.04 (m, 1H, Ar-H), 7.88 (d, J = 8.4 Hz, 2H, Ar-H), 7.56–7.48 (m, 1H, Ar-H), 7.32–7.23 (m, 4H, Ar-H), 4.72–4.67 (m, 1H, Ar-CH), 4.01 (t, J = 3.0 Hz, 1H, CH), 3.08–2.86 (m, 5H, NCH_2 and 3×CH), 2.37 (s, 3H, Ar-CH_3), 2.18 (d, J = 8.4 Hz, 1H, CH), 1.50–1.41 (m, 1H, one proton of CH_2), 1.10 (s, 3H, CH_3), 0.55–0.42 (m, 4H, CH_3 and one proton of CH_2), 0.09 (t, J = 7.2 Hz, 3H, CH_3); ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 177.0, 176.8, 145.0, 136.2, 136.1, 135.8, 129.8, 127.6, 127.2, 123.9, 123.6, 118.7, 118.2, 114.1, 48.1, 44.79, 44.76, 36.7, 36.5, 34.8, 33.1, 32.8, 32.4, 31.7, 22.9, 21.5, 11.8; MS (EI): m/z = 503 (M^+ + 1, 5.93), 502 (M^+, 21.21), 166 (100); IR (KBr): ν = 3054, 2949, 2926, 2863, 1773, 1699, 1597, 1447, 1401, 1371, 1349, 1294, 1268, 1225, 1187, 1176, 1161, 1144, 1121, 1090, 1026, 1010 cm^{-1}; anal. calcd. for $C_{29}H_{30}N_2O_4S$: C 69.30, H 6.02, N 5.57; found: C 68.90, H 6.13, N 5.41.

Synthesis of 10k: Following the procedure for the preparation of **10b**, the reaction of **5a** (438.7 mg, 1.0 mmol), $Pd(PPh_3)_4$ (57.8 mg, 0.050 mmol), K_3PO_4 (633.9 mg, 3.0 mmol)/dioxane (5 mL), and **6c** (286.0 mg, 2.0 mmol)/dioxane (5 mL) afforded the crude product after filtration.

The reaction of the obtained crude product/toluene (5 mL), *N*-phenylmaleimide **11b** (345.9 mg, 2.0 mmol)/toluene (5 mL) afforded the desired product **10k** as a solid (eluent: petroleum ether/ethyl acetate = 5/1 then petroleum ether/ethyl acetate = 3/1 twice); yield: 373.4 mg (68%); mp 113–116 °C (petroleum ether/ethyl acetate). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.10 (d, J = 7.6 Hz, 1H, Ar-H), 7.77 (d, J = 8.4 Hz, 2H, Ar-H), 7.59–7.54 (m, 1H, Ar-H), 7.35–7.25 (m, 2H, Ar-H), 7.18–7.12 (m, 1H, Ar-H), 7.10–7.03 (m, 2H, Ar-H), 6.95 (d, J = 8.4 Hz, 2H, Ar-H), 6.25–6.19 (m, 2H, Ar-H), 4.75 (dd, J = 4.6 Hz, 3.0 Hz, 1H, CH), 4.11 (t, J = 3.0 Hz, 1H, CH), 3.15 (dd, J = 7.8 Hz, 3.0 Hz, 1H, CH), 3.08 (dd, J = 7.8 Hz, 3.4 Hz, 1H, CH), 3.06–2.98 (m, 1H, CH), 2.26–2.18 (m, 4H, Ar-CH_3 and CH), 1.56 (ddd, J = 12.0 Hz, 8.4 Hz, 1.6 Hz, 1H, CH), 1.13 (s, 3H, CH_3), 0.68 (dd, J = 12.2 Hz, 7.4 Hz, 1H, CH), 0.49 (s, 3H, CH_3); ^{13}C NMR ($CDCl_3$, 100 MHz): δ = 176.2, 176.0, 144.7, 136.2, 135.8, 135.7, 131.3, 129.6, 128.5, 127.9, 127.5, 127.0, 126.0, 124.0, 123.7, 118.7, 118.4, 114.0, 47.9, 45.0, 44.9, 36.8, 36.6, 34.8, 33.6, 32.4, 31.8, 23.0, 21.4; MS (EI): m/z = 551 (M^+ + 1, 5.37), 550 (M^+, 13.61), 166 (100); IR (KBr): ν = 3063, 2951, 2926, 2862, 1777, 1716, 1597, 1498, 1481, 1448, 1414, 1387, 1293, 1267, 1242, 1212, 1175, 1148, 1121, 1090, 1064, 1023 cm^{-1}; anal. calcd. for $C_{33}H_{30}N_2O_4S$: C 71.98, H 5.49, N 5.09; found: C 71.68, H 5.69, N 4.81.

