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Rhodium(II)-catalyzed intramolecular formal [4 + 3] cycloadditions of dienyltriazoles: rapid access to fused 2,5-dihydroazepines†

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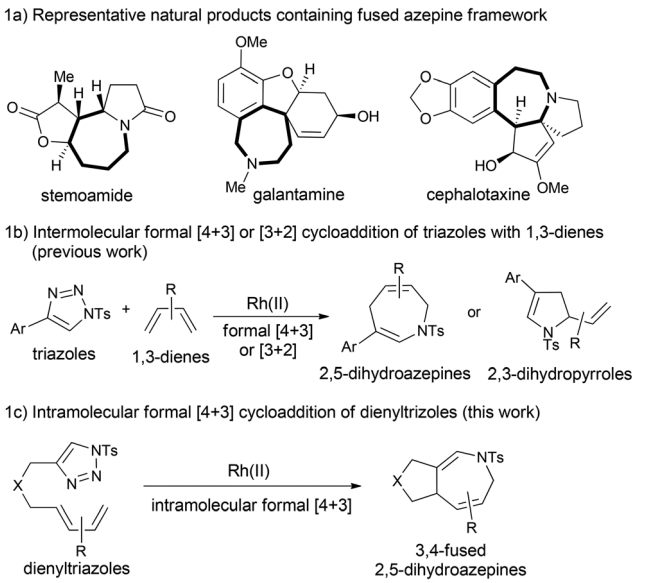
Rhodium(II)-catalyzed intramolecular [4 + 3] cycloadditions of dienyltriazoles have been developed, which enable the efficient synthesis of various fused 2,5-dihydroazepines. Mechanistically, the titled reaction proceeds *via* an interesting tandem cyclopropanation/aza-cope rearrangement.

Introduction

Development of new cycloaddition reactions for the rapid generation of azaheterocycles has been a subject of continued interest in organic synthesis. Various methods have been documented for the synthesis of five- and six-membered azaheterocycles.[1] Comparably, the approaches to construct seven-membered azaheterocycles are limited,[2] mainly due to the inherent challenges associated with their synthesis, such as the unfavorable entropic and enthalpic factors. Azepine represents a privileged structural element widely distributed in natural products and medicinally valuable molecules, such as stemoamide, galantamine and cephalotaxine (Scheme 1a).[3] Among the many strategic bond disconnections of azepines,[4] the cycloaddition reactions are particularly attractive because of their highly convergent and straightforward nature.[5]

Recently, Rh(II)-iminocarbenes, which are readily generated from 1-sulfonyl 1,2,3-triazoles upon treatment with Rh(II)-catalysts, have emerged as versatile intermediates in various cycloadditions that lead to diverse azaheterocycles.[6] As an example, we recently reported the novel Rh(II)-catalyzed cycloadditions of 1-sulfonyl 1,2,3-triazoles with 1,3-dienes, which enabled the efficient and divergent synthesis of two different types of azaheterocycles, 2,5-dihydroazepines and 2,3-dihydropyrroles, respectively, *via* the formal [4 + 3] and [3 + 2] cycloadditions (Scheme 1b).[7] As a continuation of our ongoing project directed toward the construction of heterocycle-based fragments which could be applied to the fragment-based drug discovery (FBDD),[8] we initiated a program with the objective to synthesize the structurally more diverse, fused 2,5-dihydroazepines *via* intramolecular [4 + 3] cycloaddition of dienyltriazoles. Of note, a similar transformation was independently achieved by Sarpong and co-workers very recently,[9] which stimulated us to disclose our progress on this topic.



Scheme 1 Representative azepine-containing natural products and Rh(II)-catalyzed formal [4 + 3] cycloadditions leading to azepines.

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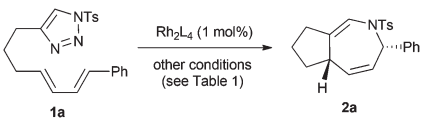
†Electronic supplementary information (ESI) available: General procedure for the preparation of **1a–t** and **2a–t**, copies of NMR spectra of **1a–t** and **2a–t**, and the CIF file of compound **2p**. CCDC 1016527. For ESI and crystallographic data in CIF or other electronic format see DOI: 10.1039/c4ob01910e

Results and discussion

In accordance with the previous work,[7] we commenced our investigations with the treatment of the dienyltriazole **1a**[10] in the presence of 1 mol% $Rh_2(oct)_4$ in 1,2-DCE at 140 °C. Gratifyingly, the starting material was consumed quickly after 0.5 h, leading to the 5–7 bicyclic fused 2,5-dihydroazepine **2a** as a single isomer in 67% yield. Moreover, different from the intermolecular reactions,[7] no trace amount of the corresponding [3 + 2] cycloadduct was detected in the reaction. Encouraged by this result, we launched a systematic study to improve the efficiency of the reaction. First of all, the effect of Rh(II)-catalysts was evaluated (Table 1, entries 1–5). It was shown that while $Rh_2(OAc)_4$ and $Rh_2(esp)_2$ showed comparable efficiency with $Rh_2(oct)_4$, the sterically more hindered $Rh_2(S\text{-ptad})_4$ and $Rh_2(S\text{-dosp})_4$ displayed a superior reactivity by affording improved yields (up to 85%, entry 4). Furthermore, it was found that the reaction temperature had a notable influence on the reaction. Indeed, the lower temperature (80, 100 or 120 °C) turned out to be detrimental to the reaction by giving decreased yields (entries 6–8). Finally, besides 1,2-DCE, several other solvents (*e.g.* $CHCl_3$, toluene, PhCl and *p*-xylene) were also examined in the reaction; however, none of them provided satisfying results (entries 9–12). It is worth noting that, while both $Rh_2(S\text{-ptad})_4$ and $Rh_2(S\text{-dosp})_4$ are chiral catalysts and have been applied to various asymmetric transformations,[11] they failed to provide good enantioselectivity in our case. Indeed, only a poor ee value (5–10%) was obtained under the currently optimized conditions.

Under optimal conditions, we turned to evaluate the generality of the reaction. First of all, various aryl-substituted dienyltriazoles were examined (Table 2). All of them (**1b–g**), either bearing electron-donating (4-Me and 2-OMe) or -withdrawing (4-Cl, 4-F, 4-Br and 4-CF_3) substitutes underwent the transformations smoothly to afford the corresponding azepines (**2b–g**) in excellent yields (entries 2–7). The naphthyl-derived substrate **1h** was also tolerated in the reaction (entry 8). More-

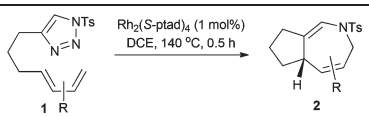
Table 1 Condition optimization of the intramolecular cycloadditions of dienyltriazole

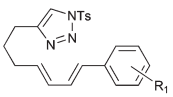
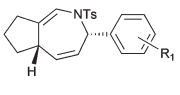
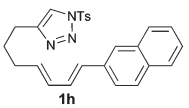
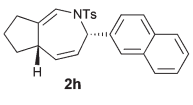
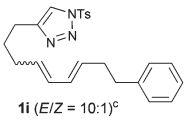
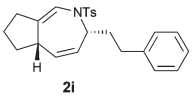
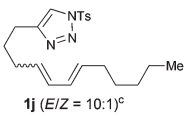
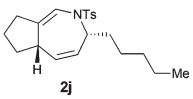
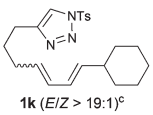
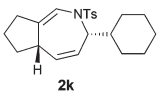
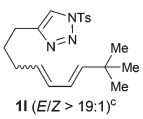
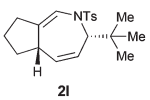
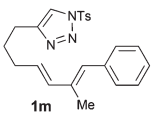
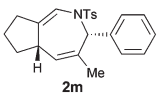
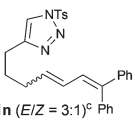
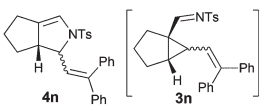


Entry[a]	Cat.	Solvent	Other conditions	Yield of **2a**[b]
1	$Rh_2(oct)_4$	1,2-DCE	140 °C, 0.5 h	67%
2	$Rh_2(OAc)_4$	1,2-DCE	140 °C, 0.5 h	63%
3	$Rh_2(esp)_2$	1,2-DCE	140 °C, 0.5 h	60%
4	$Rh_2(S\text{-ptad})_4$	1,2-DCE	140 °C, 0.5 h	85%
5	$Rh_2(S\text{-dosp})_4$	1,2-DCE	140 °C, 0.5 h	79%
6	$Rh_2(S\text{-ptad})_4$	1,2-DCE	120 °C, 0.5 h	71%
7	$Rh_2(S\text{-ptad})_4$	1,2-DCE	100 °C, 0.5 h	58%
8	$Rh_2(S\text{-ptad})_4$	1,2-DCE	80 °C, 0.5 h	50%
9	$Rh_2(S\text{-ptad})_4$	$CHCl_3$	140 °C, 0.5 h	52%
10	$Rh_2(S\text{-ptad})_4$	Toluene	140 °C, 0.5 h	40%
11	$Rh_2(S\text{-ptad})_4$	PhCl	140 °C, 0.5 h	35%
12	$Rh_2(S\text{-ptad})_4$	*p*-Xylene	140 °C, 0.5 h	40%

[a] The reaction was run with 0.1 mmol of **1a** in 0.5 mL 1,2-DCE in a sealed tube. [b] Refers to isolated yield. DCE = dichloroethane, esp = α,α,α′,α′-tetramethyl-1,3-benzenedipropionic acid, oct = octanoate, (*S*)-ptad = *N*-phthaloyl-(*S*)-adamantylglycine, (*S*)-dosp = 4-(dodecyl-phenyl)-sulfonyl-(2*S*)-prolinate.

Table 2 Scope of intramolecular cycloadditions of C-tethered dienyltriazoles



Entry[a]	Substrate	Products	Yield of **2**[b]
			
1	**1a:** R = H	**2a:** R = H	85%
2	**1b:** R = 4-Me	**2b:** R = 4-Me	78%
3	**1c:** R = 2-OMe	**2c:** R = 2-OMe	81%
4	**1d:** R = 4-Cl	**2d:** R = 4-Cl	81%
5	**1e:** R = 4-F	**2e:** R = 4-F	74%
6	**1f:** R = 4-Br	**2f:** R = 4-Br	87%
7	**1g:** R = 4-CF_3	**2g:** R = 4-CF_3	80%
8	 **1h**	 **2h**	85%
9	 **1i** (*E*/*Z* = 10:1)[c]	 **2i**	75%
10	 **1j** (*E*/*Z* = 10:1)[c]	 **2j**	75%
11	 **1k** (*E*/*Z* > 19:1)[c]	 **2k**	86%
12[d]	 **1l** (*E*/*Z* > 19:1)[c]	 **2l**	91%
13	 **1m**	 **2m**	77%
14[d]	 **1n** (*E*/*Z* = 3:1)[c]	 **4n** **3n**	60% (**4n**) (dr = 2 : 1)[c]

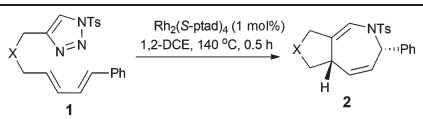
[a] The reaction was run with 0.1 mmol of **1a** in 0.5 mL 1,2-DCE in a sealed tube. [b] Refers to isolated yield. [c] Determined by ^1H NMR. [d] Extended reaction time (>12 h) was required for complete conversion.

over, the cycloadditions could be extended to the alkyl-substituted dienyltriazoles, as witnessed in the cases leading to **2i–l** (entries 9–12). Notably, for **2l** which bear a bulky *t*-butyl group on the C-1 position of the diene unit, the elongation of reaction time (16 h) was required in order to obtain good yield of **2l** (entry 12). Finally, besides the substrates bearing a 1,4-disubstituted diene unit, some more sterically encumbered dienyltriazoles were checked. It was found that while the 1,2,4-trisubstituted **1m** was amenable to the reaction (entry 13), the 1,1,4-trisubstituted **1n** (prepared as a mixture of isomers, $E/Z = 3:1$) failed to yield the expected [4 + 3] product. Instead, the fused dihydropyrrole **4n** was obtained as a mixture of diastereoisomers (*cis*–*trans* = 2 : 1) in 60% yield. Interestingly, shortening the reaction time (0.5 h) mainly resulted in the formation of another new product, which was proved to be the cyclopropylaldimine derivative **3n**. The intermediacy of **3n** was proved by its conversion into **4n** at high temperature (140 °C) in 1,2-DCE, apparently *via* the cyclopropylimine rearrangement.[12] Of note, an intermediate similar to **3n** was also identified in Sarpong's work,[9] however, it failed to undergo the ring-expansion as observed in our case. This might be attributed to the relatively low reaction temperature (60 °C) adopted in that case.