Synthesis of 10l: Following the procedure for the preparation of **10b**, the reaction of **5a** (437.6 mg, 1.0 mmol), $Pd(PPh_3)_4$ (57.8 mg, 0.050 mmol), K_3PO_4 (636.7 mg, 3.0 mmol)/dioxane (5 mL), and **6c** (285.0 mg, 2.0 mmol)/dioxane (5 mL) afforded the crude product after filtration.



The reaction of the obtained crude product/toluene (5 mL), maleic anhydride **11c** (196.9 mg, 2.0 mmol)/toluene

(5 mL) afforded the desired product **10l** as a solid (eluent: petroleum ether/ethyl acetate = 5/1); yield: 262.5 mg (55%); mp 252–254 °C (petroleum ether/dichloromethane). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 8.07 (d, J = 7.5 Hz, 1 H, Ar-H), 7.82 (d, J = 7.8 Hz, 2 H, Ar-H), 7.54 (d, J = 6.9 Hz, 1 H, Ar-H), 7.37–7.22 (m, 4 H, Ar-H), 4.76 (t, J = 3.3 Hz, 1 H, CH), 4.10–4.02 (m, 1 H, CH), 3.32–3.20 (m, 2 H, 2 × CH), 3.02–2.90 (m, 1 H, CH), 2.36 (s, 3 H, Ar-CH_3), 2.15 (d, J = 7.8 Hz, 1 H, CH), 1.53–1.42 (m, 1 H, CH), 1.09 (s, 3 H, CH_3), 0.52–0.39 (m, 4 H, Ar-CH_3 and CH); ^{13}C NMR ($CDCl_3$, 75 MHz): δ = 171.3, 145.3, 135.9, 135.8, 135.6, 130.0, 127.2, 127.0, 124.4, 123.8, 118.6, 118.4, 114.2, 47.6, 45.9, 45.1, 36.24, 36.17, 34.7, 33.3, 32.2, 31.5, 23.1, 21.6; MS (EI): m/z = 476 ($M^{+}+1$, 5.76), 475 (M^{+}, 15.47), 166 (100); IR (KBr): ν = 3056, 2953, 2927, 2864, 1861, 1836, 1779, 1597, 1494, 1481, 1447, 1415, 1370, 1269, 1232, 1212, 1188, 1176, 1161, 1149, 1122, 1079, 1025, 1008 cm^{-1}; anal. calcd. for $C_{27}H_{25}NO_5S$: C 68.19, H 5.30, N 2.95; found: C 67.99, H 5.25, N 2.74.

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[14] Crystal data for **10b**: $C_{29}H_{30}N_2O_4S$, MW = 502.61, triclinic, space group *P*-1, final *R* indices [I > 2 σ(I)], $R_1 = 0.0434$, $wR_2 = 0.1178$, *R* indices (all data), $R_1 = 0.0525$, $wR_2 = 0.1256$, $a = 8.3668(10)$ Å, $b = 9.0470(11)$ Å, $c = 16.803(2)$ Å, $\alpha = 83.024(2)°$, $\beta = 88.243(2)°$, $\gamma = 84.434(3)°$, $V = 1256.3(3)$ Å^3, $T = 293(2)$ K, $Z = 2$, reflections collected/unique: 7689/4932 (R(int) = 0.0273), number of observations [> 2σ(*I*)] 4085; parameter: 330. CCDC 1005441 contains the supplementary crystallographic data for this paper. These data can be obtained free of charge from The Cambridge Crystallographic Data Centre *via* www.ccdc.cam.ac.uk/data_request/cif.

[15] Crystal data for **10i**: $C_{33}H_{36}N_2O_4S$, MW = 556.70, monoclinic, space group *P*21/*c*, final *R* indices [I > 2 σ(I)], $R_1 = 0.0440$, $wR_2 = 0.1203$, *R* indices (all data), $R_1 = 0.0589$, $wR_2 = 0.1314$, $a = 16.7448(11)$ Å, $b = 14.5622(10)$ Å, $c = 12.1746(8)$ Å, $\alpha = 90°$, $\beta = 97.4490(10)°$, $\gamma = 90°$, $V = 2943.6(3)$ Å^3, $T = 293(2)$ K, $Z = 4$, reflections collected/unique: 17456/5772 (R(int) = 0.0269), number of observations [> 2σ(*I*)] 4361; parameter: 364. CCDC 1005442 contains the supplementary crystallographic data for this paper. These data can be obtained free of charge from The Cambridge Crystallographic Data Centre *via* www.ccdc.cam.ac.uk/data_request/cif.

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