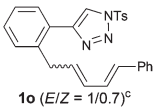
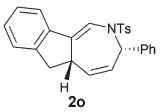
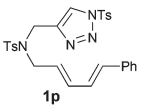
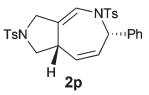
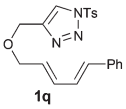
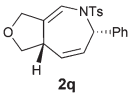
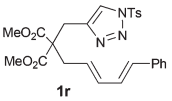
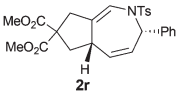
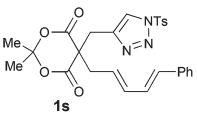
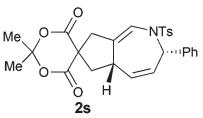
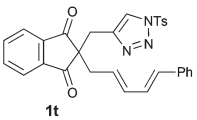
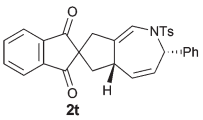
To further extend the substrate scope of the cycloaddition, we attempted several other dienyltriazoles which bear different tethers (Table 3). Among them, **1o**, wherein the triazole and diene units were attached to the *ortho* positions of a phenyl ring, underwent the reaction smoothly to afford the tricyclic fused azepine **2o** in 90% yield (entry 1, Table 3). Comparably, although the dienyltriazoles bearing the *N*-tosylamine, ether, diester or diketone groups were also tolerated in the reactions, only moderate yields of the corresponding products were obtained (entries 2–6). It is likely that the presence of some coordinative functionalities (*e.g.* ether, ester or ketone) might interfere with the reactivity of the rhodium carbene intermediate, thus decreasing the overall efficiency of the reaction. Notably, the structure of **2p** was confirmed by the X-ray crystallographic study (Fig. 1).[13]

In addition to the aforementioned outcomes, some other interesting observations deserved further discussion. For instance, when the cycloaddition of **1l** was performed with a shorter reaction time (0.5 h), the cyclopropylaldimine derivative **3l** instead of the azepine **2l** was isolated as the major product (69%). The *cis*-relationship of the imine and vinyl moieties of **3l** was established by the NOE studies (for details, see ESI†).[14] As expected, **3l** could readily convert into **2l** in nearly quantitative yield (>95%) under the thermal conditions (1,2-DCE, 140 °C), apparently *via* the aza-cope rearrangement ([eqn(1)], Scheme 2).[15] Moreover, we found that the geometry of the diene unit had a profound effect on the reaction. Indeed, when the dienyltriazole (1*E*,3*Z*)-**1a** was treated under the standard conditions (entry 4, Table 1), a mixture of 1,2-*trans*-cyclopropylaldimine **3a** (49%) and 2,5-dihydroazepine **2a** (37%) was obtained. Interestingly, *trans*-**3a** could also advance into **2a** in high yield under the thermal conditions ([eqn (2)], Scheme 2).

Table 3 Scope of intramolecular cycloadditions of dienyltriazoles with other tethers



1 2

Entry[a]	Substrate	Products	Yield of 2[b]
1	 **1o** (E/Z = 1/0.7)[c]	 **2o**	90%
2	 **1p**	 **2p**	56%
3	 **1q**	 **2q**	35%
4	 **1r**	 **2r**	42%
5	 **1s**	 **2s**	42%
6	 **1t**	 **2t**	59%

[a] The reaction was run with 0.1 mmol of **1a** in 0.5 mL 1,2-DCE in a sealed tube. [b] Refers to isolated yield. [c] Determined by ^{1}H NMR.

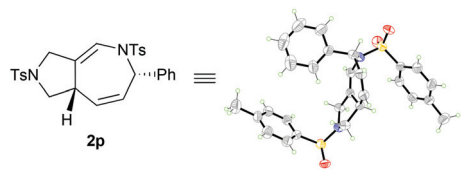
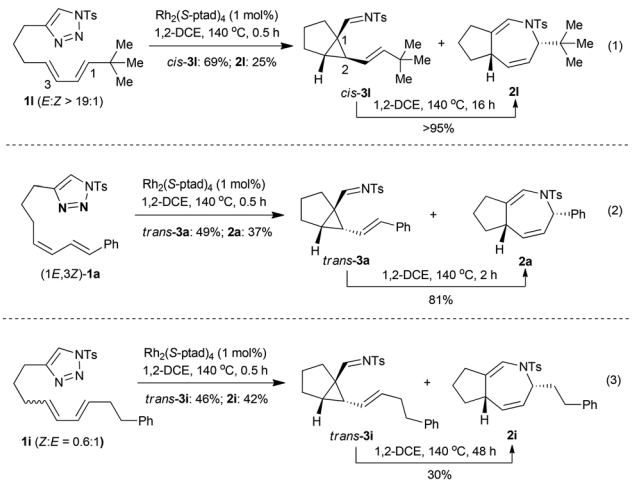


Fig. 1 X-ray crystal structure of **2p**.

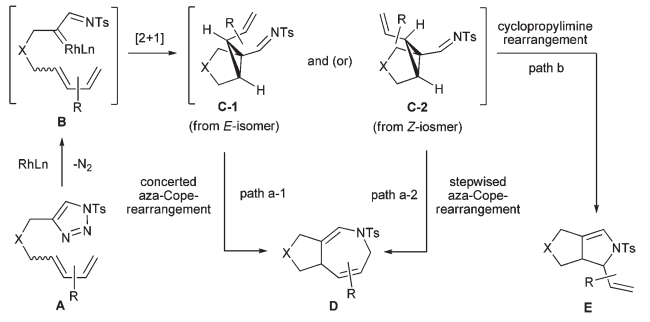
This observation was in sharp contrast with that in cycloaddition of **1a**, wherein the corresponding 1,2-*cis* cyclopropylaldimine intermediate (*cis*-**3a**, structure not shown) could not be detected. We assumed that, *cis*-**3a**, once formed, would *in situ* advance into **2a** *via* the concerted aza-cope rearrangement. Comparably, such a process was precluded for *trans*-**3a** for the unattainable stereochemical requirement. Instead, in this scenario the aza-cope rearrangement should proceed *via* the diradical or zwitterionic intermediates, which generally require harsher conditions (*e.g.* high temperature and long reaction time). This assumption was further supported by the experiments listed in [eqn (3)] (Scheme 2). As shown, when the



Scheme 2 Identification of the key cyclopropylaldimine intermediates.

alkyl substituted dienyltriazole **1i** (prepared as a mixture of *E*/Z-isomers, 0.6 : 1 ratio) was submitted to the reaction, *trans*-**3i** and azepine **2i** were obtained in 49% and 37% yields, respectively. The isolated *trans*-**3i** could also convert into **2i** as expected under the thermal conditions (140 °C, 1,2-DCE), albeit only resulting in moderate yield (30%) with a long reaction time. It should be pointed out that, an intermediate similar to *trans*-**3a** was also identified in Sarpong's work,[9] however, it failed to undergo the aza-cope rearrangement to give the corresponding azepine product, presumably due to the milder reaction conditions (60 °C) employed in that case.

Taking into consideration all of the above-mentioned results, we proposed that the intramolecular formal aza-[4 + 3] cycloaddition may follow the mechanism depicted in Scheme 3. Thus, the Rh(II)-iminocarbene **B**, generated from the dienyltriazole **A** upon treatment with the Rh-catalyst, first undergoes the [2 + 1] cycloaddition to give **C-1** (from *E*-isomer) and (or) **C-2** (from *Z*-isomer). **C-1** and (or) **C-2** could further convert into the azepine **D**, respectively, *via* the concerted (path a-1) or stepwise (path a-2) aza-cope rearrangement. This process may account for the majority of the cycloadditions discussed in this work. Besides, the reactions could also be diverted into the path b, in which **C-1** and (or) **C-2** evolve into



Scheme 3 Proposed mechanisms of the cycloadditions of dienyltriazoles.

the dihydropyrrole **E** *via* the cyclopropylimine rearrangement. This pathway may play a dominant role for some kinds of substrates, such as the 1,1,4-trisubstituted dienyltriazole **1n**. In this scenario, the huge steric hindrance of the C-1 position of the diene unit largely inhibits the pathway leading to azepine **D**, thus favoring the formation of **E** as the major product.

Conclusions

In summary, we have successfully achieved the Rh(II)-catalyzed intramolecular formal [4 + 3] cycloadditions of dienyltriazoles. Mechanistically, the titled reaction may proceed *via* the tandem cyclopropanation/aza-cope rearrangement. Comparable with our previously reported intermolecular cycloadditions of triazoles with 1,3-dienes, the intramolecular version allows to access various fused azepine derivatives with increasing structural diversity, which could not be readily achieved by the other known methods. The application of this method for the construction of the azepine-based fragment library is underway in our lab.

Experimental section

General information

NMR spectra were recorded on a Bruker AV400 instrument. TMS was used as the internal standard for ^{1}H NMR (0 ppm), and a solvent signal was used as a reference for ^{13}C NMR ($CDCl_3$, 77.16 ppm). The following abbreviations were used to explain the multiplicities: s = singlet, d = doublet, t = triplet, q = quartet, dt = doublet of triplets, td = triple doublet, m = multiplet. Infrared (IR) spectra were recorded on a Thermo Nicolet Avatar 330 FT-IR spectrometer. High-resolution mass spectra (HRMS) were recorded on a Bruker ESI-Q/TOF MS. Low resolution mass spectra were recorded on a Waters's UPLC-Mass instrument.

Reactions were monitored by Thin Layer Chromatography on plates (GF_{254}) supplied by Yantai Chemicals (China) using UV light as the visualizing agent and an ethanolic solution of phosphomolybdic acid and cerium sulfate, and heat as developing agents. If not specially mentioned, flash column chromatography uses silica gel (200–300 mesh) supplied by Tsingtao Haiyang Chemicals (China). Solvent purification was conducted according to Purification of Laboratory Chemicals (D. D. Peerrin, W. L. Armarego and D. R. Perrins, Pergamon Press, Oxford, 1980).

General procedure for Rh(II)-catalyzed intramolecular [4 + 3] cycloadditions

A 10 mL pressure tube, fitted with a rubber septum, was charged with triazole (0.10 mmol, 1.0 equiv.) and Rh_2(*S*-PTAD)$_4$ (1.6 mg, 1.0 mol%). To the reaction vessel was added freshly distilled 1,2-dichloroethane (0.5 mL) and was then sealed with a Teflon screwcap and placed in an oil bath preheated to 140 °C. The resulting solution was heated at this

temperature for 0.5 h before being cooled to room temperature and concentrated *in vacuo*. The residue was purified by flash chromatography (SiO_2, hexanes–EtOAc) to give the products **2a–2t**.

3-Phenyl-2-tosyl-2,3,5a,6,7,8-hexahydrocyclopenta[*c*]azepine (2a). Yield: 85%; ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.29–1.42 (m, 2H), 1.66–1.73 (m, 1H), 1.90–1.97 (m, 1H), 2.14–2.23 (m, 1H), 2.34 (dd, J = 17.2 Hz, 6.0 Hz, 1H), 2.41 (s, 3H), 2.55–2.64 (m, 1H), 5.52–5.60 (m, 2H), 5.70 (s, 1H), 5.92–5.95 (m, 1H), 7.21–7.30 (m, 5H), 7.36 (dd, J = 8.0 Hz, 1.2 Hz, 2H), 7.73 (d, J = 8.3 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 21.7, 24.9, 31.7, 35.0, 42.1, 59.9, 117.1, 126.6, 127.1, 127.8, 128.3, 128.8, 129.4, 130.1, 138.6, 139.7, 143.0, 149.7; IR ν_{max} (film): 1700.1, 1652.8, 1559.7, 1161.2, 1094.7, 698.2, 687.0, 682.8, 676.3 cm^{-1}; HRMS m/z calcd for $C_{22}H_{23}NNaO_2S$ $[M + Na]^+$: 388.1342; found: 388.1346.

3-(*p*-Tolyl)-2-tosyl-2,3,5a,6,7,8-hexahydrocyclopenta[*c*]azepine (2b). Yield: 78%; ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.30–1.41 (m, 2H), 1.65–1.74 (m, 1H), 1.89–1.99 (m, 1H), 2.13–2.25 (m, 1H), 2.30–2.37 (m, 4H), 2.42 (s, 3H), 2.55–2.64 (m, 1H), 5.50–5.58 (m, 2H), 5.70 (s, 1H), 5.89–5.91 (m, 1H), 7.10 (d, J = 7.9 Hz, 2H), 7.21–7.25 (m, 4H), 7.74 (d, J = 8.2 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 21.3, 21.7, 24.9, 31.8, 35.0, 42.2, 59.7, 117.2, 126.9, 127.2, 128.8, 129.0, 129.4, 129.9, 136.7, 137.5, 138.7, 143.0, 149.7; IR ν_{max} (film): 2923.2, 2358.4, 2340.7, 1337.4, 1159.9, 1093.4, 1027.4, 822.3, 813.2, 683.9, 676.2 cm^{-1}; HRMS m/z calcd for $C_{23}H_{25}NNaO_2S$ $[M + Na]^+$: 402.1498; found: 402.1498.

3-(2-Methoxyphenyl)-2-tosyl-2,3,5a,6,7,8-hexahydrocyclopenta[*c*]azepine (2c). Yield: 81%; ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.32–1.43 (m, 2H), 1.67–1.75 (m, 1H), 1.92–1.99 (m, 1H), 2.17–2.28 (m, 1H), 2.33–2.41 (m, 4H), 2.60–2.70 (m, 1H), 3.85 (s, 3H), 5.47 (ddd, J = 11.5 Hz, 5.0 Hz, 2.7 Hz, 1H), 5.56 (dt, J = 11.5 Hz, 1.6 Hz, 1H), 5.65 (s, 1H), 6.37 (t, J = 4.2 Hz, 1H), 6.81 (t, J = 7.5 Hz, 1H), 6.85 (d, J = 8.1 Hz, 1H), 7.14 (dd, J = 7.6 Hz, 1.6 Hz, 1H), 7.18 (d, J = 8.0 Hz, 2H), 7.23 (td, J = 8.2 Hz, 1.6 Hz, 1H), 7.71 (d, J = 8.2 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 21.7, 24.9, 31.8, 35.1, 42.5, 53.8, 55.6, 110.8, 117.7, 119.7, 127.5, 127.6, 129.1, 129.2, 129.6, 130.2, 138.5, 142.7, 150.3, 157.2; IR ν_{max} (film): 2957.1, 2923.7, 2332.0, 1464.2, 1341.7, 1259.2, 1246.7, 1160.5, 1094.6, 1065.9, 1027.6, 685.5, 677.8 cm^{-1}; HRMS m/z calcd for $C_{23}H_{25}NNaO_3S$ $[M + Na]^+$: 418.1447; found: 418.1448.

3-(4-Chlorophenyl)-2-tosyl-2,3,5a,6,7,8-hexahydrocyclopenta[*c*]azepine (2d). Yield: 81%; ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.28–1.40 (m, 2H), 1.65–1.75 (m, 1H), 1.89–1.98 (m, 1H), 2.12–2.23 (m, 1H), 2.34 (dd, J = 16.8 Hz, 5.7 Hz, 1H), 2.42 (s, 3H), 2.53–2.62 (m, 1H), 5.52 (ddd, J = 11.5 Hz, 5.0 Hz, 2.7 Hz, 1H), 5.59 (dt, J = 11.5 Hz, 1.9 Hz, 1H), 5.69 (s, 1H), 5.91 (t, J = 4.3 Hz, 1H), 7.23–7.30 (m, 6H), 7.73 (d, J = 8.3 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 21.7, 24.9, 31.8, 34.9, 42.2, 59.2, 117.0, 126.2, 127.1, 128.5, 129.5, 130.2, 130.5, 133.7, 138.3, 138.5, 143.2, 149.9; IR ν_{max} (film): 2955.1, 1488.9, 1338.0, 1160.7, 1092.7, 1070.0, 1015.3, 821.5, 818.6, 815.6, 677.3 cm^{-1}; HRMS m/z calcd for $C_{22}H_{22}ClNNaO_2S$ $[M + Na]^+$: 422.0952; found: 422.0957.

3-(4-Fluorophenyl)-2-tosyl-2,3,5a,6,7,8-hexahydrocyclopenta[*c*]azepine (2e). Yield: 74%; ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.27–1.42 (m, 2H), 1.66–1.74 (m, 1H), 1.90–1.99 (m, 1H), 2.13–2.25 (m, 1H), 2.35 (dd, J = 17.1 Hz, 5.9 Hz, 1H), 2.42 (s, 3H), 2.54–2.63 (m, 1H), 5.52 (ddd, J = 11.5 Hz, 4.6 Hz, 2.5 Hz, 1H), 5.58 (d, J = 11.5 Hz, 1H), 5.69 (s, 1H), 5.92 (t, J = 4.3 Hz, 1H), 6.97 (t, J = 8.6 Hz, 2H), 7.24 (d, J = 8.0 Hz, 2H), 7.33 (dd, J = 8.4 Hz, 5.6 Hz, 2H), 7.73 (d, J = 8.1 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 21.7, 24.9, 31.8, 34.9, 42.1, 59.2, 115.1 (d, J = 21.2 Hz), 117.0, 126.5, 127.1, 129.5, 130.3, 130.5 (d, J = 8.1 Hz), 135.5 (d, J = 3.0 Hz), 138.6, 143.2, 149.8, 162.4 (d, J = 244.7 Hz); IR ν_{max} (film): 2960.5, 1506.2, 1337.4, 1259.9, 1159.8, 1092.3, 1016.2, 812.7, 810.5, 799.4, 684.78 cm^{-1}; HRMS m/z calcd for $C_{22}H_{23}FNO_2S$ $[M + H]^+$: 384.1428; found: 384.1432.

3-(4-Bromophenyl)-2-tosyl-2,3,5a,6,7,8-hexahydrocyclopenta[*c*]azepine (2f). Yield: 87%; ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.29–1.41 (m, 2H), 1.64–1.73 (m, 1H), 1.89–1.99 (m, 1H), 2.12–2.22 (m, 1H), 2.34 (dd, J = 16.9 Hz, 6.0 Hz, 1H), 2.42 (s, 3H), 2.53–2.62 (m, 1H), 5.51 (ddd, J = 11.5 Hz, 5.0 Hz, 2.7 Hz, 1H), 5.59 (dt, J = 11.5 Hz, 1.6 Hz, 1H), 5.69 (s, 1H), 5.89 (t, J = 4.4 Hz, 1H), 7.21–7.25 (m, 4H), 7.41 (dt, J = 8.4 Hz, 2.5 Hz, 2H), 7.73 (d, J = 8.3 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 21.7, 24.9, 31.8, 34.9, 42.2, 59.2, 117.0, 122.0, 126.1, 127.1, 129.5, 130.5, 130.6, 131.4, 138.5, 138.8, 143.2, 149.9; IR ν_{max} (film): 1700.2, 1695.7, 1684.6, 711.7, 680.7 cm^{-1}; HRMS m/z calcd for $C_{22}H_{23}BrNO_2S$ $[M + H]^+$: 444.0627; found: 444.0631.

2-Tosyl-3-(4-(trifluoromethyl)phenyl)-2,3,5a,6,7,8-hexahydrocyclo-penta[*c*]azepine (2g). Yield: 80%; ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.30–1.42 (m, 2H), 1.65–1.74 (m, 1H), 1.92–1.99 (m, 1H), 2.13–2.23 (m, 1H), 2.35 (dd, J = 17.2 Hz, 5.8 Hz, 1H), 2.42 (s, 3H), 2.53–2.61 (m, 1H), 5.54 (ddd, J = 11.5 Hz, 5.4 Hz, 2.7 Hz, 1H), 5.63 (dt, J = 11.5 Hz, 1.6 Hz, 1H), 5.71 (s, 1H), 5.98 (t, J = 4.3 Hz, 1H), 7.25 (d, J = 8.1 Hz, 2H), 7.48 (d, J = 8.2 Hz, 2H), 7.55 (d, J = 8.2 Hz, 2H), 7.73 (d, J = 8.3 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 21.7, 24.9, 31.8, 34.9, 42.1, 59.4, 116.9, 124.2 (q, J = 270.4 Hz), 125.3 (q, J = 3.6 Hz), 125.8, 127.1, 129.1, 129.5, 130.0 (q, J = 32.1 Hz), 130.9, 138.4, 143.3, 143.8, 150.0; IR ν_{max} (film): 1700.4, 1684.6, 1652.9, 1559.8, 684.2, 679.4, 677.9 cm^{-1}; HRMS m/z calcd for $C_{23}H_{22}F_3NNaO_2S$ $[M + Na]^+$: 456.1216; found: 456.1213.

3-(Naphthalen-2-yl)-2-tosyl-2,3,5a,6,7,8-hexahydrocyclopenta[*c*]azepine (2h). Yield: 85%; ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.32–1.47 (m, 2H), 1.66–1.74 (m, 1H), 1.94–2.02 (m, 1H), 2.11–2.22 (m, 1H), 2.33 (dd, J = 16.0 Hz, 5.9 Hz, 1H), 2.42 (s, 3H), 2.60–2.67 (m, 1H), 5.64–5.71 (m, 3H), 6.07–6.11 (m, 1H), 7.24 (d, J = 8.0 Hz, 2H), 7.44–7.48 (m, 2H), 7.58 (d, J = 8.4 Hz, 1H), 7.67 (s, 1H), 7.74–7.83 (m, 5H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 21.7, 24.9, 31.8, 35.0, 42.4, 60.1, 117.2, 126.1, 126.2, 126.6, 126.9, 127.3, 127.7, 127.8, 128.2, 128.3, 129.4, 130.5, 133.0, 133.1, 137.1, 138.7, 143.1, 149.7; IR ν_{max} (film): 1700.3, 1652.9, 1559.8, 739.4, 680.4, 676.1 cm^{-1}; HRMS m/z calcd for $C_{26}H_{26}NO_2S$ $[M + H]^+$: 416.1679; found: 416.1677.

3-Phenethyl-2-tosyl-2,3,5a,6,7,8-hexahydrocyclopenta[*c*]azepine (2i). Yield: 75%; ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.18–1.39 (m, 2H), 1.65–1.72 (m, 1H), 1.77–1.91 (m, 3H), 2.21–2.33 (m, 1H), 2.36–2.47 (m, 5H), 2.64–2.80 (m, 2H),

4.63–4.71 (m, 1H), 5.25 (dt, J = 11.6 Hz, 1.7 Hz, 1H), 5.42 (ddd, J = 11.6 Hz, 5.1 Hz, 2.9 Hz, 1H), 6.06 (s, 1H), 7.16–7.20 (m, 3H), 7.22 (d, J = 8.0 Hz, 2H), 7.28 (t, J = 8.1 Hz, 2H), 7.71 (d, J = 8.2 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 21.7, 24.8, 31.8, 32.9, 35.0, 37.0, 42.7, 57.3, 116.2, 126.0, 127.2, 128.1, 128.5, 128.6, 128.8, 129.4, 138.6, 141.9, 143.0, 149.8; IR ν_{max} (film): 1652.8, 1560.2, 1507.2, 1160.9, 757.8, 696.1, 687.1, 675.4 cm^{-1}; HRMS m/z calcd for $C_{24}H_{28}NO_2S$ $[M + H]^+$: 394.1835; found: 394.1833.

3-Pentyl-2-tosyl-2,3,5a,6,7,8-hexahydrocyclopenta[*c*]azepine (2j). Yield: 75%; ^{1}H NMR (400 MHz, $CDCl_3$) δ 0.88 (t, J = 6.8 Hz, 3H), 1.20–1.40 (m, 8H), 1.42–1.54 (m, 2H), 1.64–1.71 (m, 1H), 1.80–1.88 (m, 1H), 2.20–2.31 (m, 1H), 2.37–2.46 (m, 5H), 4.54–4.61 (m, 1H), 5.22 (dt, J = 11.5 Hz, 1.5 Hz, 1H), 5.41 (ddd, J = 11.5 Hz, 5.1 Hz, 2.9 Hz, 1H), 5.99 (s, 1H), 7.21 (d, J = 8.1 Hz, 2H), 7.70 (d, J = 8.2 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 14.2, 21.7, 22.7, 24.8, 26.2, 31.7, 31.8, 35.0, 35.4, 42.6, 57.5, 116.3, 127.2, 127.8, 129.3, 129.4, 138.8, 142.8, 149.6; IR ν_{max} (film): 1695.6, 705.5, 685.5, 678.3, 675.7 cm^{-1}; HRMS m/z calcd for $C_{21}H_{30}NO_2S$ $[M + H]^+$: 360.1992; found: 360.1992.

3-Cyclohexyl-2-tosyl-2,3,5a,6,7,8-hexahydrocyclopenta[*c*]-azepine (2k). Yield: 86%; ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.05–1.34 (m, 7H), 1.42–1.53 (m, 1H), 1.62–1.92 (m, 7H), 2.20–2.30 (m, 2H), 2.37–2.44 (m, 4H), 4.31–4.38 (m, 1H), 5.26 (d, J = 11.7 Hz, 1H), 5.51 (ddd, J = 11.7 Hz, 5.2 Hz, 2.6 Hz, 1H), 6.02 (s, 1H), 7.19 (d, J = 8.1 Hz, 2H), 7.68 (d, J = 8.1 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 21.7, 24.7, 26.2, 26.3, 26.5, 30.5, 30.6, 31.7, 35.0, 43.0, 43.4, 62.6, 116.9, 127.1, 127.9, 128.2, 129.2, 139.0, 142.7, 149.2; IR ν_{max} (film): 1700.5, 1684.6, 1653.2, 1559.7, 688.0, 682.9 cm^{-1}; HRMS m/z calcd for $C_{22}H_{30}NO_2S$ $[M + H]^+$: 372.1992; found: 372.1994.

3-(*tert*-Butyl)-2-tosyl-2,3,5a,6,7,8-hexahydrocyclopenta[*c*]-azepine (2l). The reaction was run for 16 h instead of 0.5 h. Yield: 91%; ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.01 (s, 9H), 1.12–1.30 (m, 2H), 1.58–1.66 (m, 1H), 1.74–1.82 (m, 1H), 2.01–2.20 (m, 2H), 2.34–2.43 (m, 4H), 4.54 (t, J = 4.0 Hz, 1H), 5.35 (d, J = 11.9 Hz, 1H), 5.49 (ddd, J = 11.9 Hz, 4.9 Hz, 2.8 Hz, 1H), 6.05 (s, 1H), 7.19 (d, J = 8.0 Hz, 2H), 7.67 (d, J = 8.2 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 21.6, 24.6, 28.5, 32.0, 35.0, 37.0, 42.2, 66.0, 118.3, 125.3, 127.2, 129.2, 129.9, 138.6, 142.7, 148.4; IR ν_{max} (film): 2959.9, 1652.7, 1336.9, 1159.4, 1093.7, 831.8, 812.4, 684.5 cm^{-1}; HRMS m/z calcd for $C_{20}H_{28}NO_2S$ $[M + H]^+$: 346.1835; found: 346.1831.

4-Methyl-3-phenyl-2-tosyl-2,3,5a,6,7,8-hexahydrocyclopenta[*c*]-azepine (2m). Yield: 77%; ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.30–1.42 (m, 2H), 1.57 (s, 3H), 1.63–1.74 (m, 1H), 1.89–2.01 (m, 1H), 2.07–2.21 (m, 1H), 2.34 (dd, J = 17.7 Hz, 6.3 Hz, 1H), 2.41 (s, 3H), 2.51–2.59 (m, 1H), 5.36 (s, 1H), 5.58 (s, 1H), 5.66 (d, J = 3.0 Hz, 1H), 7.21–7.29 (m,7H), 7.71 (d, J = 8.1 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 21.7, 24.2, 24.8, 31.6, 35.4, 42.6, 63.6, 116.9, 125.9, 127.1, 127.8, 128.3, 129.1, 129.4, 132.4, 138.7, 138.9, 143.0, 148.7; IR ν_{max} (film): 1684.5, 1559.7, 708.3, 688.0, 681.2, 679.7 cm^{-1}; HRMS m/z calcd for $C_{23}H_{25}NNaO_2S$ $[M + Na]^+$: 402.1498; found: 402.1498.

1-(2,2-Diphenylvinyl)-2-tosyl-1,2,4,5,6,6a-hexahydrocyclo-penta[*c*]pyrrole (4n). Yield: 60%; the NMR spectra are reported for a mixture of two isomers. ^{1}H NMR (400 MHz, $CDCl_3$) δ 0.68–0.81 (m, 1H), 0.82–0.91 (m, 0.5H), 1.40–1.59 (m, (0.5 × 2) H), 1.74–2.03 (m, 3H + (0.5 × 2)H), 2.07–2.22 (m, 2H + 0.5H), 2.33 (s, 3H), 2.35 (s, (0.5 × 3)H), 2.80–2.91 (m, 0.5H), 3.02–3.13 (m, 1H), 3.88 (t, J = 9.2 Hz, 1H), 4.38 (t, J = 9.9 Hz, 0.5H), 5.95–6.00 (m, 1.5H), 6.09 (d, J = 9.9 Hz, 0.5H), 6.30 (d, J = 9.5 Hz, 1H), 7.01 (d, J = 7.9 Hz, 2H), 7.11 (d, J = 7.9 Hz, 1H), 7.17 (d, J = 7.9 Hz, 2H), 7.18–7.30 (m, 10H), 7.34–7.45 (m, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 21.6, 21.6, 21.7, 22.3, 26.6, 27.2, 28.6, 30.4, 53.8, 57.4, 61.3, 67.4, 118.7, 119.9, 125.3, 127.5, 127.5, 127.6, 127.7, 127.9, 127.9, 128.2, 128.2, 128.3, 128.4, 129.2, 129.3, 129.4, 129.9, 130.5, 132.4, 133.0, 135.0, 136.9, 139.5, 139.5, 141.5, 142.0, 142.8, 143.2; IR ν_{max} (film): 2955.6, 2362.9, 1559.8, 1340.6, 1161.8, 1093.4, 993.2, 908.6, 732.3, 701.4, 698.9 cm^{-1}; HRMS m/z calcd for $C_{28}H_{28}NO_2S$ $[M + H]^+$: 442.1835; found: 442.1839.

3-Phenyl-2-tosyl-2,3,5a,6-tetrahydroindeno[1,2-*c*]azepine (2o). Yield: 90%; ^{1}H NMR (400 MHz, $CDCl_3$) δ 2.37 (s, 3H), 2.56–2.67 (m, 1H), 2.73–2.85 (m, 2H), 5.66–5.72 (m, 1H), 5.85–5.91 (m, 2H), 6.70 (s, 1H), 7.07–7.20 (m, 6H), 7.28 (d, J = 7.2 Hz, 1H), 7.33 (t, J = 7.1 Hz, 2H), 7.49 (d, J = 7.5 Hz, 2H), 7.66 (d, J = 8.1 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 21.7, 34.3, 36.0, 59.0, 126.2, 126.3, 127.0, 127.1, 127.1, 127.4, 127.5, 127.9, 128.0, 128.7, 129.6, 133.2, 134.1, 134.3, 137.8, 140.4, 143.6; IR ν_{max} (film): 2919.7, 1717.3, 1699.9, 1557.8, 681.9, 676.9 cm^{-1}; HRMS m/z calcd for $C_{26}H_{24}NO_2S$ $[M + H]^+$: 414.1522; found: 414.1517.

6-Phenyl-2,5-ditosyl-1,2,3,5,6,8a-hexahydropyrrolo[3,4-*c*]-azepine (2p). Yield: 56%; ^{1}H NMR (400 MHz, $CDCl_3$) δ 2.43 (s, 3H), 2.46 (s, 3H), 2.64 (t, J = 9.7 Hz, 1H), 2.98–3.08 (m, 1H), 3.47 (dt, J = 14.2 Hz, 2.2 Hz, 1H), 3.66 (t, J = 8.8 Hz, 1H), 3.98 (d, J = 14.2 Hz, 1H), 5.41 (dt, J = 11.5 Hz, 1.7 Hz, 1H), 5.64 (ddd, J = 11.5 Hz, 5.4 Hz, 2.8 Hz, 1H), 5.80 (d, J = 2.0 Hz, 1H), 5.92 (t, J = 4.2 Hz, 1H), 7.20–7.26 (m, 7H), 7.35 (d, J = 8.0 Hz, 2H), 7.64–7.69 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 21.7, 41.3, 50.9, 54.1, 59.9, 119.5, 125.2, 127.0, 128.1, 128.2, 128.5, 128.5, 128.9, 129.8, 130.0, 132.0, 138.0, 138.8, 140.6, 143.7, 144.3; IR ν_{max} (film): 1700.4, 1653.0, 1559.8, 1340.6, 1160.5, 1092.2, 813.2, 685.1, 678.8 cm^{-1}; HRMS m/z calcd for $C_{28}H_{29}N_2O_4S_2$ $[M + H]^+$: 521.1563; found: 521.1565.

6-Phenyl-5-tosyl-3,5,6,8a-tetrahydro-1*H*-furo[3,4-*c*]azepine (2q). Yield: 35%; ^{1}H NMR (400 MHz, $CDCl_3$) δ 2.43 (s, 3H), 2.84–2.90 (m, 1H), 3.39 (dd, J = 10.3 Hz, 8.5 Hz, 1H), 4.11–4.19 (m, 2H), 4.41 (d, J = 13.6 Hz, 1H), 5.49 (dt, J = 11.5 Hz, 1.8 Hz, 1H), 5.71 (ddd, J = 11.5 Hz, 5.4 Hz, 2.8 Hz, 1H), 5.80 (d, J = 2.4 Hz, 1H), 6.01 (t, J = 4.2 Hz, 1H), 7.25–7.28 (m, 2H), 7.29–7.34 (m, 3H), 7.36–7.39 (m, 2H), 7.74 (d, J = 8.3 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 21.7, 42.7, 60.2, 70.3, 74.3, 116.7, 124.5, 127.1, 128.1, 128.5, 128.8, 129.7, 138.3, 139.2, 143.5, 144.8; IR ν_{max} (film): 1739.1, 1729.2, 1717.2, 1365.3, 1229.2, 1217.3, 751.9, 691.6 cm^{-1}; HRMS m/z calcd for $C_{21}H_{22}O_3NS$ $[M + H]^+$: 368.1315; found: 368.1311.

Dimethyl 3-phenyl-2-tosyl-2,3,5a,6-tetrahydrocyclo-penta[*c*]-azepine-7,7(8*H*)-dicarboxylate (2r). Yield: 42%; ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.92 (dd, J = 12.5 Hz, 11.4 Hz, 1H), 2.43 (s, 3H), 2.53 (ddd, J = 12.5 Hz, 8.3 Hz, 1.2 Hz, 1H), 2.63–2.72 (m, 1H), 2.83 (dt, J = 16.9 Hz, 2.5 Hz, 1H), 2.97 (d, J = 16.9 Hz, 1H),

3.71 (s, 3H), 3.71 (s, 3H), 5.49 (dt, J = 11.5 Hz, 1.5 Hz, 1H), 5.58 (ddd, J = 11.5 Hz, 5.0 Hz, 2.8 Hz, 1H), 5.78 (d, J = 2.5 Hz, 1H), 5.95 (t, J = 4.3 Hz, 1H), 7.24 (d, J = 8.2 Hz, 2H), 7.26–7.34 (m, 3H), 7.35–7.38 (m, 2H), 7.71 (d, J = 8.2 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 21.7, 38.8, 40.2, 41.0, 52.9, 53.1, 58.5, 59.8, 119.1, 127.0, 127.4, 128.0, 128.3, 128.4, 128.8, 129.6, 138.6, 139.4, 143.2, 145.5, 170.9, 171.2; IR ν_{max} (film): 2363.9, 2358.3, 1751.0, 1733.8, 1652.7, 1506.9, 721.9, 691.9, 686.7, 681.3, 676.4 cm^{-1}; HRMS m/z calcd for $C_{26}H_{27}NNaO_6S$ $[M + Na]^+$: 504.1451; found: 504.1453.

2′,2′-Dimethyl-3-phenyl-2-tosyl-3,5a,6,8-tetrahydro-2*H*-spiro-[cyclopenta[*c*]azepine-7,5′-[1,3]dioxane]-4′,6′-dione (2s). Yield: 42%; ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.74 (s, 3H), 1.76 (s, 3H), 2.29 (t, J = 12.7 Hz, 1H), 2.42 (s, 3H), 2.49 (dd, J = 12.7 Hz, 9.4 Hz, 1H), 2.97 (d, J = 16.8 Hz, 1H), 3.10 (dt, J = 16.8 Hz, 2.4 Hz, 1H), 3.25–3.34 (m, 1H), 5.48 (dt, J = 11.5 Hz, 1.7 Hz, 1H), 5.62 (ddd, J = 11.5 Hz, 5.2 Hz, 2.9 Hz, 1H), 5.90 (d, J = 2.4 Hz, 1H), 5.96 (t, J = 4.2 Hz, 1H), 7.26–7.32 (m, 3H), 7.34 (t, J = 7.5 Hz, 2H), 7.44 (d, J = 7.1 Hz, 2H), 7.81 (d, J = 8.2 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 21.7, 28.9, 29.1, 41.5, 42.5, 45.0, 51.8, 59.9, 105.2, 119.4, 126.9, 127.2, 127.5, 128.1, 128.5, 128.8, 129.8, 138.9, 139.3, 143.3, 144.2, 168.7, 170.0; IR ν_{max} (film): 1739.0, 1733.0, 1652.2, 1301.7, 1161.7, 704.5, 678.2 cm^{-1}; HRMS m/z calcd for $C_{27}H_{27}NNaO_6S$ $[M + Na]^+$: 516.1451; found: 516.1454.

3-Phenyl-2-tosyl-3,5a,6,8-tetrahydro-2*H*-spiro[cyclopenta[*c*]-azepine-7,2′-indene]-1′,3′-dione (2t). Yield: 59%; ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.96 (t, J = 12.4 Hz, 1H), 2.11 (ddd, J = 12.4 Hz, 8.4 Hz, 1.2 Hz, 1H), 2.47 (s, 3H), 2.58 (d, J = 16.9 Hz, 1H), 2.78 (dt, J = 16.9 Hz, 2.5 Hz, 1H), 3.34–3.44 (m, 1H), 5.49 (dt, J = 11.5 Hz, 1.7 Hz, 1H), 5.60 (ddd, J = 11.5 Hz, 5.3 Hz, 2.9 Hz, 1H), 5.89 (d, J = 2.5 Hz, 1H), 5.96 (t, J = 4.3 Hz, 1H), 7.27–7.33 (m, 1H), 7.34–7.39 (m, 4H), 7.45–7.49 (m, 2H), 7.83–7.91 (m, 4H), 7.95–8.00 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 21.8, 38.0, 41.1, 41.7, 57.5, 59.9, 119.0, 123.6, 123.7, 127.1, 127.1, 128.0, 128.1, 128.5, 128.9, 129.9, 136.0, 136.2, 139.1, 139.5, 141.0, 141.4, 143.2, 145.5, 202.0, 202.2; IR ν_{max} (film): 1705.7, 1703.9, 1539.4, 1506.6, 1160.8, 835.4, 703.0, 689.7, 686.2 cm^{-1}; HRMS m/z calcd for $C_{30}H_{25}NNaO_4S$ $[M + Na]^+$: 518.1397; found: 518.1391.

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